An investigation into the constraints limiting maintenance strategy effectiveness in the automotive supply chain.

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Abstract

The automotive manufacturing industry offers a substantial contribution to the UK economy. 856,000 personnel were employed in this sector in 2019. Although this contribution remains significant, production and trade difficulties have emerged due to socio-economic changes. As a result, operating with an efficient business model gains further prominence. Preliminary research revealed that regional Tier One suppliers to International OEM's were experiencing difficulties emulating the lean operating model of the OEM. This was exemplified by poorly performing maintenance plans. Symptoms included inaccurate performance metrics and inadequate asset management. As a result, the business would mitigate the risk of the maintenance strategy failing, by holding excessive buffer stock.

Rich data was gathered through case study work with four Tier One suppliers. Once synthesised, the data presented a series of constraints which prevented maintenance effectiveness in the automotive supply chain. These included; Maintenance planning; Equipment management and Data collection. Moreover, the consequences of cultural differences and poor working relationships became apparent. Therefore, a Gap Analysis tool was developed to identify specific issues within a functioning maintenance plan. The tool was tested in three automotive manufacturing sites and the results presented varying gaps in practice. Commonly, data management and performance indicators are neglected. Furthermore, the disregard for spare part management is causing an extensive financial burden to some partners. Also, the test revealed no clear understanding of the importance of the human element and the consequences of a poorly perceived maintenance department. These perceptions can be influenced by artefacts signalling maintenance values and working practices. These include performance displays; operating standards and housekeeping issues.

This research is a contribution to literature in maintenance strategy development in the automotive supply chain. This includes identifying characteristics which influence working relationships and the human element. A novel contribution is provided through the Gap Analysis Tool which measures the status of a maintenance strategy and the presence of influential artefacts. The tool provides results which can be used to develop and improve a maintenance function.

Acknowledgement

I would like to give special thanks to Dr. Kenneth Robson and Professor David Baglee to whom I owe a great deal. The support, encouragement and patience in managing a difficult student was exemplary. Ken and David were selfless in their Supervisory role and their style of management was fantastic.

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Publications

The following peer reviewed publications were a result of this research:

Dixon, D. *et al.* (2016) 'Improving automotive supply chain performance through maintenance strategy development.', *EuroMaintenance 2016*. Athens, Greece.

Dixon, D. *et al.* (2017) 'The Role of Cultural Development When Improving Maintenance Practice in the Automotive Supply Chain', in *COMADEM 2017*. University of Central Lancashire, p. 8.

Dixon, Derek, Robson, Kenneth and Baglee, David (2020) The development of a maintenance gap analysis tool for use within the automotive supply chain: A case study perspective. International Journal of COMADEM, Vol. 24 Issue 1, p71-72

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1. Introduction

Automotive manufacture within the UK is a prominent contributor to the national economy. Approximately 1.3 million vehicles were manufactured in the UK in 2019 and levels of export were substantial, with exports being worth £44 billion (SMMT, 2019). The prominence of the industry within the UK is reflected in the North East of England, where the automotive sector and its supply chain are a vital contributor to the economy. The manufacture of cars as well as engines in Sunderland is extensive. Nissan produced 442,000 vehicles from their Sunderland plant in 2018 (SMMT, 2019). In addition, the supply chain which supports the OEM is a vital contributor to this level of production.

The automotive manufacturing industry is synonymous with operating a lean production environment. Yet underneath this more public persona, is a dynamic, aggressive and highly competitive industry. Furthermore, there is a substantial supply network which positions the Original Equipment Manufacturer (OEM) in delivering a high volume, quality product.

The manufacturing practice of the OEM has drawn attention from scholarly research due to the apparent success and evolution of this industry. Within the academic community, concern remains, that due to the success of the OEM, there is an expectation that the supply chain must also employ similar tactics and production efficiencies.

An examination of the automotive supply chain will further develop this body of research. Furthermore, the developing complexities of trade with Europe, due to the uncertainties of Brexit and possible trade tariffs, ensure that an increased understanding of organisational performance is an emerging priority.

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1.1. Sector Challenges (UK)

A substantial issue which has emerged in the UK automotive industry is a skills gap at key, operational positions. This is recognised by Bettsworth and Davies (2016), who highlight the reduction in skill base as having a negative effect. The report by Bettsworth and Davies (2016) is focussed upon the UK automotive industry and considers both the OEM as well as upstream suppliers. The report concludes that both Maintenance Technicians as well as Maintenance Engineers are under-resourced nationally, and this will affect maintenance deployment. Additionally, the report identifies the skills gap is a symptom of the following issues:

- High business growth
- Lack of experience and skill with currently qualified practitioners
- High levels of competition in the job market
- Poor age demographic for newly qualified and developing staff.

The skills challenges faced by the automotive industry are compounded by trade uncertainty. This is underpinned by the renegotiation of a trade relationship between the UK and European union (SMMT, 2019). This departure is in the context of many OEM's sourcing suppliers based within the European Union. The geographical location of Tier One and Tier (1+n) suppliers appears to have relevance to the business performance of the downstream supply chain. (Gunasekaran, Patel and Tirtiroglu, 2001) indicated that proximity of a supply network is a key feature of effective automotive manufacture within the supply chain. Moreover, a local supply network may assist in the promotion of technical support and logistical issues. This appears particularly relevant given recent political developments. Whilst these are current challenges being reported within the UK, the context of their findings and subsequent relevance to literature will be reviewed later in Section 2.5.

1.2. What is the current situation?

Prior to the commencement of this research, anecdotal evidence from the Automotive Industry highlighted a reluctance of companies in the Supply Chain to develop and improve their internal Maintenance operations. Informal discussions with senior maintenance managers employed within the automotive supply chain, revealed a continuing frustration with blockages to Maintenance development. To further understand the potential issue, a series of exploratory meetings were organised. These meeting took place with middle and senior managers, employed within three Tier One automotive suppliers in the North East of England. As a result of these meetings, the researcher discovered a unique situation existed. Firstly, the customer/supplier relationship between a Tier One producer and the Original Equipment Manufacturer (OEM) differed significantly from other manufacturing relationships. Within a manufacturing plant, delays can be concealed internally and hidden from the customer. Conversely, within an automotive supply-chain, the OEM immediately feels the effects of any prolonged stoppages. Within a lean production environment, any production line stoppage has severe consequences for all partners. Secondly, maintenance strategies were difficult to establish and often ineffective. Thirdly, there was a distinct lack of coordinated technical engagement and maintenance support between the OEM and the Tier (1+n) suppliers. This could provide further risk to an already fragile relationship. Operating under these dynamics would be challenging in an already volatile industry. Conclusively, further research was required to identify the factors constraining the performance and development of effective maintenance within the Automotive industry. Moreover, at a more granular level, the need to acknowledge and understand these barriers was vital to allow Maintenance to succeed and improve its contribution to the organisation.

1.3. Research Question

The context of this problem has led to the following research question:

How can an automotive supplier overcome constraints, which limit the implementation of an effective maintenance strategy?

This will be answered more specifically by the following questions:

1. What are the features of ‘state of the art’ or ‘best practice’ maintenance strategies within the automotive manufacturing environment?
2. What are the constraints identified within the automotive supply chain which prevent maintenance strategy implementation?
3. What is an appropriate method of improving an existing maintenance strategy which will accommodate findings from question one and question two?

1.4. Thesis format

Following the brief description of the current situation and the research question, this thesis will be structured in the following manner:

Chapter Two will review scholarly work in maintenance management, with a focus upon the manufacturing and automotive manufacturing industry. This review will look to establish characteristics which enable best practice for maintenance strategy development, as well as inhibitors to best practice. Furthermore, the appraisal will establish where possible, factors which influence the performance of a maintenance function in a manufacturing environment. Finally, the review will conclude and identify the gap in knowledge which will be addressed by this research.

A methodology for advancing this research will be discussed in Chapter Three. This will consider the issue under investigation, findings from the literature review and the industrial context. Subsequently, Chapter Three will conclude with a final, structured method of collating, understanding, synthesising and utilising the data in a manner which will address the research question.

Chapter Four will provide summary feedback from the data collection stage at each of the four Plants in this study. This will describe the industrial context of each site and more specifically issues which are linked to the maintenance function. As well as providing detailed background information, the Chapter will present enabling and constraining characteristics for maintenance performance. This will be reviewed on an individual basis as well as understanding common issues across each Plant.

The data and findings emerging from the previous four chapters is collated in Chapter Five and developed into a tool which will address the emergent constraints to maintenance development and performance. The tool will be developed and refined through field testing with industrial experts. The final version of the tool is then tested on three plants and the results are reviewed. Chapter Six will then reflect on the field testing of the tool and the emerging results.

Finally, Chapter Seven will discuss and conclude from the test results in Chapter Six. The conclusions will contain a response to the research question as well as a series of recommendations to the automotive supply chain. In addition, Chapter Seven will confirm the contribution to knowledge provided by this research and identify areas of further research.

2. Literature review

2.1. Introduction

Chapter 1 introduced this thesis and offers an overview of issues influencing this investigation. The research question in Section 1.3 provides a direct link to the structure of the literature search, the question providing key areas of focus. These include:

- Constraints to maintenance effectiveness
- Maintenance best practice
- Automotive supply chain
- Development of maintenance strategies

The supply chain is of interest to this work. It is postulated that maintenance strategy development has been well researched, but not in the context of the automotive supply chain. Lean principles form the foundation of automotive manufacture (Womack et al. 2007; Thun et al, 2011). Moreover, maintenance concepts are well developed at OEM level, yet initial rich data suggests this practice has failed to develop in upstream suppliers.

The literature search will focus on previously established maintenance strategies within the automotive environment, yet also consider aspects of good practice from other areas of manufacturing. Additionally, broader concepts such as strategy development and deployment will be considered. This will inform the concept development of this work. Furthermore, supply chain theory will be reviewed, in order to fully understand the dynamics of a crucial relationship within a tiered supply and manufacturing platform. Finally, this chapter will investigate the importance of organisational culture and the human element to the performance of any business.

The structure of the Literature Review is as follows:

Section 2.2 –will provide a focussed view of the automotive manufacturing sector in the UK, along with traditional production methods. Moreover, maintenance strategies associated with this sector will be discussed.

Section 2.3 – will review lean production methods traditionally deployed within the automotive manufacturing industry. Furthermore, the impact these production methods have on linked functions such as engineering maintenance.

Section 2.4 –will identify the current state of the automotive manufacturing sector in the UK, as well as the issues which present operational difficulties to both production and maintenance.

Section 2.4 – will review literature and note features of best practice, as well as challenges regarding maintenance strategies. In addition to offering an insight into concepts based within general manufacturing, the discussion will sharpen the focus towards the automotive industry. Moreover, there will be a comparison with techniques synonymous with other industries.

Section 2.5 – This section will contain an overview of supply chain management, considering aspects of best practice. Furthermore, it will conclude with an understanding of the influence this has on the research question.

Section 2.6 –The importance of both organisational and department culture will be reviewed, including a discussion relating the benefits of a positive culture. This will include the impact of culture on the success of the organisation, as well as the factors which influence working practices.

Section 2.7 – Will conclude the literature review, identifying a basis for further work, whilst confirming the need for further research. Moreover, a series of propositions will be developed which provide the foundation for analysing this problem.

2.2. Automotive industry

This section comprises an overview of the automotive industry, the importance to the national economy and the constituents that make up the sector. Additionally, the context of the automotive manufacturing environment will be considered, to increase the depth of understanding. The section concludes with challenges the sector faces moving forward.

Manufacturing maintenance, including the automotive industry, has developed due to a combination of political, economic and engineering drivers (Borris, 2006). During the early 20th century, the surplus of labour, combined with the production capacity, tended to satisfy market demands. Consequently, reactive maintenance would be used (Pophaley and Vyas, 2010). Indeed, Henry Ford and Frederick Taylor used a strategy where production ruled and maintenance was only deployed when there was a critical breakdown (Borris, 2006). The second world war introduced a period of austerity where materials, labour and cost were of paramount importance. These drivers influenced the introduction of preventive maintenance, to facilitate more efficient manufacturing (Kelly, 2012). The resultant period of industrial development saw further, more rapid developments in maintenance management. Restrictive financial management, a recognition of the importance of customer requirements and increasingly complex process machinery introduced more advanced concepts. These include predictive maintenance, Total Productive Maintenance (TPM) and Reliability Centred Maintenance (RCM) (Campbell, Jardine and McGlynn, 2010). As a result, it can be concluded that maintenance strategy development is driven by multiple influencing factors (Borris, 2006; Campbell, Jardine and McGlynn, 2010; Pophaley and Vyas, 2010). To further develop existing strategies, there is a continuing need to understand current and future operating conditions.

Automotive production has fluctuated over the previous decade. Following the national and international recession, vehicle manufacture in the UK was measured at one million vehicles in 2009. This rose to 1.6 million vehicles in 2017 (SMMT, 2019). Since then, levels of automotive manufacture have experienced a staged decline (SMMT, 2019). Despite the decline, the contribution to the local, national and international economy is substantial and the importance of the industry remains. According to

(SMMT,2019) there are over 2500 registered automotive suppliers in the UK and approximately 82,000 people employed within that supply chain. The Original Equipment Manufacturer (OEM) remains the end point and assembler of components produced within that supply chain.

Automotive manufacture within the UK incorporates the production of cars, commercial vehicles and engines, yet the volume of production is at its greatest for car manufacture (SMMT, 2019). Table 2.1 indicates the top five automotive production OEM's based within the UK.

Table 2.1 An overview of UK based OEM production volume in 2018 Source SMMT report (2019)

Make	**Annual Volume**
Jaguar Land Rover	449,304
Nissan	442,254
BMW	234,183
Honda	160,676
Toyota	129,070

Additional car manufacturers based in the UK include Vauxhall, Bentley, Aston Martin and Lotus, though production volumes are substantially less than those listed in Table 2.1.

Understandably, automotive production in the United Kingdom has demonstrated periods of growth and decline. What remains consistent, is the impact it can deliver to the Manufacturing portfolio and industrial infrastructure of the UK.

2.3. Lean production methods

The automotive manufacturing industry operates with lean production principles. Thun et al. (2011) and Womack et al. (2007), discuss lean production and the importance of the Toyota production principles. These principles have been established within a number of modern automotive manufacturing companies. The aim is to eliminate waste and reduce cost, by maximising resources and efficiency. Lean production can be characterised by concepts such as Just in Time (JIT), Total Productive Maintenance (TPM) and Total Quality Management (TQM) ((Moyano-Fuentes et al. 2012). The foundations of JIT within Toyota were discussed by Womack et al. (2007), where minimum inventories were the expectation, and parts were delivered to the production line when required. The authors highlighted challenges of this production methodology, where participating suppliers felt pressurised into accepting the responsibilities of additional inventory, to ensure consistent on time delivery. Harrison, (1992) and Jacobs and Chase (2010), discussed the extension of the JIT concept to all aspects of manufacturing. The authors confirmed that deploying this technique holistically, will bring challenges at an operational and organisational level. Additionally, the authors concluded that the reduction of inventories and thus waste, can also expose numerous issues within the business that were previously masked by stock.

TPM will be reviewed in greater depth in Section 2.5.1, yet this section offers a brief insight into the concept. According to Kelly (2012), TPM is considered a holistic approach to maintenance and can maximise the performance of the manufacturing equipment. This is achieved by small teams who act autonomously, with the aim of improving maintenance practice. These teams will include operator level staff. As with JIT, TPM can be applied to all aspects of the business and as such, relies on all staff to participate. Murthy, Atrens and Eccleston (2002) argued that TPM is a broader business facing strategy and relies on a nominal machine or process condition. Additionally, the strategy may not consider degradation and wear which may appear, due to extreme process loading for increased production requirements. As such, the anticipated gains TPM may offer do not materialise. Moreover Tsang (2002), discussed the extensive resource implication required for the success of TPM, including the responsibility of Senior Managers to resist the pressure for short term gains.

TQM forms the final part of this ‘trinity of practice’, linked to lean production. Jacobs and Chase (2010) generalised the concept to having two main aims which concentrated on the design of the product and the organisational system to support the consistent manufacture of that design. This may seem simplistic, but points to the common theme of all three lean strategies- a whole business approach. Hietschold, Reinhardt and Gurtner (2014) placed an additional 2 points to the general aims of Jacobs and Chase; Improved organisational performance and removal of errors. Both authors agreed that a fundamental focus of this concept does not rest with the product, but must be applied to personnel, tasks and processes. Additionally, Hietschold, Reinhardt and Gurtner (2014), discussed the need for ‘*critical success factors’*. This includes the need for a positive supplier partnership and development of a clear and communicative culture.

Aside from the lean production method deployed within the automotive industry, the requirement for all parts of the business and indeed, supply chain to participate are evident. If a holistic approach is not adopted, challenges and consequences emerge.

2.4. Maintenance concepts within the manufacturing environment

The purpose of this section is to review engineering maintenance best practice, identified through a detailed examination of current literature. The discussion will classify types of maintenance and identify modern practice. This will include general manufacturing as well as manufacturing in an automotive environment. Additionally, the review in this section will note maintenance concepts which have emerged from the literature. The section will not consider all material, only areas that are relevant to the study topic.

Maintenance is an essential feature of an effective manufacturing business. Moreover, the impact a maintenance function can provide towards the efficiency of the production department is substantial and well recognised (Kumar *et al.*, 2013). A well-considered maintenance strategy forms the cornerstone of a maintenance department and how effective it may be (Robson, Trimble and MacIntyre, 2013). Maintenance strategy development has been extensively researched over previous years and the emergence of strategies that are synonymous with specific industries is not new. Reliability Centred Maintenance (RCM) was developed to be used as a tool within the aviation industry (Kelly, 2012). Furthermore, TPM was developed for use within the automotive industry in the late 20th century (Waeyenbergh and Pintelon, 2002).

The importance of a maintenance strategy and the subsequent link to the performance of a business is reviewed by Swanson (2001). The author recognised maintenance strategies fall into three areas; Reactive, Proactive and Aggressive. Swanson characterised a reactive strategy as an operational technique which is built upon 'run to breakdown' and Mobley (2013) described it as 'run to failure'. In this scenario, the machine will only be repaired when it cannot continue to produce the output for which it has been designed. Mobley (2013) established that the advantages of this technique include a reduced number of maintenance personnel, who may possess a smaller skillset. This strategy has disadvantages which include increased cost due to higher levels of scrap, as well as unpredictable production stoppages due to breakdown. A secondary consequence can emerge with the potential damage to customer satisfaction due to production issues. Salonen and Deleryd (2011) discussed reactive maintenance as being viewed by manufacturing managers as financial waste and non-value adding. Reactive maintenance is aligned with a staged model by Waeyenbergh and Pintelon (2002), whereby the authors proposed that companies who employ reactive maintenance techniques are 'Internally neutral' and maintenance is seen as a necessary evil.

A progressive maintenance technique can be further categorised into predictive and preventative maintenance (Swanson, 2001), yet both look to reduce breakdown by monitoring process condition and administering specific minor maintenance tasks. Preventative maintenance can be applied through scheduled maintenance tasks supplied by the machine manufacturer or by the design of specific maintenance personnel. Moreover, Wireman (2010, pp. 121) described it as a '*planned maintenance activity*, *designed to improve equipment life*.'

Through predictive maintenance, evidence of machine degradation is gathered by monitoring equipment, subsequently it is analysed and the information is fed back to key personnel. This information is then transformed into a specific maintenance activity to reverse the degradation before production or quality is affected (Velmurugan and Dhingra, 2015). Preventative and predictive techniques are slightly different in their approach. Preventative maintenance is based upon a specific schedule of tasks, which is carried out as a routine whilst predictive maintenance identifies maintenance tasks based upon process condition, so the frequency may be variable. Swanson confirms both approaches possess ability to improve the performance of the maintenance department. A manufacturer who utilised either concept would be typified in maintenance practice as retaining skilled and well trained staff, with close alignment of business and maintenance strategies (Wireman, 2010; Kelly, 2012). The challenge when deploying a progressive concept is the requirement of a relatively high maintenance budget.

The final aspect identified by Swanson is the aggressive approach, which looks to improve machine performance as opposed to offer remedial action or scheduled tasks. Swanson aligned this approach with TPM, which in turn is a feature of JIT manufacture. TPM is focussed primarily on improving equipment effectiveness (Kelly, 2012) by maximising efficiency and reducing breakdowns. Swanson and Kelly agreed that this is a team based approached that may involve all departments within the business. Tsang (2002), confirmed the features identified by Swanson and Kelly, discussing that encouraging participation of all staff in maintenance activities encourages ownership by providing responsibility. The utilisation of operators in lower level maintenance tasks and identifying early signs of degradation improves machine performance and impact on the business. Additionally, the use of small teams to target specific areas of process and production improvement.

Scholarly categorisation of maintenance strategies can provide differing viewpoints. Pintelon, Pinjala and Vereecke (2006) aligned the development and impact of a maintenance strategy with a model proposed by Hayes, R and Wheelwright (1984).

The Hayes and Wheelwright model measures the effectiveness of a manufacturing strategy in four progressive stages. Pintelon, Pinjala and Vereecke (2006) further developed this model and identified features of business and maintenance practice which characterise performance. The stages are noted as describing internal and external stability, so ensuring the maintenance strategy can be identified as having an impact inside and outside the business. The apex of the model - stage four, is recognised as '*externally supportive'* and pursuing a competitive advantage. Conversely, it may be argued that this model offers only a few indicators to establish maintenance strategy effectiveness. The simplicity of these indicators, such as possessing a CMMS system or considering a maintenance strategy alongside the business strategy, would lead to a well-defined analysis of strategy performance. Conclusively, there are no performance indicators evident within this model which would demonstrate the quantitative effect improved maintenance performance would have on the business.

The relative cost of maintenance and its impact on the economic performance of a business is recognised as being substantial (Salonen and Deleryd, 2011; Kelly, 2012). From this standpoint, it is apparent firms would immediately identify maintenance as being able to offer a competitive advantage to a business. Porter (2004), identified competitive advantage as including features of an organisation which can significantly impact on financial performance of the business. Yet if financial expenditure of the maintenance function were the only focus, then a reduction in that particular budget could lead to an improved economic performance. Alsyouf (2007) confirmed that senior management often see maintenance as being a cost centre, as opposed to a profit centre. Moreover, the ability for maintenance to demonstrate impact can be troublesome, unless there exists a mechanism for reporting economic or engineering performance. The paradigm discussed by Porter possibly needs to be extended to include a high potentially impact. Muchiri *et al.* (2010), confirmed that this can be only be established if an infrastructure is in place which measures the performance of the department. Maintenance Performance Measurement (MPM) including performance indicators is reviewed in Section 2.4.5.

2.4.1. Total Productive Maintenance:

An understanding of the constituent parts of an existing maintenance strategy is essential, if development of any new plan is to prove successful. As the focus of this investigation is specific to automotive manufacture and the supply chain, a review of established industry specific maintenance strategies will assist in the progression of this investigation.

Section 2.2 described how the automotive industry operates with lean production principles, with TPM being a fundamental element (Thun et al. 2011) (Womack et al. 2007) (Moyano-Fuentes et al. 2012). TPM is described by Wireman (2004) as an advanced manufacturing technique, which aims to achieve the following:

- Improve equipment effectiveness
- Improve maintenance efficiency and effectiveness
- Manage equipment early and implement preventive maintenance
- Train people to improve skills
- Involve operators in routine maintenance

An alternative perspective is developed by Rich and Jones (2001), who related TPM as a set of management practices. The fulfilment of those practices would result in a reduction in losses in 6 areas:

- Breakdown
- Set up and adjustment
- Idling and minor stoppages losses
- Reduced speed losses
- Quality defects and defects
- Yield losses due to start up

Moreover, Bamber *et al*. (1999), identified the stages required to the implement TPM into 6 specific areas, as seen in Figure 2.1:

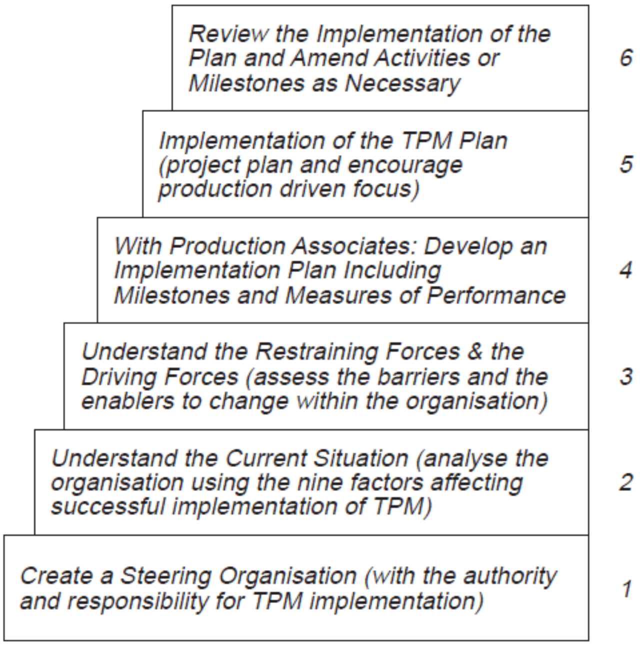

Figure 2.1 The 6 activities of TPM implementation

The success of the TPM programme within a business is measured by Overall Equipment Effectiveness (OEE), and this metric is used as an indicator to gauge the relative success of improving production and workforce productivity whilst reducing defects, waste and costs (Muchiri and Pintelon, 2008).

The programme aims, focus and methodology appear attractive. Tsang (2002) identified TPM as being a business wide approach to loss reduction, with people being at the core of the concept. The holistic approach can be characterised by activities such as preventative maintenance activities implemented by operators and the formation of cross functional improvement teams. Additionally, the absolute necessity to train and educate all personnel within the company is well recognised (Tsang, 2002; Wireman, 2004; Kelly, 2012). This approach to the concept promotes empowerment, demonstrated by the expected autonomous nature of operational personnel. The reduction in the more mundane preventative maintenance activities carried out by operators releasing the resource of the skilled maintenance technicians for improvement activities (Rich and Jones, 2001).

The benefits of a successful TPM programme appear extensive, certainly within a JIT production environment. Yet the question arises, why is this programme not deployed within all manufacturing sites which operate in a lean environment? The foundations for the TPM programme lie within the holistic approach, employee empowerment, education and training. These foundations become unstable if the senior management team do not invest in the programme, financially and emotionally (Wireman, 2004; Kelly, 2012). Senior management personnel may not enter into a relationship with the TPM programme being sceptical, yet they may quickly become this way if results are either not produced, or more importantly not measured in the first place. Wireman (2004), identified that TPM will not meet senior management expectations if improvements are not linked to financial gain. The financial implications of an organisation wide project are prominent for senior management personnel (Kelly, 2012).

Recently, Marodin *et al.* (2019) proposed the use of Lean Centred Maintenance (LCM) as a principle of maintenance strategy development. LCM uses the principles of lean production and applies those to the objectives of the maintenance department. These principles include such the reduction of waste and increase of efficiency. The discussion by Marodin *et al.* (2019) identifies the introduction of autonomous maintenance and specific KPI's which lead to improvements in machine availability. Clearly, TPM continues to be a fundamental principle in this sector of maintenance development.

The apparent weakness of TPM is not in the programme design, but in the attitude, persistence and deployment of the manufacturing site. Wireman (2004) confirmed there is no simple recipe for its success, as any such programme cannot predict the skill profile or age range of the employed staff. The programme must be tailored to the needs of the site. Conclusively, this relates directly to the extensive resources required to implement and persist with such a programme. Whilst the programme has its origins within automotive manufacture, the required financial investment for successful deployment causes conflict with business objectives. This appears at odds with the automotive industry, where cost reduction and financial efficiency is at the very heart of automotive supply chain goals (Singh, Smith and Sohal, 2005).

2.4.2. Reliability Centred Maintenance:

Comparing a maintenance technique which has its origin in an alternative industry offers an additional maintenance perspective. Reliability Centred Maintenance (RCM) was developed in the aviation industry and was based around aircraft maintenance (Pintelon, Nagarur and Van Puyvelde, 1999). Moubray, Network and Lanthier (2016) stated the strategy is based upon 7 questions, which probe the consequences of asset failure and the effect of predictive maintenance approaches. Additionally, the author detailed the benefits of this technique to the business, including outputs such as:

- Increased cost effectiveness
- Comprehensive plan for all assets
- Extending operational life of assets.

Kelly (2012) extended the discussion to confirm the benefits discussed by Moubray, Network and Lanthier (2016), but went on to detail RCM as having the ability to analyse and dispense with unnecessary and ineffective preventative maintenance activities. This has the additional benefit of contributing towards the improved cost efficiencies. Backlund and Akersten (2003), expand the details surrounding RCM, indicating the ability of the strategy to improve the reliability and availability of an asset, as well as reducing any risks the item may contribute to a safe environment. The ability of the strategy to increase the potential for safe operation of the asset confirms the origins of the concept, where aviation is heavily regulated due to the nature of its business. Backlund and Akersten (2003) discussed the very nature of such a heavily regulated industry can provide the foundation for strategy success, but also failure. Extensive maintenance management resources must be in place for RCM to be effective. Additionally, it may be concluded that if such resources are in place, maintenance is valued and promoted by the senior management team. Management commitment is essential if a RCM strategy is to be successful.

This commitment is required as the concept is driven by a whole organisation approach, including workforce training and education(Backlund and Akersten, 2003). Conversely, a lack of momentum behind these attributes will lead to poor or unsuccessful implementation of RCM. The authors offered the view that RCM is less successful in the manufacturing sector, as opposed to heavily regulated industries such as aviation and nuclear. Hansson, Backlund and Lycke (2003) expanded upon the pre-emptive and ongoing requirements of RCM and discuss the strategy may not consider organisational matters, yet organisational change is an absolute requirement. This paradox points towards difficulties of implementation, if resource and commitment are not in place. The authors discussed intangible factors which must be considered when deploying a new strategy, and the need for an organisation to consider business history, employee culture as well as geographical location. This can prove an added complication to an already intricate process.

2.4.3. A comparison of RCM and TPM

RCM aims to select and apply the correct maintenance activity for specific components, machines and processes (Prajapati, Bechtel and Ganesan, 2012). This is applied throughout the life cycle of the asset and begins in the design stage. Selecting the correct maintenance strategy from all available or known strategies appears to offer an attractive route, yet there are inhibitors. These include the required financial investment as well as the business wide commitment (Kelly, 2012). Whereas these factors are identified as enablers, a lack of investment and organisational commitment become inhibitors if not in place for the implementation of RCM.

The holistic commitment of RCM also features as an enabler for successful TPM implementation and in this manner also becomes a blockage if not fulfilled (Wireman, 2004). TPM becomes more distinct in the core aims addressing the human element of any maintenance strategy. By including the human element, the strategy becomes more of a philosophy and can be adapted for differing manufacturing situations(Camacho-Miñano, Moyano-Fuentes and Sacristán-Díaz, 2013). Furthermore, the fundamental aims of TPM to maximise production availability, reduce cost and minimise waste are appealing to the manufacturing sector (Camacho-Miñano, Moyano-Fuentes and Sacristán-Díaz, 2013). Conclusively, both strategies require site specific consideration before implementation as well as whole organisation commitment.

2.4.4. The importance of Maintenance strategy development and selection

The previous section discussed specific maintenance strategies, their benefits, the consequences of poor deployment and relevant industrial applications. More importantly, the discussion highlighted the opportunities and threats which are presented to the end user if they are selected as off-the-shelf solutions. This section will use literature to consider the use of maintenance management tools to identify a suitable maintenance strategy for a specific business.

2.4.4.1. A strategic approach to Maintenance

Maintenance management, including the generation of any operational strategy by the appropriate leadership team, must be linked to the business objectives (Alex Hill & Terry Hill, 2009; Robson, Trimble and MacIntyre, 2013). The efficiency of this process directly affects how well the strategy is deployed (Crespo Márquez *et al.*, 2009). Velmurugan and Dhingra (2015) discussed the importance of maintenance management having longer term goals within a business, including sustainability and external competitiveness. Moreover, this leads to the importance of a strategic view of maintenance and the increased significance of selecting the appropriate strategy for the business. Numerous authors Muchiri *et al.* (2011); Velmurugan and Dhingra (2015); Mahlamäki and Nieminen (2019) identify the need to integrate a maintenance department with the business. Previously it had been recognised within the literature that maintenance was seen as a necessary evil and a fixed overhead (Tsang, 1998; Pintelon, Pinjala and Vereecke, 2006). Recent research has recognised the importance of the maintenance function to the business as a whole, which includes its ability to offer a competitive advantage (Muchiri and Pintelon, 2008; Muchiri *et al.*, 2010). The maintenance strategy within a business, its maturity and efficiency can provide an insight into its stature within the business. As recognised by Al-Turki (2011), the lack of integration with business goals can prove problematic to the organisation.

The importance of the holistic view of maintenance, including an appreciation of what it can contribute to quality, cost reduction and production availability is highlighted by Velmurugan and Dhingra (2015). The authors promote and enforce the value of using the business goals and objectives as a start point for maintenance concept development. Following this platform, it is important to incorporate production objectives and finally confirm maintenance objectives. Crucially Velmurugan and Dhingra (2015) identified that a maintenance strategy was the vehicle that converts business objectives into maintenance objectives. This perspective supplements the paradigm for maintenance strategy selection and its influence in how effective maintenance can be to a business.

2.4.4.2. Maintenance concept development

Waeyenbergh and Pintelon (2002), discussed maintenance concept development and the importance of a customised, bespoke model which will satisfy the individual needs of the end user. The framework is represented by Figure 2.2 but may be summarised by the following steps:

- Identification of objectives and resources.
- Identification of most important systems.
- Performance measurement.
- Maintenance policy decision step.

This paper includes a decision tree which leads to a maintenance plan for a specific asset. The plan may be ‘design out maintenance’ or corrective maintenance. Additionally, the preventative maintenance activities for that particular asset are optimised at this point.

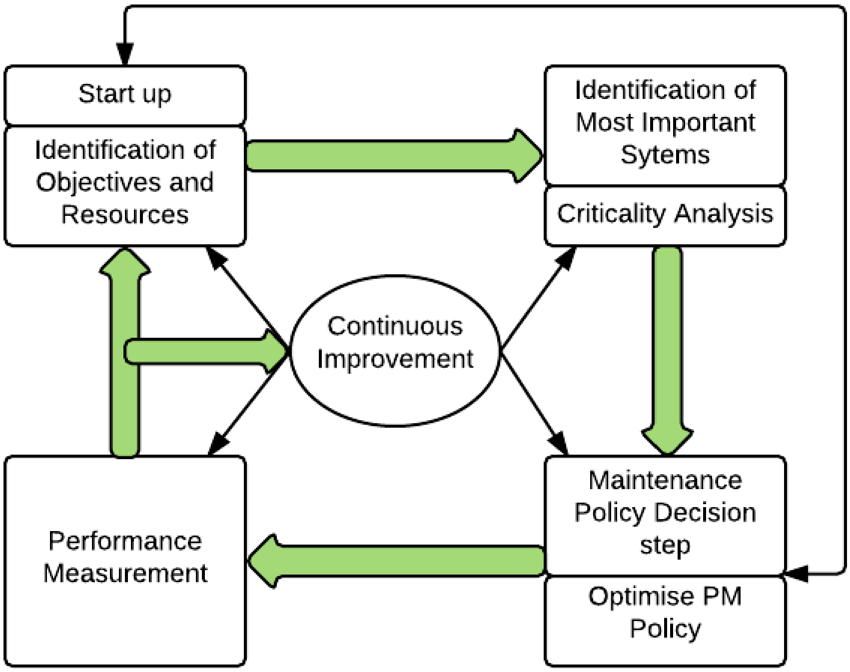

Figure 2.2 Framework Overview

Source: Waeyenbergh and Pintelon, (2002)

The paper offers very little insight into the performance measurement system, only that the emerging concept should be measured and evaluated. At the core of this concept is a feedback loop, which highlights the need for a continuous improvement of any maintenance strategy. The paper presented by Waeyenbergh and Pintelon (2002) is instructive, as it reinforces the need for a customised maintenance strategy. Additionally, the authors indicate the need and value of utilising the undervalued resource of tacit knowledge. Explicit knowledge such as performance data, manufacturer's guidelines and even standard operating procedures are valuable, yet experiential knowledge of key operational personnel is underdeveloped. This aspect will be explored in Section 2.7. The lack of detail for a performance measurement system is acknowledged by the author, though the missing detail devalues the overall use of the framework as a practical solution for industry.

The relationship between a manufacturing organisation and its maintenance function could be considered symbiotic in nature. The need for focus and direction for strategy development is clear, yet the criteria which contribute towards this process are substantial. Pintelon, Pinjala and Vereecke (2006) considered key elements which contribute towards maintenance development and performance within a business. The purpose of the paper is to establish a method of evaluating the effectiveness of a maintenance strategy which is being deployed by a business. As well as being a valuable touchstone for confirming points established earlier in this section, the paper provides an alternative approach for a longer-term method of improving maintenance performance. The approach for developing a maintenance strategy is summarised in Table 2.2. and shows ten decision elements (Pintelon, Pinjala and Vereecke, 2006). The authors classify the elements into structural or infrastructural, alongside a contextualised description of the element.

The classification of the decision elements in the first four rows are described as being maintenance resources and fixed in their nature. These four elements are then identified as occupying the majority of any maintenance budget, yet their effectiveness being heavily influenced by decisions taken in the infrastructure elements.

Pintelon, Pinjala and Vereecke (2006) acknowledged that an effective maintenance strategy must consider all these elements over a period of time, to allow improved maintenance strategy development. The importance of this holistic viewpoint is confirmed by Wireman, (2010); Kelly (2012); Kumar *et al.* (2013). Where the decision elements are prescribed by Pintelon, Pinjala and Vereecke (2006), there is also the need for a business to respect the context of its own contributing factors and hence develop a customised strategy (Waeyenbergh and Pintelon, 2002; Garg and Deshmukh, 2006; Pintelon, Pinjala and Vereecke, 2006; Al-Turki, 2011). Additionally, the alignment with business and manufacturing strategies is crucial.

Table 2.2 Maintenance Strategy Decision Elements. Adapted from (Pintelon, Pinjala and Vereecke, 2006)

Structural decision elements	**Identifying features**
Maintenance capacity	Capacity in terms of workforce, supervisory and management staff. Shift patterns and temporary staff.
Maintenance facilities	Tools, equipment, spares, workforce specialisation (mechanical/electrical), location of workforce.
Maintenance Technology	Predictive maintenance or condition monitoring technology, expert systems, intelligent maintenance
Vertical integration	In house maintenance versus outsourcing, relationship with suppliers.
Infrastructure decision elements	**Identifying features**
Maintenance organisation	Organisation structure (centralised, decentralised or mixed)
Maintenance policy and concepts	Policies such as corrective, preventive or predictive maintenance, concepts such as TPM or RCM
Maintenance planning and control systems	Maintenance activity planning, scheduling. Control of spares, costs, etc. Computerised Maintenance Management System (CMMS)
Human resources	Recruitment policies, training and development of workforce. Culture and management style.
Maintenance modifications	Maintenance modifications, equipment design improvements, new equipment installations and new machine design support.
Maintenance performance measurement and reward systems	Performance recognition, reporting and reward systems. OEE and BSC.

The model proposed by Pintelon, Pinjala and Vereecke (2006), attempts to reduce the decision areas, as formulating a strategy can prove an overwhelming task (Madu, 2000; Waeyenbergh and Pintelon, 2009; Faccio *et al.*, 2014; Parida *et al.*, 2015). Supplier relationships and customer demands can influence a maintenance policy.Pintelon, Pinjala and Vereecke (2006) indicated that government legislation or industry led conformance requirements can influence maintenance strategy effectiveness within the business.

The importance of infrastructure to support maintenance is discussed by Tsang, (2002), who acknowledged the prominence of the following four characteristics:

- Service delivery options
- Organisation and work structuring
- Maintenance methodology
- Support systems

Tsang, (2002) promotes the need for a business to engage with the work force when developing a maintenance strategy (Sheikhalishahi, Pintelon and Azadeh, 2016). Moreover, if the workforce are to become committed to a maintenance strategy through and participate in autonomous activities, the human element is crucial. The human element is an extension of the point made by Waeyenbergh and Pintelon, (2002), who described the need for a strategy to utilise the intangible aspects of the workforce when developing maintenance, such as personal experience and knowledge. Tsang, (2002), acknowledges that certain factors contribute towards the required empowerment of all members of the workforce. These include education and training of staff as well as clear lines of communication. These points are reinforced by Murthy, Atrens and Eccleston, (2002) who go on to state the importance of culture within the business. This brings the fourth dimension discussed by Tsang into sharp focus as a direct contributor towards a positive and committed workforce, which creates a culture of maintenance engagement. Where the paper offered by (Tsang, (2002) is a comprehensive and structured consideration of maintenance management, it does offer invaluable commentary on components of maintenance infrastructure which can inform aspects of strategy development. These include:

- Participation and autonomy
- Hierarchy and communication
- Education and training
- Reward and recognition
- Performance measurement
- Management information systems
- E Maintenance

Reviewing Table 2.2, it can be seen there is synergy between the infrastructure elements proposed as being important by Tsang, (2002) and those described by Pintelon, Pinjala and Vereecke, (2006). Tsang looks to place the workforce and human aspect of his maintenance management concept at the heart of the paper, focussing on clear lines of communication to an engaged and committed workforce.

Simplifying the process of maintenance strategy development is problematic, as the contributing factors are extensive. This is recognised by Shafiee, (2015), who identified that the selection of a maintenance strategy is a Multi-Criteria Decision Making (MCDM) problem. MCDM relies on a finite set of maintenance approaches for selection – including opportunistic maintenance or predictive maintenance. Prior to this selection, the MCDM method takes the user through a ranking and weighting process of criteria such as social, economic or environmental. Shafiee, (2015) recognises the benefits of considering all the criteria a business may deem important, but also recognises the problems associated with this method. To conclude, Shafiee, (2015) established that MCDM tools are well established in literature yet they lack classification towards particular industries. Additionally, the tools rely on the accurate recording and delivery of key pieces of data which is an area of inconsistency and within industry.

2.4.5. Performance indicators

Performance measurement of any business function is essential for any improvement and contribution towards business goals (Parida and Kumar, 2006; Muchiri *et al.*, 2011). The selection of performance indicators, which form part of the measurement system, needs to be rigorous and well defined. The importance of establishing and refining performance indicators is discussed by Pintelon and Van Puyvelde, (1997) who argued that management personnel receive substantial business level information, and performance can only be evaluated if the information is presented clearly. The authors continued, that unless the correct metrics and indicators are selected, then difficulties emerge. There is a need for managers to be assured that the maintenance department is meeting its operational targets at an optimum cost (Muchiri *et al.*, 2010). Tsang, (1998) proposed the link to strategy is essential, including the explicit engagement of senior management in the design and analysis of a Maintenance Performance Measurement (MPM) system. A note of caution emerges from literature that measurement systems and performance indicators can be selected based upon the perspective taken by the organisation. Consequently, how the maintenance department is perceived by the business will have a direct impact upon how it is measured (Kumar *et al.*, 2013).

The features of an MPM system is discussed by Parida and Kumar, (2006), who indicate that a performance measurement system should be developed which considers internal and external effectiveness of the maintenance function. The authors discuss MPM as a set of specific indicators which are used to address the strategic aims of the business. The authors recognise internal effectiveness can be satisfied through Overall Equipment Effectiveness (OEE), though the challenge exists in developing a system which can measure and improve the external effectiveness of the function. The majority of data used to inform key performance indicators throughout literature is quantitative (Kumar *et al.*, 2013) including cost analysis, on time delivery or mean time to failure. The execution of most maintenance tasks could be expected to involve the human element, and this is discussed by Berges, Galar and Stenström, (2013). The authors describe the human element as an essential consideration for performance measurement, drawing attention to individual factors such as expertise and motivation. Additionally, temperature, humidity and lighting contribute towards the work environment and these factors, if perceived in a negative manner, can diminish the efforts of an employee. What emerges throughout the paper, is that although they can be difficult to establish and incorporate within an effective measurement system, a system which utilises both qualitative and quantitative data would prove beneficial for maintenance performance.

The merits of having a specific set of performance indicators which are aligned to the maintenance strategy is discussed by Pintelon and Van Puyvelde, (1997). The paper suggested the importance of considering alternative systems that are specific to the user, as opposed to implementing a standard set of metrics based upon maintenance cost, performance and output. Whilst this is valuable information – the authors proposed it is useless unless used as part of a structured feedback loop. The selection of the correct maintenance performance indicators, can be troublesome. Tsang, (1998) discussed how the selection of performance information can be based upon historical practice, ease of acquisition or even following a comparable measurement system to competitors. The volume of qualitative and quantitative data available can be daunting, though Tsang confirmed the need for a strategic viewpoint when selecting the appropriate metric. A study by Muchiri *et al.* (2010) into the selection and use of maintenance KPI's within individual manufacturing organisations is summarised in Figure 2.3. The quantitive data collected by Muchiri *et al.* (2010) acknowledges that indicators can emerge from a range of sources. The response of 'Own creation' suggests a bespoke and contextual selection. Alternatively, the study also reports the selection of metrics which are predefined.

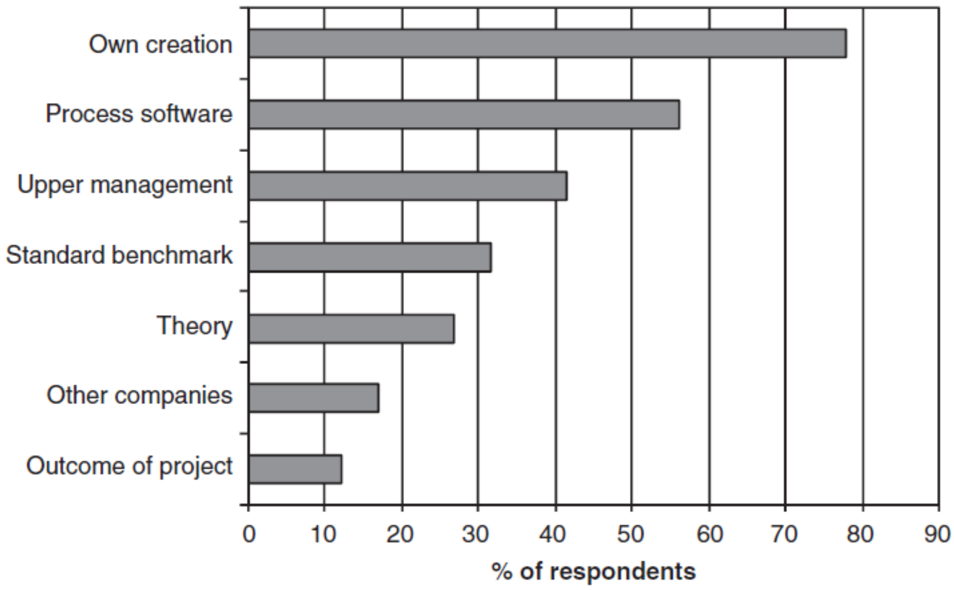

Figure 2.3 A bar chart presented by Muchiri et. Al (2010) demonstrating the source of maintenance indicators in manufacturing organisations.

The nature of the indicator and relevance to the business is worthy of further analysis. The standpoint of Tsang, (1998) is noteworthy, as it aimed to align the use of indicators with a specific measurement tool. The balance scorecard is the basis for Tsang discussing indicators which provide information to a measurement system, which are leading (performance drivers) or lagging (performance killers). It is possibly unfair to typify lagging indicators as performance killers and conversely leading indicators as drivers. Kumar *et al.* (2013) identified leading indicators as providing advanced warning of a change in performance which may affect the business. The effect would tend towards an economic improvement or deterioration, Moreover, the indicator which may fall into this area is classified as being ‘soft’ and can be found in areas such as customer satisfaction ratings. Additionally, ‘soft’ information such as customer feedback must be used with care, as it may provide conflicting views or be unreliable. A lagging indicator is discussed by Tsang, (1998) and Kumar *et al.*, (2013) as following a change in economic performance. Kumar *et al.*, (2013) offered an additional view which is not explicitly linked to financial variance, where a lagging indicator is observed as a direct result of a direct action. Figure 2.4 categorises indicators into leading or lagging, yet this is subjective. It could be argued that it is the link between the strategy of the business and maintenance department which defines the nature of the performance indicator. Projecting that further, the argument exists that the nature/classification of the indicator is immaterial. Conversely, how it is used is crucial. This conflict is endorsed by Stenström *et al.*, (2013) who described on time delivery could be termed a lagging indicator of past performance, but a leading indicator for customer satisfaction. The inspiration for the continued research in this area, can be found in the limited application of research findings in industry. Muchiri *et al.*, (2010), identified with this frustration and recognised there is often limited impact to a business using an MPM system.

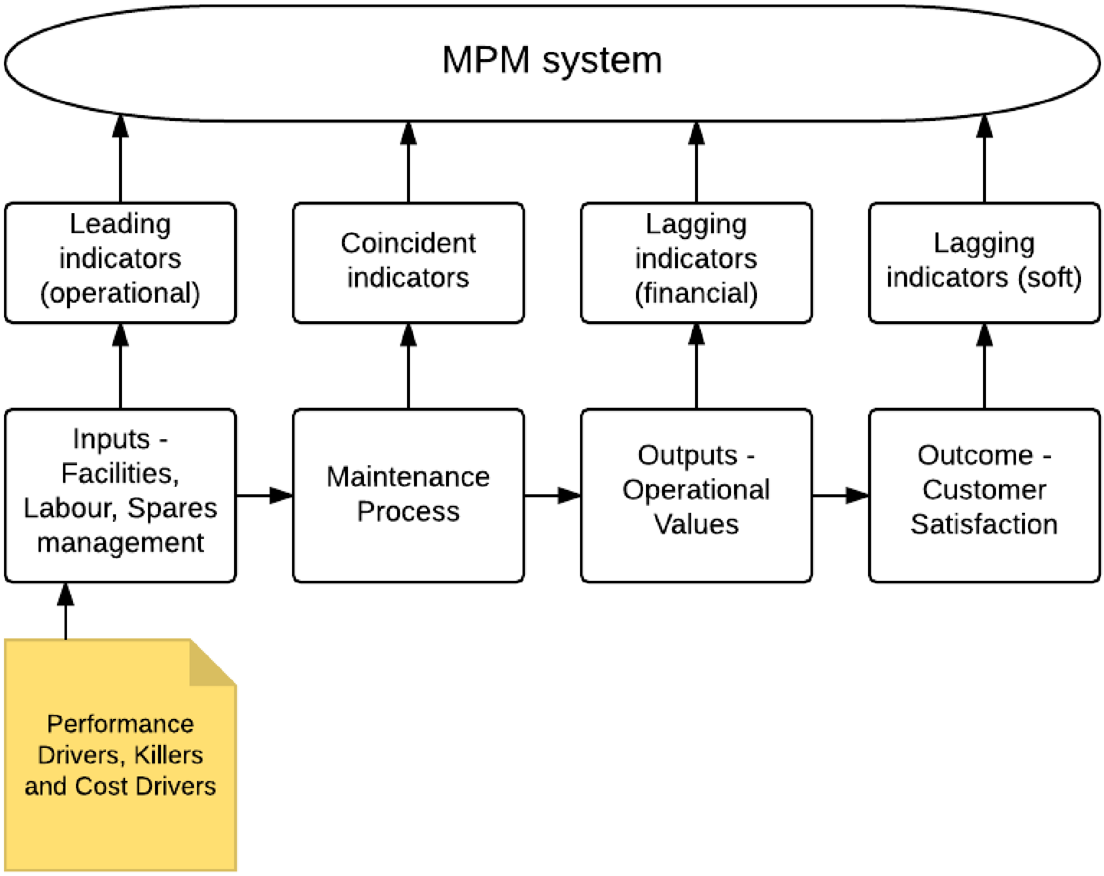

Figure 2.4 Indicators and the MPM system, adapted from (Stenström et al.*, 2013)*

Muchiri *et al.*, (2011); Parida *et al.*, (2015) reflected on the opportunity for performance measurement to provide a strategic direction to an organisation, yet there is little research to provide a methodology that would assist the developer and end user. The use of performance indicators as a method of delivering business objectives appears to be established, yet challenges remain. The need for extensive senior management support is evident, with the need for a clearly defined set of metrics linked to business objectives.

The lack of a methodology identified by Muchiri *et al.*, (2011) in selecting the relevant performance indicators within an MPM system is explored by Stenström *et al.*, (2013), who use the perspective of Value Driven Maintenance (VDM) as a method of selection. The authors referenced previously established literature but define VDM as being focussed on 4 main drivers; asset utilisation, resource allocation, health, safety and environment and finally cost control. It is this focus that provides a framework for the selection of specific KPI's. The emphasis is aimed at investment return and value for money. This may be restrictive to the end user, who may require alternative performance measures. Conversely, Salonen and Deleryd, (2011) proposed Cost of Poor Maintenance (CoPM), which can select and justify maintenance strategies. This methodology is based upon establishing the cost associated in 4 areas of maintenance;

- costs for indispensable corrective maintenance
- costs for valid preventative maintenance
- costs for non-accepted corrective maintenance
- costs for invalid preventative maintenance

The paper by Salonen and Deleryd, (2011) had limitations in the lack of detail and empirical testing. Additionally, the cost based focus of the methodology reinforces the traditional viewpoint of maintenance being a burden on financial resource to most businesses (Swanson, 2001; Wireman, 2010; Kelly, 2012). Conversely, the concept proposed by Salonen and Deleryd, (2011) does reinforce a number of points made by Stenström *et al.*, (2013) and Parida *et al.*, (2015) who discussed that a performance measurement framework can be utilised to develop, justify and improve a strategy if it is aligned with the goals of the business and if it has a methodology for selecting the indicators.

2.5. Supply chain management

This section will provide definitions of supply chain partnerships as well as features of a strong partnership. This will include a sharp focus on the relevance to the automotive industry and consider some pertinent dynamics to that sector. The discussion will conclude with methods of improving the supply chain, some of the benefits and how this paradigm can influence the research question.

Research has led to an elementary classification of the relationship a manufacturer may have with its suppliers. Hill, T and Hill, A, (2009) classified the possible relationships as beginning with '*Trawling the markets*', progressing to '*Ongoing* *relationships*' leading to '*Partnerships*' and finally '*Strategic alliances'*. The relational possibilities are simplified by Singh et al., (2005), who described the relationship as being relational or contractual. A relational affiliation can be described as promoting a close working association, sharing information and best practice. Conversely, a contractual relationship is more formal and could be described as combative. The geographical location of the supply chain and the customer OEM, provides an additional insight into the relationship dynamics. Monden, Y, (2012) proposes that Japanese auto manufacturers have fewer suppliers and thus tend to have a closer, problem solving relationship. Conversely, Western manufacturers have multiple suppliers leading to confusing lines of communication and increased issues. The factors which contribute towards the nature of the relationship between suppliers within the automotive supply chain, provide an insight into relationship inhibitors and enablers.

The inhibiting factors are explored to a greater depth by Wit and Meyer, (2014a), who discussed the complexity of advancing industrial development. Two factors, industrial recipe and institutional pressures appear influential within the context of supply chain management. The authors define Industrial recipe as being the rules of the game, where the rules are established by incumbents. In this instance, supply chain partners. Moreover, the rules are difficult to change as they have been developed by the stakeholders. It is these rules which can provide a platform for defining the nature of relationships within supply chain management. This can be reinforced by the second term – institutional pressures. In this instance, what is normal and conventional becomes very difficult to change. This is a differentiator between a partnership which may develop and improve and one which is adversarial and static (Wit and Meyer, 2014a).

Lean production principles and systems are widely deployed within automotive manufacture (Doran, 2001, 2004; Singh, Smith and Sohal, 2005; Al-Turki, 2011; Thun, Druke and Hoenig, 2011). Yet utilising this production system provides substantial challenges to the supply chain and can define the nature of relationships. These difficulties are recognised by Slack, Brandon-Jones and Johnston, (2013) who debate the difficulties in deploying such principles throughout the supply chain. The need for lean principles to be applied throughout the supply chain is confirmed by Moyano-Fuentes, Sacristán-Díaz and José Martínez-Jurado, (2012), who identified that lean systems cannot be confined solely to manufacturing operations. Success is dependent on the application to all aspects of the business. The utilisation of lean principles to provide a platform for improving the performance of the supply chain is discussed by Thun et al. (2011). Additionally, Thun et al. (2011) offered a note of caution, indicating that automotive supply networks are complex and as such are vulnerable when poor performance in one area can have a cumulative effect downstream. Indeed, Moyano-Fuentes, Sacristán-Díaz and José Martínez-Jurado (2012), recognise that any attempt at implementing lean principles below Tier One can be problematic. In short, the greater the distance up the supply chain, the greater the reduction in any OEM authority.

An improved level of performance is possible if a supportive, communicative, relational association is evident between the constituents of the supply chain (Coronado Mondragon and Lyons, 2008; A. Dellana and F. Kros, 2014; Agrawal, De Meyer and Van Wassenhove, 2014). Hill & Hill (2009), identify the transfer of technical knowledge and expertise throughout the supply chain will offer substantial, valuable results to the product and supply chain. This is acknowledged by Doran (2004), who recognised the benefits of sharing information and best practice. A simple model of this relationship is shown in Figure 2.5.

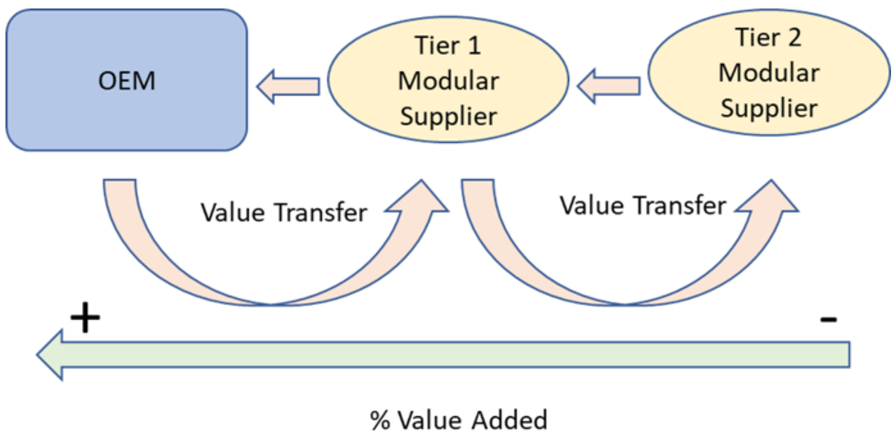

Figure 2.5 A model by Doran (2004) recognising the benefits of sharing best practice.

Slack, Brandon-Jones and Johnston (2013), confirmed the sharing of information on a technical level is crucial to improving the supply chain. The authors stated that eliminating sources of inefficiency or ineffectiveness will improve operational performance. Additionally, adopting similar techniques for decision making at key points within a process can help achieve these efficiency gains. The influence and resources an OEM may possess is highlighted by Singh, Smith and Sohal, (2005); Thun, Druke and Hoenig (2011), as well as the responsibility they have for improving the technical ability of their supply chain. Yet Singh, Smith and Sohal, (2005); Thun, Druke and Hoenig (2011), both recognised the realities of proposing such an open and sharing environment. Singh, Smith and Sohal (2005), proposed that OEM's become involved to help reduce costs and can see this as being helpful, whereas the supplier can view it as being a stressful activity and egocentric. The underlying barrier of trust is confirmed by Womack, Jones and Roos (2007), who identified that full disclosure of costs, techniques and technology can be difficult for any supplier as it will leave them feeling vulnerable in an already unbalanced relationship. The sharing of information and mutual technical support seems crucial for supply chain performance improvement, yet there exists a fundamental need for an established foundation of trust and mutual benefit.

The need for the automotive manufacturing supply chain to be comprised of dynamic members is recognised by Slack, Brandon-Jones and Johnston, (2013) and Gunasekaran, Patel and Tirtiroglu (2001), who cite both flexibility and responsiveness are key aspects of the inherent production system. Both authors, noted that achieving on-time delivery of goods is essential in maintaining a positive relationship with the customer. Realising this objective through being responsive to customer demands, can come at a cost to the business. Thun, Druke and Hoenig (2011), discussed the inefficient practice of the supply chain member holding extensive buffer stock to meet the demands of the downstream customer. Moreover, the author establishes this may be the practice of a SME yet it can be a consequence of any business which may have reduced resources and inflexible systems. Utilising such a reactive tool is in conflict with lean principles, Monden, Y, (2012) and highlights the dangers of achieving external satisfaction through internal inefficiencies.

2.6. Organisational Culture

This section will discuss the importance of the human aspect of maintenance management as well as the characteristics which define this. These characteristics include staff training, motivation, engagement and leadership. The contribution by Tsang, (2002); Waeyenbergh and Pintelon, (2002); Pintelon, Pinjala and Vereecke, (2006) highlight the importance of culture within the sphere of maintenance strategies. Clearly, an understanding of organisational culture would appear to be relevant.

The culture of an organisation, workplace or business, is elusive in nature yet has a direct influence on the day-to-day actions of all participants within the organisation. This apparently intangible characteristic has not prevented scholarly literature attempting to both define and understand organisational culture. Hofstede, Hofstede and Minkov, (2010); Keyton, (2010); Hitt, Miller and Colella, (2014); Schein and Schein, (2017) differ in the language they use to describe culture, yet all follow a similar trajectory. Hofstede, Hofstede and Minkov, (2010) defined culture as being made up from symbols, heroes, rituals and values. This is echoed and advanced by Schein and Schein, (2017) who discussed supported values, rules of the game, climate, personal skills and thinking patterns as being defining features. The importance of these relatively singular nouns is highlighted by Hitt, Miller and Colella, (2014) who described how shared values and beliefs lead to models of behaviour. The shared values and beliefs are a direct result of interaction and communication (Keyton, 2010). As described by Hitt, Miller and Colella, (2014) these everyday behaviours predictably lead to actions, with associated results in the workplace. These results are then either praised or penalised. In this way, the culture becomes self-reinforcing and difficult to change.

Organisational culture may appear to consist of features which exist within the subconscious Cameron and Green, (2015), yet a review of symbols and artefacts provide a more tangible characteristic. Losonci *et al.*, (2017) described culture as the invisible artefacts of the business, yet numerous scholars disagree. Brown, (1998); Keyton, (2010); Schein and Schein, (2017) counter, discussing artefacts as being the most superficial and visible aspect of culture. An artefact can be identified as the physical result of a human action and Table 2.3 provides some examples:

Table 2.3 A table providing examples of cultural artefacts within an organisation. Adapted from Brown, (1998 p12)

Artefact	Example
Material Objects	Manufactured product. Sales images.
Physical Layout	Workshop space – size and placement. Dress codes. Appearance.
Equipment	Level of technology utilised within the organisation.
Language	Jokes, technical language, stories.
Methods of conduct	Meeting and celebration schedules. Procedures for action.
Rules and Procedures	Appraisal. Meeting and committee terms of reference. Programmes of work.
Symbols/Images	Posters. Charts. Physical items and images.

Table 2.3 highlights the universal presence of culture within a normal organisation. Artefacts are important as they subconsciously guide employees in how to behave towards each other. In addition, they are the first thing which is noticed within an organisation (Keyton, 2010). Whilst this is illuminating, it also demonstrates their importance.

2.6.1. Influencing factors

The clear, physical representation of culture within an organisation through artefacts, provides an interesting perspective. Although Keyton, (2010) argues the culture is self- reinforcing and difficult to change, there are a number of characteristics which influence the direction of an organisational culture. A common agreement exists amongst several authors, that the culture of an organisation is permanently bound to its external environment (Handy, 2005; Cameron and Green, 2015; Schein and Schein, 2017). This phenomenon is further explored by Handy, (2005) who identified multiple factors influencing the formation of culture, including procedures; job descriptions; leadership style; size of the organisation; technology and objectives. Furthermore, the economic state of the company and industrial marketplace are influential. This is supplemented by Keyton, (2010) who argues communication within an organisation as being the key influencing factor on organisational culture. Schein and Schein, (2017), explores the individual influence further and discussed the personal culture which is attached to the job role of the individual. The author generalises, yet recognises that an operator, engineer and senior manager will all have differing values – and thus culture. Importantly, their operational environment forms part of that influence and is equally as significant (Keyton, 2010). The role of the senior manager is crucial within the sphere of organisational culture Schein and Schein, (2017), and this is compounded by study completed by Pakdil and Leonard, (2015). The link between senior management objectives, production environment and the resultant culture are identified as being highly relevant. Within the context of lean manufacturing, Pakdil and Leonard, (2015) associate organisational leaders developing and influencing their staff as being highly important to the success of lean processes. Finally, Bititci *et al.*, (2006) elevated the importance of employees, their role and the deployed manufacturing strategy. According to Bititci *et al.*, (2006), the manufacturing strategy and the interplay between strategy and organisational culture, can have a direct effect on business performance.

2.6.2. Organisational culture and performance

The relationship between business performance and the culture of an organisation is debated, yet Brown, (1998); Keyton, (2010), discussed this objectively. The author states that the same technology, equipment and staff type may be replicated across two sites within the same manufacturing environment, yet this does not guarantee they will both perform to the same level. The differentiating factors are the beliefs and values of each set of staff. The discussion of Hofstede, Hofstede and Minkov, (2010); Keyton, (2010); Hitt, Miller and Colella, (2014); Schein and Schein, (2017) in Section 2.7 help remind us that these are fundamental characteristics of culture. The prominence of culture when discussing business performance is further analysed by Handy, (2005), who recognises that as well as individual occupations such as Engineers, possessing a different culture to a fellow employee, the same may be said of individual departments. The interaction and subsequent cooperation between these departments is crucial to business success (Handy, 2005).

Pakdil and Leonard, (2015), studied the importance of culture within a lean process environment being highly relevant to the success of the business. The importance of the relationship between performance, strategy and culture is reviewed by Bititci *et al.*, (2006) who uses a performance measurement strategy (PMS) to demonstrate the link and influence between all three factors. Bititci *et al.*, (2006), describes how the manufacturing strategy of a business of a can be directly influenced by the prevailing organisational culture. Crucially, recognising the importance of cultural elements is important for the success of the strategy.

2.6.3. Enabling Organisational cultural change

Section 2.7.2 discussed the ability of culture within an organisation to influence business performance. Recognising the need for cultural change and subsequently enabling that change, is a challenge for senior managers (Brown, 1998; Handy, 2005; Schein and Schein, 2017). Table 2.4 offers a synopsis of enabling factors for change:

Table 2.4 Enabling characteristics for changing an organisational culture.

Enabling Factor	**Reference**
Management engagement	(Brown, 1998; Smith, 2003; Bititci *et al.*, 2006; Keyton, 2010; Losonci *et al.*, 2017)
Staff/Team engagement	(Smith, 2003; Rollinson, 2008; Taneja, Sewell and Odom, 2015; Losonci *et al.*, 2017; Schein and Schein, 2017)
Communication	(Smith, 2003; Keyton, 2010)
Vision and effective planning	(Smith, 2003; Cameron and Green, 2015; Schein and Schein, 2017)
Manufacturing Strategy alignment	(Brown, 1998; Smith, 2003; Handy, 2005; Bititci *et al.*, 2006)
Trust	(Simpson and Cacioppe, 2001)
Resources	(Simpson and Cacioppe, 2001)
Motivation and reward	(Brown, 1998; Simpson and Cacioppe, 2001; Bititci *et al.*, 2006; Rollinson, 2008; Cameron and Green, 2015; Schein and Schein, 2017)
Employee autonomy and problem solving	(Maletič, Maletič and GomiščEk, 2014; Pakdil and Leonard, 2015)
Appraisal and Training	(Pakdil and Leonard, 2015; Losonci *et al.*, 2017; Schein and Schein, 2017)
Departmental culture alignment	(Brown, 1998; Smith, 2003; Bititci *et al.*, 2006; Losonci *et al.*, 2017)
Artefacts/Symbols	(Brown, 1998; Rollinson, 2008; Keyton, 2010)
Performance measurement	(Simpson and Cacioppe, 2001; Cameron and Green, 2015; Schein and Schein, 2017)

The factors identified in Table 2.4, may seem common in the workplace, yet failure to affect these characteristics will lead to a cultural status quo. Senior Management engagement described by Brown, 1998; Smith, (2003); Bititci *et al.*, (2006); Keyton, (2010); Losonci *et al.*, (2017), demonstrated importance when leaders become part of a visible change process which includes regular contact with employees (Smith, 2003). In addition, Table 2.4 reveals the fundamental importance of the senior management team in establishing many of the listed characteristics. Linked closely with management is that of communication. If a cultural change process is in motion, the momentum and success is supported by consistent communication on the performance of the change objectives, (Smith, 2003). Moreover, Keyton, (2010), identified communication as a key enabler for cultural creation, maintenance and change. Table 2.4 recognises staff engagement and motivation are of significance and both are closely related. Rollinson, (2008), described the importance of staff feeling involved in a decision-making process, resulting in ownership of the new direction. This is supplemented by Losonci *et al.*, (2017), who related staff engagement as a key feature of success when implementing and managing lean manufacturing. Brown, (1998); Simpson and Cacioppe, (2001); Bititci *et al.*, (2006); Rollinson, (2008); Cameron and Green, (2015); Schein and Schein, (2017), agree that engagement is closely associated with motivation and reward. The consistent motivation for engagement is through work satisfaction and reward (Schein and Schein, 2017). Importantly Brown, (1998), identifies high employee motivation with high performance.

The alignment of departmental culture and strategy, is recognised as being important to departmental performance and success (Brown, 1998; Smith, 2003; Bititci *et al.*, 2006; Losonci *et al.*, 2017). Smith, (2003), describes the need for strategy objectives to be supported by the prevailing culture if they are to be achieved. This is reinforced by Losonci *et al.*, (2017), who characterises lean manufacturing as requiring autonomous decision making along with the importance of quality. Yet Losonci *et al.*, (2017), continues, stating the futility of these objectives unless there is no culture of training, motivation or awareness of the importance of the customer. The importance of the relationship between culture and strategy is demonstrated further in the case study by Bititci *et al.*, (2006), who discusses the implications of having a performance measurement driven strategy and a culture which is not aligned. The impact of a disjoint between the two is negative for both the culture and business performance. Cameron and Green, (2015), discussed that a successful relationship between this strategy and an appropriate culture, features enablers such as team working, employee engagement as well as a supportive and engaged senior management team. Crucially, the context of the organisation must be understood before applying any alignment or change.

The significance of artefacts and symbols in defining and enabling culture is reflected by Cameron and Green, (2015), who acknowledged the importance of artefacts in symbolising culture and the instantaneous nature of them. This can be attributed to their conscious visibility (Cameron and Green, 2015). The relevance of artefacts when demonstrating culture or change of culture, is continued by Keyton, (2010), who related artefacts to beliefs which can provide an identity – much in the way of a organisation uniform. Furthermore, Keyton (2010) demonstrated the use of artefacts to signify alignment, suggesting if a business requires a fully integrated and efficient team, there should be an artefact or symbol that represents teamwork as important. Conclusively, Brown, (1998) confirms the importance of artefacts as they represent the beliefs and values of the organisation. As a result, if an improvement in performance is required and a change in culture is attempted, the importance of surrounding artefacts must be acknowledged.

2.7. Conclusion

The purpose of this Chapter was to establish characteristics of maintenance best practice in relation to the research question. This section provides a summary of the Literature Review as well as highlights the key points informing the development of a new tool in Chapter Five. Finally, this review identifies a gap in knowledge which supports the need for this research.

When considering the importance and the need for a maintenance strategy, there are clearly many challenges facing a maintenance function. It is evident from the literature that developing a maintenance strategy can be both difficult and complex. Moreover, for the companies who use a mostly reactive maintenance policy, there is a clear need to improve and move to more preventative measures. The literature also advises a bespoke strategy which considers the context and characteristics of the organisation.

Moreover, scholarly work recognises the need to utilise a clear, appropriate and accurate performance measurement system.

However, one important area where there is little empirical research, is the topic of organisational and workforce culture. According to the literature, organisational culture is an intangible contextual factor and difficult to measure. However, some authors still consider it important to investigate the human element for motivation and engagement. Whereas others suggested culture was influenced by the role of the employee, external environment, industry sector, and technology. Additionally, there is an important connection between artefacts, symbols and cultural change. In summary, there are a multitude of challenges for practitioners when considering the culture in a business. Yet it should not be ignored, as it can have a significant effect on the outcome of a strategy and business performance.

In conclusion, this review has identified the content of a maintenance strategy should draw on the following enablers. These are:

- Senior Management Engagement
- Training and Skills
- Staff Resources
- Perception and Integration
- Equipment and Spares
- Planning and Performance
- KPI's
- Budget

By focussing on these enablers, it should be possible to develop a successful maintenance strategy in any industry. To assist in the development of a solution to facilitate this development, these enablers have been transposed into propositions. The propositions are listed in Table 2.5

Table 2.5 A series of categorised propositions acknowledging maintenance best practice.

Category	Proposition	Reference
Senior Management	• Senior management participation is essential for strategic maintenance development.	(Jacobs and Chase, 2010; Lloyd, 2010; Kelly, 2012; Campbell and Reyes-Picknell, 2015; Schein and Schein, 2017)
Training and Skills	• Training for maintenance staff must be appropriate, relevant and timely and accordance with the working environment.	(Tsang, 2002; Wireman, 2014; Campbell and Reyes-Picknell, 2015; Shanmugam and Paul Robert, 2015; Schein and Schein, 2017)
Staff Resources	• Staff resources and skills should be flexible and aligned to maintenance strategy requirements.	(Murthy, Atrens, and Eccleston, 2002; Pintelon, Pinjala and Vereecke, 2006; Lloyd, 2010; Shanmugam and Paul Robert, 2015; Schein and Schein, 2017) (Davies, Holweg and Wood 2017)
Perception and Integration	• The perception of key stakeholders can be influenced by cultural artefacts displayed by the Maintenance function.	(Tsang, 2002; Smith, 2003; Kelly, 2012; Campbell and Reyes-Picknell, 2015, 2015; Shanmugam and Paul Robert, 2015; Schein and Schein, 2017; Mahlamäki and Nieminen, 2019)
Equipment and Spares	• The equipment and spares management system must support efficient and effective maintenance activity.	(Wireman, 2004; Womack, Jones and Roos, 2007; Muchiri and Pintelon, 2008; Thun, Druke and Hoenig, 2011; Moyano-Fuentes, Sacristán-Díaz and José Martínez-Jurado, 2012; Campbell and Reyes-Picknell, 2015)
Planning and Performance	• A comprehensive work order planning system is needed to ensure the quality assurance of completed work.	(Smith, 2003; Pintelon, Pinjala and Vereecke, 2006; Al-Turki, 2011; Golinska, Fertsch and Pawlewski, 2011; Kelly, 2012; Cameron and Green, 2015)
KPI's	• The identification and accurate application of relevant performance measures, is a key characteristic of a successful maintenance strategy.	(Muchiri *et al.*, 2011; Salonen and Bengtsson, 2011; Salonen and Deleryd, 2011; Kelly, 2012; Berges, Galar and Stenström, 2013; Kumar *et al.*, 2013; Stenström *et al.*, 2013; Parida *et al.*, 2015)
Budget	• Adequate financial and human resources are required to support and drive the maintenance strategy.	(Tsang, 2002, 2002; Wireman, 2010; Kelly, 2012)

Furthermore, the review identified a dearth of research into maintenance management within the automotive supply chain. The need for more research was highlighted in Section 2.2 because of the many challenges specific to the automotive industry. This research will go some way to bridging the gap in knowledge by providing context and application for the subsequent maintenance strategy development, within the automotive supply chain.

2.7.1. Gap in knowledge

The review of literature has identified specific areas to investigate further during the empirical research phase. Moreover, Chapter Two established a lack of literature in relation to maintenance management within the automotive supply chain. Conversely, scholarly work reviewing maintenance management appears in abundance in the wider lens of the manufacturing industry. Furthermore, literature acknowledges the use of maintenance concepts within the automotive industry but is focussed on the OEM, not the supply chain.

The impact of organisational culture on business or department success, is considered in this chapter. Moreover, scholarly work combining characteristics of organisational culture and maintenance management in the automotive supply chain, has revealed a distinct lack of published research - despite the relevance.

As a result, the gap may be summarised as:

- Maintenance strategy development in the automotive supply chain.
- The influence and effect of organisational and department culture on maintenance performance and development.

This research will now attempt to address the gap in knowledge. This will begin by developing a methodology which will allow a deeper understanding of maintenance management and organisational culture in the automotive supply chain. This framework will also look to understand any constraints which prevent maintenance development in a Tier One supplier. Establishing this information will facilitate the development of a tool which acknowledges scholarly guidance, rich data from the supply chain as well as site specific inhibitors.

3. Research Methodology

3.1. Introduction

Chapter Two concluded with several key findings which helped shape the design of the research methodology. Most influential, was the impact of the human aspect of maintenance performance and management. This included engagement, motivation, training and more broadly, organisational culture. Subsequently these findings suggested a need to gather rich data in order to address the dearth of scholarly work in the field of maintenance management within the automotive supply chain. Moreover, it was important to recognise that any maintenance strategy must be bespoke to an individual business. As a result, the integration of a site-specific investigation within the research design became important.

This chapter presents the research design and the rationale behind the selection of methods. It begins with the aims and objectives of the research followed by an explanation of the research approach, the methods considered, and the choices made. Finally, there is a discussion representing the coding and processing of data in a valid, reliable and ethical manner.

3.2. Research Aim

The aim of this research was to develop a tool which could identify the areas enabling or inhibiting, effective maintenance strategies within the automotive supply chain. By doing so, this would form the basis of a strategy which would address and appease the unique constraints within the automotive industry. Importantly, this would allow well designed maintenance strategies to prevail.

3.3. Research approach.

Figure 3.1 represents the relationship, order and description of research methods used.

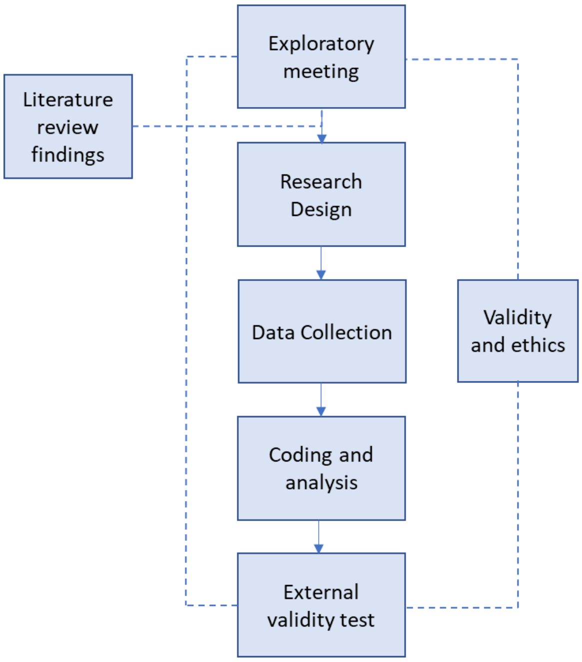

Figure 3.1 A diagram representing the stages of research deployed

3.3.1. Research motivation

The initial motivation for this research was a single, albeit valid conversation with a senior manager indicating a problem with maintenance effectiveness. Clearly, this required confirmation through additional exploration – with more than one source.

Further exploration was initiated through a pilot study, to confirm a problem existed for maintenance deployment specifically in the automotive supply chain. A meeting with a senior manager and maintenance engineer was the most accessible option for gaining this information. Furthermore, it was expected this meeting would establish a foundation of trust between the researcher and the organisation. A good working relationship was important if the investigation was to progress. Two sites were chosen to confirm the issue. The first site was the workplace of the senior manager who prompted the investigation. The site was a Tier One global supplier to varying OEM's. A second site was then incorporated, which increased the ability of the researcher to understand the scope of the issue. The second site was accessible due to a prior connection to the business yet differed in several ways. This included a substantial difference in geographical location, differing downstream OEM's and a variation in the product and supporting processes. This variation in site specific dynamics provided a wider understanding of some of the issues. Conclusively, the two meetings provided confirmation of the issue as well as the need for further research.

3.4. Research Methods

3.4.1. Case study approach

A series of case studies were deployed as being the primary and most effective way of answering the research question. The context of the individual business within the automotive supply chain is a key aspect of the design consideration for this methodology. Gray, (2017), identifies context as being crucial and highly relevant within management research and the use of case studies. As part of this investigation, the researcher was looking to study the phenomenon of maintenance and the context of the manufacturing environment in which it was operating. The dynamics of the automotive manufacturing industry and the specific influence upon maintenance effectiveness, was of direct importance when identifying a case study strategy (Colin Robson, 2002). Moreover, David de Vaus, (2013), describes case studies as providing the ability to provide the full picture of the case including the context. This method of data compilation, combined with having the opportunity to understand the context of the information over a period, confirmed the selection of the case study as the primary design method. Furthermore, the case study facilitated an in-depth review of a small number of organisations. Conclusively, the case study provided the opportunity for the understanding and ensuing resolution of a problem (Stake, 1995).

Each individual case study taking part in this investigation could expect variation in the following areas:

• The product which is manufactured and its contributing processes

• The OEM which is supplied

• Number and experience of the workforce, both technical and operational

• Geographical location

• Management structure

• Business development history.

Each of these characteristics would be specific and individual to each supplier. The research question could only be answered if each area was investigated, considered and understood. In confirmation of this method, Stake, (1995) discusses case study research having the ability to effect change within the industry under review. Reference to research question 3 identifies the importance of this point. Conclusively, David de Vaus, (2013) identifies the importance of the case study when the research is unable to focus one particular phenomenon and exclude all other external variables. The apparent impact of the industry, culture and organisation on maintenance effectiveness established in Section 2.6, ensured the need to include those influences.

3.4.2. Type of case study

A case study can be single or multiple in design (Yin, R, 2003). The nature of the primary research question indicates the possibility of operating with a single case study. If this was to be pursued, the findings would lack rigour and encounter issues with external validity (Gray, 2009). A key rationale for utilising a single case study design is that the single case must be considered to be representative, typical or unique (Yin, R, 2003). This could not be expected within the automotive supply chain, due to the variants listed in Section 3.4.1. Furthermore, a fundamental reason for the selection and use of the case study was that context may be appreciated between differing businesses. The difficulty with single case design continues when reviewing research question two. The supply chain is the theme of the question, so the use of a single case study becomes redundant. Considering these details, it became apparent that the case study design was self-selecting, and a single case design would not allow an accurate response to the research questions. Finally, using a multiple case study creates an environment where the evidence and findings are considered more robust (Yin, R, 2003).

3.4.3. Number of case studies and selection criteria

The number of case studies was initially proposed as three Tier One suppliers as well as three direct suppliers to those businesses. They would be termed Tier Two suppliers and are upstream of the OEM in the supply chain. Tier One and Tier Two suppliers would constitute the units of analysis**.** This would lead to six participants in total. Rigorous data collection and synthesis across six case studies involves a large volume of work and effective planning was crucial. Whilst the workload was substantial, it provided the opportunity for extensive data leading to a useful, transferrable and effective output for this thesis.

This design was amended part of the way through the data collection stage of this research. Engagement with Tier One suppliers revealed that there were relatively few Tier Two suppliers within the automotive industry. Where Tier Two suppliers did exist, they did not operate solely within automotive manufacture. This information led to an understanding that these operating conditions would skew the data collected from Tier One suppliers. Furthermore, the importance of industrial context to this research would become diluted. This resulted in the design being amended to expand the number of Tier One case study partners to four. This ensured the level of engagement and depth of data collection remained stable.

The depth of engagement increased the range of data collection which was possible, as well as exposing different aspects of the automotive manufacturing landscape. This included a variation in the OEM that was supplied. This variation resulted in each Tier One supplier experiencing differing levels of pressure and operating dynamics. Furthermore, the selection of case study participants was carefully considered. A review of the business, product and customers led to a range of criteria being used. Firstly, the product sold by the business was required to be manufactured on site, hence involving a production process. This process would require some form of maintenance or it would, at some point, be prone to breakdown and failure (Renna, 2012).

Secondly, the product manufactured had to be a made to order component, which formed part of an overall assembly process. This ensured a continuation of the prevailing production constraints throughout the supply chain. Finally, the case study participant could not be an SME. The exclusion of SME's from consideration for Tier One suppliers sharpened the focus for the key issues affecting maintenance strategy development. In the first instance, this exclusion ensured the research did not cross over into previous areas of literature and scholarly work. Secondly, a small to medium sized enterprise has less than 250 employees and a turnover which may suggest a reduced ability to contribute towards engineering resources. This strategic selection of case studies allowed the study to investigate the research question in an effective manner (David de Vaus, 2013; Gray, 2017).

3.5. Data Collection

The case study strategy provided the opportunity for both qualitative and quantitative data to be sourced (Yin, R, 2003). The key conclusions from literature, as well as emerging issues from the pilot study, provided a focus for areas requiring investigation. Table 3.1 provides a snapshot of this review and indicates qualitative data to be more valuable to this study. The qualitative nature of the research design did not exclude quantitative information. Where possible, this could complement alternative sources (Easterby-Smith *et al.*, 2018). An additional influence in the decision to focus primarily on qualitative data emerged from the pilot study. Both meetings which formed the pilot revealed the competitive nature of the automotive supply chain. Consequently, this ensured any statistical information would be restricted or unavailable. Crucially with regards to this research, the open-ended nature of the research question promoted the need for a flexible, or qualitative design. As confirmed by Colin Robson, (2002), the lack of knowledge on the specific nature of the issue for maintenance within the automotive industry, precludes the use of a fixed or solely quantitative design.

Table 3.1 A summary of key findings from literature and pilot study with reference to data collection.

Research design	Research requirements					
	KPI's	Leadership engagement	Sector specific issues	Site specific dynamics	Human aspect	Organisational culture
Quantitative	✓		✓	✓		
Qualitative	✓	✓	✓	✓	✓	✓

3.5.1. Types of qualitative data collection methods.

There are a range of qualitative methods available, yet adopting the case study strategy had an impact on the selection of method. Colin Robson, (2002) identifies the method of data collection for case studies in a flexible design as including interviews, observations and analysis of physical items. Both observation and physical items encourage direct contact and time on the site of the case study partner. Interviews offer the opportunity for a discussion away from the workplace. At this stage, it would be pragmatic to understand alternative qualitative methods through a scholarly review, to ensure a prudent and assured decision was reached.

In order to proceed with a review of qualitative methods, it is important to offer a reminder of the industrial landscape. Whilst the magnitude of the automotive manufacturing industry is extensive, the number of OEM's and cooperative Tier One suppliers is not. The competitive, time constrained and dynamic nature of each business at this level reduces the opportunity for active research work. Conclusively, the advantage of the author having an initial foothold in a small number of suppliers within the North East was an opportunity to be exploited. Yin, R, (2003) confirms the legitimacy of such an advantage. These opportunities and associated constraints were prominent in the decision-making process for data collection. The findings of the literature review and pilot study were, primarily human centric. These issues included organisational culture, training and skills, leadership engagement as well as industry specific problems. Conversely, an acknowledgement of KPI's and their use within the industry was identified as important to the research aims. As a result, methods of understanding people and what they do within their professional life was recognised as important. As indicated by Colin Robson, (2002), to understand what people do and think within their employed role enables interviews and questionnaires as a data collection method. These two approaches were appropriate for the collection of data within a case study approach (Yin, R, 2003). This has been evaluated in the following section.

3.5.1.1. Observation

Observation, within the case study research design provides a viable method of data collection (Yin, R, 2003). A discussed by Colin Robson, (2002), observation involves the recording of people and their actions – a relevant description when noting the importance of context and the human element within this study. Observation as a technique can emerge in two forms, participant observation and structured observation.

Structured observation is used more frequently in a fixed design and utilises quantitative data. This style involves the use of trained observers and the deployment of a coding scheme for the measurement of behaviours and actions. This style of observation, whilst seeking specific reasons for certain actions, is utlised more in field experiments (Colin Robson, 2002).

Participant observation is often used with a flexible research design and is qualitative in its nature. The recording of data for this mode of data collection can come in varying non-specific forms. Note taking, pictures, recording of conversations are all relevant methods and is at the discretion of the researcher, within the context of the observation (Colin Robson, 2002).

Observation has the advantage of being a direct method of establishing the views of people being studied (Colin Robson, 2002). Certainly, in an environment where there are factors resulting in a specific consequence, the technique of observation in a workplace could be useful. Moreover, if observation is not the primary mode of data collection, an observation can certainly compliment data gained from another technique.

3.5.1.2. The survey and questionnaire

Colin Robson, (2002), discusses surveys and identifies the use of a questionnaire as a means of collecting the data to complete the survey. The author acknowledges that a survey may also come in the form of a series of observations of a specific event, though is primarily formed through a questionnaire. A questionnaire consists of a series carefully worded, fixed choice and unambiguous questions which will lead to information on a defined set of people (Easterby-Smith *et al.*, 2018). There are advantages to this method of data collection, including the accessibility of the results. The accessibility emerges from the clarity and unambiguous nature of the questions (Colin Robson, 2002). This clarity of results, whilst advantageous is countered by several disadvantages. A survey, ran as a questionnaire requires advanced knowledge of the acceptable level of accuracy and sampling error (Vaus, 2013). There are several definitions of an appropriate size but it may not necessarily be of significant volume. What does emerge, is that it must be noteworthy to be able to generalise the results for the whole population. The population for any questionnaire must be focussed on a specific set of individuals (Colin Robson, 2002; Easterby-Smith *et al.*, 2018) yet the research question directs the respondent having a relatively detailed knowledge of maintenance practice within a given business, as well as prevailing issues which may prevent the effectiveness of maintenance. Conclusively, this quantitative method requires specific knowledge of the incumbent issues to inform fixed questions as well as having access to a specific number of informed, relevant respondents. Within the context of the case study research design, this would be challenging. As a result, these research methods have been excluded.

3.5.1.3. The interview

An alternative method of qualitative data collection is through interviewing selected personnel from each business. This method of rich data collection is relevant, as the investigation would benefit from the individual perceptions of each participant (Gray, 2017). The perceptions could include business organisation and communication or historical events, leading to findings in a certain culture or practice (Robson, 2002).

The researcher led, personnel interview is a well-used method of qualitative data collection (Stake, 1995; Colin Robson, 2002; David de Vaus, 2013). The interview process may be structured in three different ways; structured, semi structured and unstructured. A formal structured interview is commonly used within a survey where set questions are used (Colin Robson, 2002). This format has limitations, due to the requirement of following a rigid set of questions without deviation. This may hinder the opportunity to explore some the contextual issues and personal experiences of the participant. Unstructured interviews can be characterised by a short, opportunistic chat or an in depth, lengthy discussion. This type of interview is open ended and without formal questions – operating dynamically and simply flowing with the emerging discussion (Colin Robson, 2002). This format, whilst promoting flexibility, may not give the interviewer the opportunity to cover the points they may require to inform the research. Colin Robson*,* (2002) indicates that a semi-structured interview provides a structure but allows deviation from the question format where necessary. This form of interview also allows the interviewer to omit unnecessary questions or include additional questions prompted by a given answer. This semi-structured format is advantageous as a method of data collection. Whilst it encourages a consistent set of questions for each interview, it allows the opportunity to explore individual perceptions and industrial context.

The interview as a method of data collection presents both advantages and disadvantages. The opportunity to supplement an answer to a question, with an observation of the body language of the respondent can be invaluable. It may provide a polar view of the verbal answer (Stake, 1995) and alter the course of the remaining questions (Colin Robson, 2002). Tellingly, the interview engenders an understanding of the situation – if the correct format and questions are used. Moreover, the professionalism of the researcher becomes crucial in ensuring the reliability of the resulting data, during an unstructured or semi structured interview.

3.5.1.4. Interview questions

The questions within an interview must be carefully worded as they have the potential to influence the understanding the research problem. Discovering what people do, how they achieve it, what particular processes and techniques they may follow can be achieved by specific or closed questions (Colin Robson, 2002). Conversely, if a semi structured or unstructured interview is used, care must be taken not to close the question completely, allowing a simple yes or no answer when a deeper understanding is required. Interview bias is a challenge for the researcher, yet the importance of asking each question in a fresh, unaffected manner increases the ability of answers to be of a corroborative nature (Yin, R, 2003). Conclusively, interview questions are a unique collection of tools which must be administered carefully.

3.5.1.5. The participant

The selection of personnel to be interviewed across all case study participants is crucial and where possible, must be consistent. Due to the varying nature of any organisation's infrastructure and differing role naming conventions, it was felt it was not possible to be job title specific. Selection was centred on employees who play an active role in maintenance development and deployment. This allows rich data to be gathered from staff who have both direct and indirect roles within engineering maintenance. The range would include those who have the responsibility of developing maintenance strategies, personnel who are required to manage the strategy and finally employees who have an active role in deploying the strategy. This cross section of employees offers the opportunity to explore the rich data from staff with varying technical and academic backgrounds. The job roles would typically include senior managers through to production operators. Conclusively, the key interviews were directed at staff in senior management; middle management and maintenance operations.

3.5.2. Summary of research design and data collection

A review of literature relating to research design and data collection methods, combined with the conclusions from Chapter Two, led to the final design for a research strategy. The need to confirm, understand and explore the problem establishes the validity of engaging in a pilot study. This study provided the opportunity to confirm the existence of an issue with maintenance effectiveness in the automotive supply chain. Moreover, they established a platform for further research in the form of growing the personal relationships within those organisations. Engaging with more than one business to discuss the potential of an issue was crucial.

The significance of context and understanding within this research is clear, with David E. Gray, (2009); David de Vaus, (2013) confirming the case study as a suitable strategy to accommodate this characteristic. Moreover, the case study provided the researcher with the ability to investigate a small number of organisations over a period of time (Yin, R, 2003). Furthermore, David de Vaus, (2013) recognised the capacity for the case study to be used when the research cannot focus on one particular phenomenon. The unknown constraints stated within the research question, offered compatibility with the point raised by (David de Vaus, 2013). The number of businesses engaged within this research was crucial for the ability of the emerging data to be representative of the automotive supply chain. Yin, R, (2003) discusses the multiple case study as offering the opportunity for the emerging findings to be considered more robust due to varying origin. Also, the findings will have increased rigour and deliver the prospect for generalisation. In this instance, the generalisation would be across the automotive supply chain.

A preliminary understanding of the dynamics of the automotive supply chain, refined the selection of case study participants. The initial suggestion of Tier One and Tier Two organisations emerged as being unsuitable. The amendment towards four Tier One suppliers would expand the scope of the data collection, due to the range of products and associated processes which are involved within the automotive supply chain (Holweg, Davies and Podpolny, 2009).

The qualitative methods available for this study are discussed by Colin Robson, (2002), who confirmed the interview, observations and the use of physical items for evidence as being appropriate. The literary review and pilot study identified characteristics which appeared to be human centric. This was augmented with the knowledge that some issues are site specific, including the varying use of KPI's. Conclusively, it appeared that understanding people and how they execute their role within a business was prominent. Crucially the interview provided the opportunity to understand the culture within an organisation, due to it providing the platform for a deeper perception of the topic (Stake, 1995; Colin Robson, 2002).

The research plan of this investigation was directed through a case study strategy of flexible design. The primary data collection method was semi structured interviews with specific, knowledgeable personnel. These personnel had similar responsibilities within each business and cover a range of roles, from leadership to maintenance practitioner. The content of the interview was informed by findings from the literature review and the pilot study. Detailed notes were produced from each interview and where appropriate, a transcript of the discussion. From these, emerging issues and a deeper understanding developed. The rich data from the interview process was supplemented, where possible, from observations during site visits as well as a small amount quantitative information.

3.6. Synthesis of findings

The strategy used to synthesise the findings from the data collection stage of this research emerged from grounded theory. As discussed by Colin Robson, (2002), the case study approach does not define a particular method of data analysis, yet should be linked to the type of study being completed. This research is grounded in nature, characterised by the interview being the primary method of data collection. Additionally, this research required a period of time in the field. For clarity, a glossary of terms has been presented in Table 3.2.

Table 3.2 Definition of terms used in grounded theory data analysis. Adapted from (Gray, 2017)

Term	**Definition**
Coding	The process of analysing data
Concept	Conceptual labels placed on separate events
Category	A classification of concepts

According to Colin Robson, (2002), the coding process may be interpreted in the manner displayed in Figure 3.2.

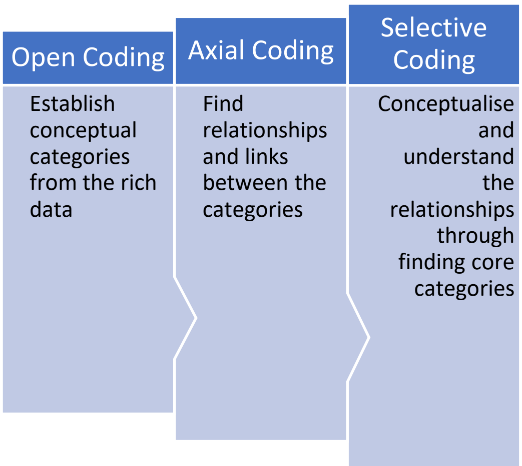

Figure 3.2 Data analysis sequence within grounded theory. Adapted from Colin Robson, (2002)

Open coding involves the splitting of rich data into separate entities, then that aspect of data is categorised, or labelled in a relevant manner. Following the open coding process, axial coding becomes the next important stage. Axial coding utilises the results of open coding and begins to link the categories established through open coding. These links may then appear as a new category, or more general heading which describes the relationship (Colin Robson, 2002). Finally, selective coding reviews the relationships established within axial coding and establishes a core category or categories, which assist in explaining the overall phenomenon (Colin Robson, 2002). Interestingly, Gray, (2017) follows a similar path in the coding process, yet the process concludes with a single core category being identified.

The coding process used within this study is explained and expedited in a more transparent manner through the work of (Charmaz, 2013). In this Charmaz, (2013) describes the first stage as initial coding, where the data is analysed and coded through the lens of action based words – as opposed to people. This occurred through a staged review of the data collected and included the evaluation of:

1. Audio recording of the interview
2. Transcribed interviews and notes
3. Observation notes.

As agreed by Charmaz, (2013), this process is relatively quick and seamless. Figure 3.3 further describes the framework for developing the focussed codes and emerging categories. It is these categories which formed the basis of further analysis and work. Charmaz, (2013) agrees that initial and focussed coding is sufficient for most projects. The work of Charmaz, (2013) was instrumental in guiding the coding process for this research. The simplicity of the process and the ability of the researcher to use interpretation was of great value. Moreover, Corbin and Strauss, (2015) acknowledge the importance of context when completing the coding process. This is in direct contrast to the pure grounded theory approach which would rely solely on the data collected

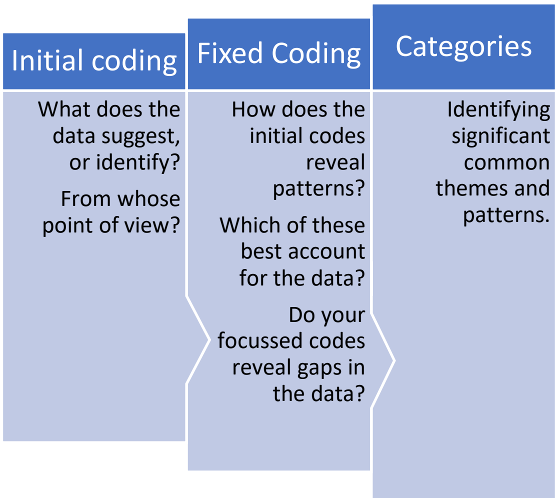

Figure 3.3 Coding sequence and category identification. Adapted from Charmaz, (2013)

3.7. Validity

The quality assurance of this research required a consistent approach to all practice throughout this thesis. The validity of the research design and data collection occupies one aspect of the methodology, yet the ethical principles which must be applied transcend the entire thesis. Figure 3.4 offers a visual description of the relationship between the data and the quality assurance process.

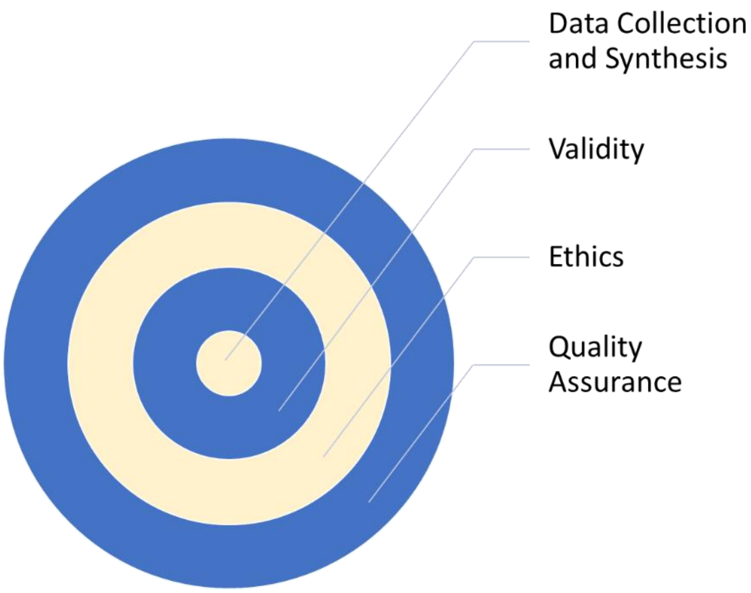

Figure 3.4 A diagram representing the relationship and governance of information within this research.

The validity of the findings which emerge from the analysis of the data, can be characterised as the trustworthiness of those findings (Colin Robson, 2002). If this research is to experience a high degree of trust with the conclusions, recognition of threats to research validity must be acknowledged. Furthermore, the threats must be managed.

3.7.1. Internal validity

David de Vaus (2013) described the degree of internal validity as a direct reflection of the level of confidence that may be taken from the research findings. The threats to this confidence vary in terminology, but the definition remains largely similar throughout research design literature. Henn, Weinstein and Foard, (2005) describes subjectivity as a threat, going on to describe it as the manner in which the researcher will synthesise the information they experience. Colin Robson, (2002) elaborates, labelling the threat more clearly as Interpretation. The author continues, defining this as the researcher imposing a framework or meaning on what is happening. This would be detrimental and Colin Robson, (2002) encourages the researcher to facilitate the framework or meaning to emerge from the events under investigation. Confidence levels maybe further affected by what Colin Robson, (2002) identified as Description.

As the term suggests, providing a true and valid description of events, interviews or artefacts is essential. Henn, Weinstein and Foard, (2005) continues, describing the concern in this area by discussing reactivity. The author identifies the danger of personnel changing the way they behave or respond to questions, due to the presence and requirements of researcher.

3.7.2. Reliability

Reliability is described by Gray, (2017) as the ability of a researcher to replicate the study used by another and reach similar conclusions. The significance of this replication is recognised by Henn, Weinstein and Foard, (2005) who identifies the importance of a systematic approach to data collection. Typically Colin Robson, (2002) simplifies the definition as the importance of the researcher to be honest, professional and truthful in their practice. These characteristics and methods of identifying this practice can be found in Table 3.3.

3.7.3. External validity

The external validity of the findings within the context of a case study design are debated in literature with concern (Yin, R, 2003; Vaus, 2013; Gray, 2017). One perspective states the findings of a particular case cannot be applied to other cases or to a different population. Gray, (2017) alludes to the dangers to external validity when operating research with a small or singular number of case studies.

The threats to the quality assurance of the findings are collated in Table 3.3. In addition, a summary of the tools utilised within this research to manage those threats and minimise any associated risk are recognised. Furthermore, the legitimacy of the techniques are identified through reference to literature.

Table 3.3 Threats to validity and research coping mechanisms

Threat	Characterisation	Research techniques deployed	Legitimacy
Internal Validity	Subjectivity	1. Consistent level and type of personnel interviewed. 2. All interviews completed on site. 3. Initial and focussed coding technique used.	1,2: (Yin, R, 2003; Henn, Weinstein and Foard, 2005) 3. (Charmaz, 2013)
	Interpretation	1. Use of semi structured interviews, observations and artefacts. 2. Coding technique and category identification.	1. (Colin Robson, 2002) 2. (Yin, R, 2003; Charmaz, 2013)
	Description	1. Audio account of interviews. 2. Transcription, notes taking 3. Observation, artefacts.	1,2: (Colin Robson, 2002; Gray, 2017) 3. (Yin, R, 2003)
Reliability	Replication Systematic	1. Protocol and procedures for data collection.	(Henn, Weinstein and Foard, 2005) (Yin, R, 2003)
External Validity	Generalisation	1. Multiple case study participants used, with varying business dynamics. 2. Review of categories with maintenance expert at Site 1 Ltd.	1. (Colin Robson, 2002)

3.7.4. External validity exercise

The methodological process of data collection and synthesis provided a series of categories or themes, which were of key interest in response to the research question. Although the coding and categorisation process followed a structure identified within Section 3.6, the validity of this process experienced further examination. The external validity of the findings was reinforced, through a focussed discussion with a maintenance expert. This may be further noted in Table 3.3. The expert was a maintenance manager operating in the food processing industry (Site 1ltd). The exposure of the main categories and findings to the expert, provided the research findings with a sense check and offered the opportunity for the researcher to establish the relevancy of the findings outside of the automotive industry. This additional stage within the methodology was also executed to increase the generalisation of the findings. The results of this meeting provided a useful reinforcement of the research methods and results.

3.8. Ethics

The execution of this research utilised guidance from literature, as well as the research practice requirements of the University of Sunderland. Ethics is a crucial practice in delineating the three central characters within a research project: participant, researcher and research (Corbin and Strauss, 2015). The relationship between the participant and researcher is built on trust and confidentiality and this extends to respectful acknowledgement of the resources provided by the participant toward the research. In addition, the integrity of the research must be maintained as well as having the aim of completion. Finally, the researcher must complete the work to the highest of their ability. These characteristics have formed the foundation of the ethical principles used within this investigation.

The three central characters of researcher, participant and research discussed by Corbin and Strauss, (2015), are characterised in a similar manner throughout ethical literature. Table 3.4 offers a summary of these characteristics:

Table 3.4 A summary of threats to ethics within the research environment.

Ethical Feature	Description	Reference
Consent	Ensuring the participant knows each aspect of the research is voluntary.	(Henn, Weinstein and Foard, 2005) (Colin Robson, 2002) (Bryman, 2015)
Anonymity	Protection of identity and location	(Henn, Weinstein and Foard, 2005) (Bryman, 2015)
Confidentiality	Protection of information emerging from engagement	(Henn, Weinstein and Foard, 2005) (Easterby-Smith et al., 2018)
Respect	Acknowledging time, resource and engagement with the participant.	(Corbin and Strauss, 2015) (Colin Robson, 2002)
Mental health	No method used which applies stress or upset to the participant	(Colin Robson, 2002) (Gray, 2017)
Data Protection	Ensuring confidentiality and anonymity through data protection guidelines.	(Easterby-Smith et al., 2018)
Coercion to participate	Research is not performed under false pretences or the participant is not forced.	(Colin Robson, 2002) (Bryman, 2015)

Incorporating the threats identified in Table 3.4 as well as recognising the risks detailed in Table 3.3 provided a rigid structure to the research methodology. Literature clearly identifies themes which are common, yet often does not go as far as to offer an ethical solution. With that in mind, a summary of research solutions to these issues which were deployed, may be noted in Table 3.5:

Table 3.5 A summary of ethical principles deployed within this investigation

Ethical Characteristic	**Technique deployed**
Consent	Initial case study engagement required written company permission. Subsequent engagement was permitted through email consent by senior manager. Individual consent provided at the beginning of each data collection exercise.
Anonymity	Anonymity facilitated through substitute names being provided for each business within the report. Individual engagement information not transferred to subsequent interviews with alternative participants.
Confidentiality	Participation remained undisclosed internally and externally for each participant. Also – see data protection.
Respect	All contact with participants followed strict recognition of time, effort and pressure it took to be part of the research. Also, adherence to anonymity, confidentiality and consent with each participant.
Mental health	All participants were identified by the case study participant as being able to engage in the research. No line of inquiry was pursued which led to any discomfort.
Data Protection	Adherence to confidentiality, anonymity and consent was explicit with each participant. Also, adherence to guidelines from University of Sunderland on GDPR.
Coercion to participate	Permission to continue with any engagement was verbally sought at the beginning of any meeting. This was done verbally and in private with each participant, at all times.

This research provided an interesting ethical perspective, whereby consent was often provided by the senior manager on behalf of other organisational staff members. This was outside the sphere of control of the researcher and wherever control was regained, the ethical protocol was consistently followed. Conversely, following the majority of ethical principles identified in Table 3.5 became relatively straightforward, as it became part of the research routine adapted with each participant. The discussion on subjectivity and reliability in Table 3.3 discusses consistency of questions and protocol when engaging with a participant (Yin, R, 2003; Henn, Weinstein and Foard, 2005). These characteristics can be extended to incorporate, as part of the protocol, recognition of the need for each participant to be reminded of their right to grant consent for any engagement to continue. In addition, at the beginning of each engagement, the protocol included a brief reminder of the research practice which ensured anonymity as well as confidentiality. Furthermore, these initial protocols allowed the discussion to be conducted with mutual respect.

The review of literature regarding ethical principles was supplemented by incorporating guidelines from the University of Sunderland cyber security and information governance policy document (V1.0 January 2018). The guidelines from the University of Sunderland have been developed in relation to the GDPR act of May 2018 and offer guidance on how personal data must be collected, handled and stored. Table 3.6 provides a summary of the six key principles included in the guidelines and the research response to those principles:

Table 3.6 Summary of research response to University of Sunderland information governance policy

Principle	Description	Research response
Lawfulness, fairness and transparency	Processed lawfully, fairly and in a transparent manner.	Consistent anonymity and confidentiality applied to participants.
Purpose limitation	Collected for specified, legitimate and explicit purposes.	Data utilised solely within the scope of the research question.
Data minimisation	Adequate, relevant and limited to what is necessary	Data utilised solely within the scope of the research question
Accuracy	Accurate and where necessary up to date	Research engagement transcribed and recorded in an accurate and consistent manner.
Storage limitation	Kept in a form which permits identification of data subjects for no longer than in necessary	Relevant data stored in a secure and access limited location.
Integrity and confidentiality	Processed in a manner that ensures appropriate security of the personal data	Research integrity maintained as an ethical professional.

3.9. Summary of coding and quality assurance practice

The quality assurance of data and the management of this research information was completed through consistent and systematic practice. The threats to the validity of the information in areas such as Subjectivity, Interpretation and Description were mitigated through a consistent approach to all data collection and processing. The selection of participants for interview was applied through the lens of organisational role and maintenance experience. The coding technique used to identify key categories from interviews and observations alleviated the threat of interpretation. This was further supplemented by the testing of the categories to an external maintenance expert for relevancy. The recording of the information addressed the accuracy of the information and detailed note taking allowed additional descriptions to supplement any audio record. The use of observation as well as identification of artefacts, although not the main area of data collection, provided useful context to the threat of interpretation and description. Finally, the management of internal validity was completed by acknowledging the need for systematic replication of the data collection protocol. This applied to the interview discussion, note taking, recording and coding activities. This systematic and consistent approach to all data collection allowed this research to integrate ethical principles into participant engagement.

Each engagement would ensure the participant was comfortable, consensual and respected throughout the process. In addition, the anonymity of the subject was confirmed and remains consistently applied within this thesis.

3.10. Conclusion

Section 3.4.2 summarises and justifies the techniques deployed by the researcher when designing, then implementing the methodology of this research. The identification of key authors who endorsed specific grounded theory practice was invaluable within the scope of this research landscape. A primary feature of this was incorporating a design which promoted an understanding of context and allowed interpretation of the data. The quality assurance and ethical practice of this research, although discussed separately, was embedded throughout the research practice. The results and categories which emerged from this stage of the research will be identified and discussed in the next Chapter. Chapter 4 will summarise the prominent categories which developed through the coding process, as well as the discussing specific case study results.

4 Case Study review

4.1. Introduction

Chapter 3 reviewed several techniques which were available to answer the research question. The research design concluded a case study strategy was appropriate. Data collection was primarily through semi structured interviews, with a range of appropriate staff at each of the four sites. The collation of this rich data and subsequent focussed coding, produced categories which reflect the data across all four case study participants. It is these categories which form the basis for providing a solution to the research question at the heart of this study. The categories are identified in Table 4.1:

Table 4.1 Categories of constraints which resulted from the coding process.

Category
Senior Management Engagement
Skills and Training
Staff Resources
Perception & Production Integration
Equipment and Spares
Performance
KPI's
Supply Chain
Maintenance Shift System
Budget
Buffer Stock

The categories are named to be recognisable terms. 'Perception and Production Integration' relates to the perception of maintenance within the organisation, as well as the working relationship it has with the production unit.

This chapter will discuss each case study participant in turn, providing a description of the rich data from each site. This is presented under the appropriate category which emerged from the coding process.

The chapter will conclude with a summary of key constraint from all four case study sites. In addition, enabling characteristics are also presented, where appropriate. These enabling characteristics have emerged from the same rich data, but have been found to lead to a successful aspect of maintenance management within the plant.

4.2 Plant 1

Plant 1 is based in the North of England and is a Tier One automotive manufacturing supplier. The plant has only one customer and this is an OEM based in the UK. The plant is part of a worldwide corporation which has global headquarters in Japan. Moreover, sibling plants are located internationally. The only customer of the plant also owns a 40% stake of the global business. This site manufactures various parts for the interior of the vehicle which includes the use of injection moulding processes and paint lines.

The plant was established by a previous owner in 1991 and manufactured products of a similar nature to the current owners. The present employers took over the business in 2006 and this prompted staffing issues which still affect the business today. Following the takeover, a change in management structure and working conditions led to a loss of skilled staff from the business, which directly affected the maintenance department at Technician and Engineer level. This is currently in the process of recovery. At the time of the study, 300 employees worked at this site, including nine maintenance technicians. The maintenance technicians operate on a three shift system, 24 hours per day, 5 days per week. This mirrors the production shift system as well as the shift pattern of the OEM. The Maintenance Technicians report directly to the Maintenance Engineer, who then reports to the Manufacturing Manager. The Maintenance Engineer had substantial influence over the direction of the maintenance function within the business and regularly exerted this influence. The Manufacturing manager has little to no maintenance experience.

The plant production system is both synchronous and JIT, dependent upon the part requested by the customer. There is low level integration between production staff and maintenance with the recent introduction of operating staff completing some, low level maintenance tasks. This is known as Production Led Maintenance (PLM). Despite this, the maintenance department operates with a maintenance strategy which is 60% reactive. The remaining activities are planned, preventative tasks. There is a Computerised Maintenance Management System (CMMS) but this is gravely underutilised by all parties. Although the plant operates under a continuing drive for efficiency and cost cutting the maintenance budget is approximately £1 million per year. This is within the context of a contractual expectation by the OEM of a 5% year on year reduction in costs.

Interviews were completed with the Plant Manager (PM), Manufacturing manager (MM) and Maintenance Engineer (ME). Responses tended to be short and to the point. No Maintenance technicians were available for interview. The rich data was supplemented with a 1-day observation of maintenance activities within the business.

4.2.1 Senior Management engagement:

The discussion with all participants revealed a relatively strong element of senior management engagement in maintenance development, with some exceptions. ME related the advantage of MM having cross discipline authority over both production and maintenance, with ME reporting directly to MM. Moreover, PM had previous occupational experience within the maintenance environment, which according to ME assisted with requests for maintenance development opportunities. The positive aspects of this relationship were also contradicted to some degree, through the observation carried out at Plant 1. Plant objectives were printed and displayed within each department in the business, except for the maintenance function. Moreover, an example of the support afforded to ME for maintenance development provided some interesting insight. Previously, ME had requested the opportunity and resource to implement PLM. The senior management team consented, but the implementation of this initiative was left solely with ME. This implementation involved ME personally introducing and promoting the concept to each of the 140 production operators. This was across a 3-shift pattern and took three weeks to complete.

4.2.2 Skills and Training:

PM identified the skills issue facing the maintenance function and described the difficult transition of the plant from previous, to current ownership. The working conditions of the present owners influenced existing staff sufficiently to prompt several maintenance personnel to leave the business. This introduced a skills and knowledge gap within the plant which has proved difficult to negotiate. PM described an additional issue "***We have a big job to identify who needs training on what to cover the whole plant, the whole time***" This was confirmed by MM, who indicated there was currently insufficient knowledge on specialist processes such as injection moulding within the maintenance department. Furthermore, MM also confirmed "***to be honest no, there isn't a training plan for staff***"

The erosion of previous skills, combined with the concern over current skill levels within the maintenance team was highlighted during an observation of ME. During the shift handover maintenance technicians were in transition and it became apparent there was little communication between the staff, either describing the status of previous activities or ongoing tasks. Consequently, there was a reliance on ME to facilitate the handover and ensure relevant tasks and details were communicated clearly. ME later disclosed that this was not unusual and there was a lack of autonomy and ownership within the team. Conclusively, this lack of ownership and knowledge resulted in ME being regularly called out to the Plant by maintenance technicians, to assist in breakdown repair. Further discussion revealed ME had no complaints with this tactic, appearing to enjoy the close involvement.

4.2.3 Perception and Production Integration:

The interview with PM highlighted the concerns held around the attitude and commitment of the employees. PM insisted the success of the PLM initiative was dependent on a change of culture and mind-set from 80% of the plant. These concerns did not appear to extend to the temporary production staff. PM discussed the openness of temporary staff to new ideas and their willingness to change by saying "***Agency are keen to buy into new things and they haven't got the hang ups of working here for 8 or 10 years***". In addition, temporary staff apparently did not have any long-standing issues with the business which affected their attitude and beliefs. The ratio of permanent to temporary production operators was 80:20, respectively. ME highlighted that there was progress in improving the relationship by working with the production department, some conflict did still exist. According to ME, the primary source for this was the inaccurate manner of recording of downtime. This included accurate timing of a breakdown occurrence, fault description and an identification of the remedial action taken.

Discussion and observation with all interviewees revealed the implementation of PLM was highly facilitated by ME, with personal briefings carried out with each participating operator. Although this personal intervention apparently took 3 full weeks, ME was satisfied it had promoted the initiative sufficiently. Furthermore, PM and MM had granted operators one hour per day for the completion of associated tasks. ME discussed the positive feedback received from operators on the initiative, identifying the importance of the PLM pilot targeting features which directly affected their working environment. This included lighting or ventilation**, "*The feedback from the shop floor was very positive on the communication.*"**

Aside from initiatives which positively influenced this category, ME maintained there was still an issue with the perception of maintenance within the business, citing two examples. The first example was the prominent display of business objectives in each department in a specific area, this was with the exception of the maintenance function. In the opinion of ME, this was a typical lack of care by senior managers. The second example emerged from the production engineering department and involved the purchase and commissioning of new equipment. These activities were consistently completed without any consultation with the maintenance function, to the continued frustration of ME.

4.2.4 Equipment and Spares:

Despite the manufacturing processes within the plant being restricted to injection moulding and a paint application line, PM admitted there was no standardisation of equipment and spare parts, ***"we have a diverse range of equipment with a lot of different manufacturers. There's been no standardisation of any equipment, such as PLC's, hydraulic and pneumatic equipment"*** The equipment originated from various OEM's and this resulted in problems procuring the numerous and varying spare parts. Due to this variation, there were training issues for associated maintenance tasks ***"it's a nightmare. I've got to have enough spares to cover all the kit we carry. At least enough knowledge to make an attempt to diagnose the fault".*** ME agreed with this and identified the organisational purchase strategy was based solely on cost, with no consultation of the maintenance requirements. This cost driven activity perpetuated the lack of standardisation within the plant and compounded the issues with technician training.

4.2.5 Planning and Performance:

When discussing the deployment and effectiveness of the maintenance department, PM immediately related this to OEE and identified the increased performance of the plant. OEE had generally been recorded as 75% the previous financial year, yet had improved to 85% at the time of discussion. This was the only measure used by the PM to describe the performance of the maintenance department. ME discussed performance and strategy in depth, revealing the maintenance plan was still mostly reactive with some preventive work. This included the newly implemented PLM schedule, yet the effectiveness of this programme was still in doubt. MM further discussed the preventative tasks which were in use, identifying 161 activities were in the schedule but there was no evidence to show that they had any positive impact on production. Apparently, this included a large proportion being carried out on assembly jigs which were not critical to the production process ***"We had 161 PM's to do in a month, a vast majority of which were against assembly jigs which had no critical effect on production…so what was their worth?"*** These issues were compounded by ME disclosing the dissatisfaction and reluctance within the department to engage with the current CMMS. The discussion revealed the technicians did not trust the consistency or user interface of the system, yet ME disclosed the unwillingness of technicians to have their work activities recorded.

4.2.6 Key Performance Indicators:

The maintenance metrics described across all interviews were limited in scope. PM described OEE as the main measure for maintenance activity, along with machine availability. This was confirmed by MM, who revealed OEE was the only metric associated with maintenance which was reported to the parent company. ME supplemented the discussion, by including completion rate of preventative maintenance activities as part of the department metrics. ME acknowledged the accuracy of all maintenance metrics was dubious due to the manual recording of downtime on a large majority of maintenance activities **"*there is still conflict with the machine down time and what is attributed to maintenance. The maintenance activity is not measured*."**

4.2.7 Supply chain:

There was limited feedback in this area although PM revealed there was no sharing of best practice within the supply chain for developing maintenance yet conversely the OEM would address an issue differently if there was a production line stoppage. "***As soon as you do stop the line, they're all over you, but if you're not causing them any problems, they don't tend to ask any questions".***

4.2.8 Budget:

The budget provided to the maintenance department was approximately £1,000,000 per annum. This was acknowledged as being substantial yet was eroded due to the range and expense of spare parts required by certain individual machines. Indeed, it was revealed that a range of spare heating units held at the plant for the injection moulding process was at a cost of £400,000.

4.2.9 Summary of constraints and enabling factors:

Table 4.2 A summary of constraining and enabling factors for Plant 1

Category	Constraint	Enabler
Senior Management Engagement		✓
Skills and Training	✓	
Perception & Production Integration	✓	
Equipment and Spares	✓	
Performance	✓	
KPI's	✓	

The positive work discussed by ME when introducing PLM and the resultant improvement in working relationship between production and maintenance is of merit. As a result, the engagement and support by senior managers for this initiative demonstrates positive engagement. Conversely, there were numerous constraints identified once the coding activity was completed. These were informed by characteristics such as no training plan, a reduced capacity for spare part management and the inability to record accurate maintenance data.

4.3 Plant 2

Plant 2 is based in the North East of England and was established in 1989. In addition, the plant is part of a global business group. The reach of this global group is much reduced in comparison to other case study participants, although similarly, group headquarters are in Japan. The plant manufactures a range of exterior and interior trim products and is a Tier One supplier for several OEMs'. All OEM's are located within the UK, with around 50% of the plant output provided to one OEM. The remaining yield is distributed to two other automotive manufacturers. The company positions itself as being flexible, reactive to customer demands, operating with a high degree of quality and constantly seeking to continuously improve. The plant employs 550 members of staff, although around 45% of these are temporary production operators. This results in a high degree of staff turnover with semi-skilled employees. The site consists of 3 separate production units, with six different buildings contributing to production output. The manufacturing strategy is a mix of batch and synchronous production which introduces complex planning issues.

The aim of the business is to be both flexible and reactive to the customer. This introduces a tremendous strain on specific departments within the plant. There is a huge array of equipment due to current manufacturing techniques utilising 70 different production lines, all with individual pieces of equipment. As a result, the business has difficulty managing the quality expectations of the customer. Furthermore, there is a strain on the resources contained within the maintenance department. There are 24 maintenance technicians, 12 mechanical maintenance technicians and 12 electrical maintenance technicians. No technicians are multi skilled. The operational maintenance staff operate on a three shift system each day over a period of five days. The production facility operates a continental shift system over seven days per week. The department is overseen by a senior manager who also controls the tooling department for the site.

The maintenance strategy is wholly reactive, with very little preventative maintenance occurring. There was outsourcing of maintenance which included **"*some specific planned maintenance with some of the large injection machines where we'll pay for a contractor to come in*"** but this had limited impact on the resource issues within the department. This strategy has led to substantial tension between production and maintenance, due the ineffective nature of the maintenance plan. Poor maintenance skills and techniques have resulted in persistent breakdowns, failure to repair and delivery concerns. This has resulted in formal customer concerns for the plant. Despite this business level impact of poor maintenance performance, the function displays little motivation for change.

Interviews were conducted with the Production Manager (PM), Maintenance manager (MM) and Operational Maintenance (OM).

4.3.1 Senior Management engagement

MM, who was identified as a senior manager, appeared to have little hesitation discussing the views and levels of engagement of other senior managers towards maintenance. Indeed, the conversation revealed the perspective of most senior managers towards maintenance as being a necessary evil **"*a necessary evil I would say. My background is as a mechanical maintenance technician, and I've been here since I was 22. That's definitely how I see it and I definitely believe it."*** Furthermore, there was limited interaction between senior management and the maintenance function on strategy development. The negative relationship between other senior staff and maintenance was confirmed in a discussion with PM, who appeared in conflict with the department on several issues. These issues included performance, staff motivation and equipment spares.

Both MM and OM indicated previous senior management decisions had a negative effect on the ability of maintenance to perform effectively. OM discussed how historically, two previous '**crises**' with the OEM had directly resulted in a restructuring of the operational maintenance team. In the view of OM, this restructuring was both reactionary and had a negative impact on team confidence and performance. Furthermore, MM believed the aggressive business strategy of constantly pursuing additional production orders had overwhelmed the maintenance function and directed the maintenance plan to be wholly reactive in nature.

4.3.2 Skills and Training

The skill set of maintenance technicians provided a valuable insight. MM revealed all department staff at technician level were categorised by a mechanical or electrical discipline **"*Were a bit old fashioned in that the mechanical and electrical divide – it's a little bit old shipyard mentality*".** The shipyard mentality statement alluded to a traditional, discipline focussed approach to training. Previous experience and training may have resulted in staff being multi-disciplined, but employment and subsequent tasks were categorised as being either a Mechanical or an Electrical maintenance task. This was confirmed by OM and it became clear, this employment and training strategy was acceptable within the business. Conversely, the apprentice training was based upon a multi-discipline route, yet OM indicated that the plant did not believe this was a progressive training strategy. Once qualified to technician level, the apprentices would revert to a strict, discipline focussed, mode of operation. OM described *"**Plant 2 still believe in separate skills set with 2 staff attending a breakdown (Mech&Elec)**"*

Both MM and OM discussed the skill set of operational staff as having deteriorated over previous years. This was directly attributed to difficulties in recruiting technical staff, yet OM revealed the consequence of these difficulties had led Plant 2 to simplifying the aptitude test for recruitment candidates. This simplification resulted in successful candidates having to undergo additional training once employed. This would have to be funded by an already restricted training budget. According to OM, this recruitment and training initiative, had led to a lack of specialist knowledge within the maintenance team. Apparently, this knowledge would help alleviate complex issues in production such as injection moulding or hydraulic work.

4.3.3 Staff resources

OM and MM both agreed the maintenance department was under resourced at technician level. PM described the situation; "***I believe they're under resourced.***

They cannot cope, we've got ageing equipment out there which means it's getting harder" The department operated with 12 mechanical technicians and 12 electrical technicians, deployed over a three-shift system, five days per week. This lack of resource was compounded by the discipline focussed training and deployment of the technician. As a result, a mechanical and electrical technician attended any given breakdown, further depleting staff resources.

The internal view of an under resourced department was directly related to the extensive and varied range of equipment within Plant 2. As discussed in Section 4.3, there were three separate production units on the site, housing over 70 different production lines. MM discussed how this variation in equipment and manufactured product, ensured staff training and resource was very difficult to manage. This view was confirmed by PM, who added that a large percentage of the equipment was ageing and difficult to maintain. Worryingly, PM also confirmed that the maintenance function consistently relied on "***only a very small number of key personnel to get us away".*** This statement by PM was indicating there were insufficient experienced maintenance practitioners employed by the business.

The difficulties in recruiting qualified staff were alleviated somewhat by the maintenance department using an apprenticeship programme. OM described there were five apprentices undergoing training, but through a multi discipline route. In the short term, MM related the difficulties in recruiting appropriate technician staff, citing the proximity of an OEM as draining potential staff resources. This view was acknowledged by OM who described candidates as "***following the money***", when being attracted to the OEM.

4.3.4 Perception and Production Integration

The activities of both production and maintenance were discussed as being separate in nature, with very little in the way of cooperative working. This was confirmed individually by all three interviewees. OM described how there were no PLM activities and very little prospect of maintenance being developed this way. The common reason described for this decision was the unreliability of temporary staff employed by the site. PM revealed that approximately 45% of the workforce were temporary agency staff and indicated that these staff were unreliable and lacked quality. MM continued, identifying that due to the lack of quality, this group of staff caused problems for both production and maintenance. According to MM, historically the plant utilised PLM when all staff were employed with a permanent contract. The subsequent change in employment strategy led directly to a negative impact on maintenance activities. This included a lack of ownership of the work area with MM describing it as ***"really difficult to get that mind-set in place."***

The traditional, negative perception of a maintenance function was evident, with OM revealing the department was considered a necessary evil by the senior management team. This view was confirmed by PM, who further discussed that the maintenance department had no ownership of equipment or tasks and '***did not care'***. In addition, department cultural issues were demonstrated by a general lack of urgency for breakdown occurrences, or other day to day activities. These cultural issues could be exemplified in several areas, including the start and end time of a shift. PM indicated that production staff worked from bell to bell, due to delivery demands. This was not the case for the maintenance function, ***"If you'd have walked through the tool room to the maintenance shop, you'll see them stopping working 20 mins before the end of their shift to wash their hands ready for leaving"***. This was an obvious demonstration of differing values and working practice. This was not a single opinion, with MM labelling the department as '***having a shipyard mentality****.'* This was further explained by a work to rule attitude, with technicians demonstrating little flexibility.

PM went to great lengths to discuss other examples of poor practice by the maintenance function. The conversation explored the values of the maintenance department in other business matters, such as a lack of engagement by the department in business-critical performance indicators. PM expanded, insisting the maintenance area had no interest in any performance measurement and that maintenance staff felt they did not contribute towards production KPI's. Furthermore, this was compounded by maintenance apparently having very few performance measures. PM added ***"I think there is some serious cultural issues with the maintenance department."***

This apparent poor attitude was not restricted to maintenance operatives and PM discussed how current, more senior staff who had been promoted from maintenance technician level, displayed similar character traits. This created a consistent culture which, according to PM, would be difficult to alter and ideally would require a large-scale staffing change. The negative culture was also self-perpetuating according to PM, as the reliance on the maintenance technicians to fulfil optional weekend work led to a lack of challenge by senior managers for any poor performance *"**There's an element of 'don't upset them' cos I need him to come in tomorrow.**"*

In contrast, OM provided a positive feature of the working relationship between production and maintenance. An example was given where a recent major delivery issue to the OEM which resulted from continued equipment breakdown, was resolved through an increased maintenance presence within the affected areas. In the opinion of OM, the closer working partnership between the two departments helped resolved some of the outstanding friction and negative perceptions of the maintenance department.

4.3.5 Equipment and Spares

The equipment contained within Plant 2 appeared to offer a wide variation in application, age and location. Section 4.3.3 identified over 70 differing production lines existed within the plant, across 3 production sites. According to OM, this encompassed ***'over 1300 individual pieces of equipment'***. This resulted in spares management being extremely challenging and according to MM, the identification of critical spares within the plant was only partially complete. No figure was provided regarding the percentage completion. This high degree of challenge was also discussed by MM, who pinpointed certain production areas such being very difficult to maintain due to the equipment being over 20 years old. Seemingly, this placed the production machinery beyond the reach of any preventative maintenance activities.

PM expanded on some of the concerns affecting maintenance and revealed there was a distinct lack of spares due to the range of equipment within the plant. The concern extended to include the incomplete assessment of critical spares within the plant. This was due to a lack of urgency from the maintenance department in completing the necessary assessment, as well as the associated cost of purchasing the required part. PM contextualised the problem with an example of a breakdown which resulted in an OEM line stoppage "***we found out that we didn't have the right sort of PLC, then we found out we didn't have the right spares, then we found out we couldn't get spares."*** PM described this example as typical and used it to demonstrate the significance of the situation.

4.3.6 Performance

All staff who were questioned on maintenance performance agreed that the maintenance function was underperforming. OM described the maintenance plan as extremely reactive and the department were firefighting, although there was some outsourcing of maintenance for automated equipment. MM admitted that although planned and preventative activities were a feature of the maintenance strategy, they were extremely limited in their effectiveness. This lack of impact was a result of production providing no scheduled down time for planned activities. In addition, the completion of the preventative maintenance schedule was ad hoc. This situation was also confirmed by PM. The discussion with OM expanded on this point and it emerged the effectiveness of preventative tasks were superficial. All preventative maintenance tasks on a piece of equipment consisted of a visual check only, with no physical intervention. MM admitted ***"It's very limited what we do as preventative maintenance to be honest"*** This was due to the reduction in planned maintenance hours, which in turn were a direct consequence of the strain on maintenance resources.

Poor maintenance performance was further discussed within the context of the vast range of equipment and the large percentage of temporary production operators. MM attributed the poor standard of first line maintenance tasks, such as housekeeping and equipment care, as having deteriorated over a time. Both PM and OM agreed this created a negative impact on maintenance performance. Finally, MM provided a new focus on maintenance blockages, discussing the lack of data surrounding maintenance activities. This lack of data was partly due to the absence of any automated maintenance recording system. All downtime was recorded manually, and the existing procedure ensured there was no information retained regarding the breakdown itself. The only recorded information was based on downtime, with no focus on equipment performance. As a result, the method of resolving a breakdown could not be tracked for effectiveness. This issue also extended to monitoring the effectiveness of preventative activities.

4.3.7 Key Performance Indicators

When questioned on maintenance performance measurement, MM identified indicators including downtime, scrap rate and OEE. The only specific KPI's which could be attributed to maintenance activities was the percentage completion rate of planned maintenance activities and machine downtime. The completion rate for planned activities was acknowledged as 97% and OM identified the reason as being the new, one-hour visual check strategy. MM reiterated the desire to have an additional indicator within performance measurement, which utilised information on the effectiveness of any maintenance activities, as opposed to completion. Finally, PM provided insight into the difficulties experienced by the department in maintenance measurement by supplementing the discussion on data recording and accuracy. The absence of any system resulted in equipment breakdown having no recorded cause, which subsequently ensured any remedial action was difficult to manage. Finally, PM responded to a question asking if the maintenance department engaged with performance measurement "***No. No chance. I don't believe they think they contribute at all towards that I don't think they care***."

4.3.8 Supply chain

Interaction with the supply chain was limited and confined to production reviews with the OEM. There was recognition that the OEM held a great deal of influence as well as technical knowledge which may improve maintenance activities, though MM indicated there had been no sharing of best practice in this area. Indeed, MM displayed a reluctance to enter into this type of arrangement, due to the influence of the OEM on future business. ***"I think with the OEM there is a chance it could pick holes in things and create a risk to their supply chain or take it down an avenue where they're looking for a cost down."*** The discussion moved to the regional automotive alliance initiative, which promotes sharing of good practice between members. Once more, the interview revealed a suspicion of this initiative and further reluctance to divulge technical information with potential competitors.

PM and OM both confirmed the absence of any best practice initiatives from either the OEM, or an upstream Tier Two supplier. OM recalled that training initiatives for maintenance only tended to occur when there had been a line stoppage at the OEM. This line stoppage would have been directly attributable to an unresolved equipment breakdown at Plant 2. OM highlighted the benefits of this additional training and skill improvement but also identified the negative, longer-term effect of continued OEM intervention.

4.3.9 Maintenance shift system

The production facility within Plant 2 operated a continental shift system which effectively worked 24 hours a day, seven days a week. This was in contrast to the maintenance shift pattern which was deployed over three shifts per day, from Monday to Friday. This resulted in a gap in maintenance cover over any given weekend. OM revealed the gap in cover was alleviated by overtime work from maintenance operatives, although this did not cover night shift work. This arrangement was of great frustration to PM, as the voluntary nature of the overtime work led to a reluctance by other senior managers to negatively disrupt the maintenance department. Furthermore, OM revealed a transition from the current 3 shift pattern to a continental system for maintenance operatives had been proposed for some time. At the time of the interview, this was not being imposed due to a general reluctance to change from the maintenance team.

4.3.10 Budget

The magnitude of the maintenance budget was not revealed through interview, yet OM provided an interesting perspective on the effect of a reduced budget. Apparently, the consequence of the disjointed maintenance shift pattern and subsequent overtime, resulted in a continued drain on the maintenance budget. Moreover, this reduced maintenance budget facilitated the '**make do and mend'** strategy of the department.

4.3.11 Buffer stock

The utilisation of buffer stock was identified by both MM and OM as an insurance plan for maintenance failure. There was approximately 2 days of finished product stock held at the plant as well as 12 -24 hours of product held between each stage of production. The cost to the business of this stock was discussed, though there was a reluctance for publication of this information.

4.3.12 Summary of constraining and enabling factors:

Table 4.3 A summary of constraining and enabling factors for Plant 2

Category	Constraint	Enabler
Senior Management Engagement	✓	
Skills and Training	✓	
Staff Resources	✓	✓
Perception & Production Integration	✓	
Equipment and Spares	✓	
Performance	✓	
KPI's	✓	
Supply Chain	✓	
Maintenance Shift System	✓	
Buffer Stock	✓	

The enabling factor cited in the staff resources section may be attributed to the apprenticeship scheme. Although the department is widely discussed as being underutilised, this may have been exacerbated had it not been for the continued recruitment, training and deployment of this apprenticeship model.

4.4 Plant 3

Plant 3 is a manufacturing business based in the North of England which acts as a Tier One supplier to the automotive manufacturing industry. The site is part of a global company with headquarters in Japan, operating in multiple countries throughout the world. A key commitment of the parent company is lean manufacturing with optimum efficiency – at all stages of the business. As a result, the Operations Director at Plant

3 has two key objectives; to increase profitability and reduce inventory. The site is approximately 30 years old with 560 employees, of which around 20% are temporary production staff. A large majority of the original installed manufacturing equipment is still in use at the site and being used daily. The plant produces two typical components for use within the automotive industry, both products are a result of the deformation and joining of sheet metal. The plant supplies two OEM's at the time of this investigation, with the majority of this supply going to a local OEM. The production strategy deployed by the site was JIT manufacture, though safety stock is utilised to act as a buffer. The plant operated with a three-shift system, five days per week.

The plant has held supply contracts with multiple OEM's for several years but has experienced some quality issues in the past. This has resulted in an ongoing tension between the plant and one particular OEM. The supply contract with a very important OEM contains an annual financial condition where costs are reduced by 4% to 5% for the duration of the contract. This has an impact on all business functions.

The organisational structure for the plant begins with an Operations Director, supported by an Executive Manager. The Operations Director and Executive manager have inter-site responsibilities within the group. Subsequently, a Senior Manager holds site specific responsibilities for both Manufacturing and Maintenance and reports directly to the Operations Director. The Senior Manager has extensive experience in both Manufacturing and Maintenance. The maintenance department have three technicians per shift and report to a maintenance engineer. The maintenance engineer works day shift and despite the title, is highly operational and works alongside technicians on maintenance tasks. The maintenance engineer reports directly to the Senior Manager for Manufacturing and Maintenance. The maintenance strategy is highly reactive with any planned maintenance only occurring at a weekend, during normal production downtime.

Interviews were completed with the Operations Director (OD), Executive Manager (EM), Senior Manager (SM) and Maintenance Engineer (ME).

4.4.1 Senior Management Engagement

The engagement of senior staff in maintenance management appeared in conflict and contradictory at times. Throughout each interview, except for OD, there was agreement that the maintenance strategy needed to move from being reactive to planned and preventative. The conduit for this move would be PLM. The most senior manager disagreed with this as a development, due to a lack of trust in the ability of production staff to complete any maintenance task competently. Indeed, OD insisted tasks for production staff should be restricted to simple, repetitive manufacturing operations. When discussing the ability of production staff to contribute towards maintenance OD stated ***" I don't want them, I don't pay them to have that responsibility*. *I pay them to do the same thing 400 times, boring jobs but well paid".***

This view was isolated and was not held by other managers, who favoured PLM as a change mechanism. Interestingly, answers given by MM reflected this conflict, indicating a negative perception of maintenance taken by senior managers at executive level. This negative perception apparently having resulted in a lack of investment and resources for the maintenance function. This view was compounded by ME, who disclosed doubts about PLM from a different perspective. ME identified PLM as a positive step forward yet doubted if a new maintenance programme would be successful. This was due to a historical lack of any implementation strategy from senior managers for new maintenance initiatives.

4.4.2 Skills and Training

ME identified the strengths of the maintenance department as deploying reactive maintenance techniques. Consequently, most of the work completed by the department consisted of reactive maintenance tasks ***"our focus is to always repair".*** Moreover, this was recognised as a strength by all interviewees. Planned maintenance activities were delivered by the department at the weekend, with very little preventative work completed. A training plan was submitted by ME each year for the department and subsequently amended as a result of the annual cost down requirements. OD confirmed the reduction of training requests was used as a method of satisfying annual financial targets. ME revealed the impact of a reduced training plan, describing how changes to engineering legislation ensured most of a reduced training budget could be taken by simply completing legislative training for technicians. This included fork lift truck training, scaffolding and grinding regulations accounting for a large percentage of the training budget in one year ***"So where I would love to spend about 16 grand purely on technical, I'll probably have to spend 6 grand on legislation and 10 grand on technical".***

4.4.3 Staff Resources

Staff resources for general maintenance activity was discussed as being satisfactory at that point in time, though planned maintenance activities were completed through overtime and goodwill. ME discussed a reduced capacity for any additional work, emphasising the difficulties in resourcing an initiative such as PLM, which would require maintenance technicians to train production staff.

4.4.4 Perception and Production Integration

Discussions with MM and ME revealed the maintenance function experienced a number of difficulties completing any progressive maintenance tasks during normal worktime. In particular, the JIT production strategy had a damaging impact on the completion of maintenance tasks. Furthermore, production was never halted to incorporate these maintenance activities, with access only granted during production downtime. This was acknowledged as a frustration by MM, indicating it was out of their control. This scenario was compounded by most of the equipment being beyond the manufacturers guaranteed life cycle of operation.

EM revealed an awareness of the need for the plant to progress towards the use of PLM but warned of the issues and difficulties surrounding such a move. These issues were focussed on cultural problems and embedded beliefs by long serving staff ***"This is a 25-year-old site and it's never happened here, it's more of a cultural thing to***

change” This opinion was not directed at operating staff, but middle management personnel. The indication from all interviewees, was that operating staff would welcome additional maintenance tasks. A conflict of opinion emerged when interviewing MM, who suggested the reluctance within the business to introduce PLM emerged from managers at executive level. Moreover, MM described plant senior management as having a traditional, negative perception of the maintenance department ***“Changing mindset of senior people within the business as to the importance of maintenance. Away from the traditional view of ‘they do nowt them’.”***

The interview with MM revealed a separation had emerged between production staff and the maintenance department. According to MM, the symptom of this problem was a general lack of ownership throughout the plant of any machine or process-based problems ***“A big part is ownership, well, it’s not my problem”.*** Apparently, this existed due to a distinct lack of engagement between maintenance and production for any improvement activities. MM continued, stating this was exemplified by the absence of any suggestion or reward scheme and a general lack of engagement with operational staff. Consequently, this resulted in apathy and lack of ownership for production issues. Conversely, an example was provided during the same discussion of a joint maintenance/production improvement activity, which resulted in production improvements. MM described the results of this activity as increasing morale and forging closer working relationships between production and maintenance.

4.4.5 Equipment and Spares

The age of the site and associated equipment was acknowledged by all participants as an ongoing issue, negatively affecting maintenance performance. ME identified two features within the plant which were of concern. Firstly, approximately 40% of production equipment was over 15 years old and subsequently operating beyond the recommended life cycle. Secondly, any new equipment which was purchased was of relatively low quality. According to ME, this low quality provided an additional burden to the maintenance function. This point was also discussed by other interviewees. OD provided valuable insight into the issue, remarking that winning a new order invariably led to permission from the parent company to purchase new equipment. This purchase was restricted and had to be attributable directly to the new product. As a result, OD revealed that generic, long-standing equipment tended to be omitted from any purchase strategy. As a result, this equipment became older and more difficult to maintain. Furthermore, OD revealed the level of investment within the plant was insufficient and below what current production levels required.

ME and EM both discussed the issue of recently purchased production equipment being of low quality and related the problem directly back to the plant purchasing strategy. The yearly cost down target of the business resulted in the purchasing department having the same cost reduction target as all other departments. As a result, EM agreed the priority when purchasing new equipment was cost ***"The biggest things is getting purchasing on board as its normally purchasing department that go out and buy the equipment".*** Two issues appeared to emerge from the purchase strategy. ME reflected on the immediate maintenance issues which arose with low quality machinery, whilst EM discussed a longer-term consequence. The consistent purchase of equipment, which was the cheapest option, invariably led to a diverse range of machine manufacturers being utilised by production. Consequently, both MM and EM identified the spare parts required to support such a diverse range constantly grew and became difficult to manage. This was of great concern to EM and the interview revealed the misalignment of objectives between the maintenance and purchasing department having an increased impact on the plant ***"Purchasing's target is just to spend less. Not to give the maintenance department an easy time. A lot of the targets within our business conflict with each other"***

4.4.6 Planning and Performance

MM revealed the nature of the maintenance strategy for the site ***"Not much preventative maintenance. Strategy is based upon breakdown"***. The small amount of preventative activities were scheduled each weekend due to the reluctance of production to incorporate this within their normal work schedule. Preventative maintenance consisted of a visual inspection of scheduled areas only. The schedule for these inspections was based upon the top 10 worst performing items for machine availability, from the previous month. Throughout this conversation MM acknowledged the unsatisfactory nature of the maintenance plan and indicated the wish to move to a more proactive approach. According to MM, this proactive approach would require production staff to become maintenance active. The importance of a more proactive approach was identified by EM as being crucial for the development in maintenance performance. In addition, MM recognised any developments would also have to include improvement to the recording of maintenance data. This was discussed as being a manual process, lacking detail and accuracy.

OD revealed the high-volume requirement of the main OEM resulted in production consistently running at maximum capacity and they were "***a victim of their own success. Building huge amounts of cars and not investing properly as they should have".*** In the opinion of OD, this was damaging to older equipment and resulted in worrying failures. This was a concern echoed by ME, who bemoaned poor access time for maintenance activities due to the requirements of production.

4.4.7 Key Performance Indicators

When participants were questioned on maintenance KPI's, feedback tended to vary. OD responded, identifying budget, OEE and machine downtime. OEE was a common response across all interviewees. This was expanded upon by EM who included Break - Down Rate (BDR) as a maintenance focused KPI. Similarly, the ME added completion of preventative maintenance tasks as a department indicator. Both OD and MM revealed concern for the accurate recording of data to inform KPI's. Finally, MM reflected on the importance of OEE regarding poor maintenance investment. The discussion revealed the stability and relative satisfaction with plant OEE from senior managers at group level, yet according to MM, this satisfaction reinforced the persistent under investment and lack of regard for the maintenance function "***the OEE as a measurement KPI affects the attitude. If OEE is good – why spend more?"***

4.4.8 Supply Chain

When discussing the supply chain relationship, OD identified the contractual cost down requirement resulting in the business struggling to survive. Consequently, the ability to improve was inhibited. ME further reflected on the cost down impact, suggesting it resulted in difficult choices between new staff or spare parts. Moreover, all participants agreed that although some degree of sharing of best practice may occur for specific production techniques, this did not occur for maintenance. This applied both downstream and upstream of the plant.

4.4.9 Budget

EM revealed the annual budget for maintenance activities was approximately £700,000 per annum, yet OD, EM and ME agreed that whilst this was substantial, the sum was inadequate for empowering maintenance development and improvement. Indeed, ME identified the lean nature of automotive manufacturing as having a detrimental effect. This detrimental effect applied to maintenance training, staff resources and spares parts. ME discussed the reality of deploying a relatively large budget in an ageing plant ***"Lack of investment in degradation, that's machines that are growing old. 40% of my plant is over 15 years old and 40% of that plant I'm now buying 2nd hand bits for***". A further inhibitor was highlighted by OD, who revealed the difficulties in the parent company agreeing to any increase in annual Capital Expenditure (CapEx) budget for the plant. This discussion also revealed this restriction in the CapEx budget resulted in sacrifices to previously planned staffing, training and any purchase of new equipment.

4.4.10 Buffer Stock

The relevance of buffer stock to maintenance management became apparent through the discussion with EM, who revealed buffer, or break glass stock was maintained with dual purpose. The interview related the primary purpose was to ensure the consistent delivery of product to the customer. Whilst this appears normal in an automotive manufacturing environment, EM also revealed the level of break glass stock was greatly increased due to the ineffectiveness of the maintenance plan. This discussion continued with OD, who divulged the cost of held stock at that moment ran into tens of millions of Euros.

4.4.11 Summary of constraining and enabling factors

Table 4.4 A summary of constraining and enabling factors for Plant 3

Category	Constraint	Enabler
Senior Management Engagement	✓	
Skills and Training	✓	
Perception & Production Integration	✓	
Equipment and Spares	✓	
Performance	✓	
KPI’s	✓	
Budget	✓	
Buffer Stock	✓	

There were no enabling factors of sufficient impact recorded during this case study.

4.5 Plant 4

The fourth participant to take part in this research is a seven-year-old operation based in the North East of England. The site is a foam manufacturing facility and operates with duality, supplying at both Tier One and Tier Two. As with all other participants, the plant is part of an extensive global corporation, with headquarters in the United States of America. The company has wide-ranging financial resources with global sales of approximately £18 billion, occupying a position in the upper third of the Fortune 500. This corporation manufactures a large range of differing products which all exist within the sphere of the automotive industry. The strategy for delivering the business objectives consisted of five key targets, all focussed upon solvency, profit and growth.

Plant 4 manufactures with two key processes, utilising press operations and chemical processing. Within these processes there is some degree of automation, but no specialist robot activity. The age of the equipment is relatively new and exists within a site footprint of 5500 square metres. The production department operates on a JIT basis over a period of 24 hours, 5 days per week. As with other supply chain operators, the production shift pattern is driven by that of the OEM. The site supplies two large OEM's, one which is situated locally, the other nationally. There are 185 personnel employed at Plant 4 with approximately 20% of these consisting of temporary, agency staff. If the temporary staff demonstrate competency and commitment to the role, there is an ongoing opportunity to be employed permanently. Plant 4 is operating from a position of stability, having experienced a period of consistently achieving financial and manufacturing targets over recent years. This had led to the possibility of expanding the plant and subsequent operations.

The plant is overseen by an Operations Director but led by an Operations Manager. There are several middle managers reporting to the Operations Manager and this includes what is known as the Maintenance Controller. The Maintenance controller manages the maintenance department which consists of nine multi discipline technicians and a maintenance team leader who works day shift. There are three maintenance technicians per shift and additional weekend work is considered overtime. There is some tension within the maintenance function as the technicians must also change press tools as part of their day to day role. This responsibility has been imposed by the operations manager and takes precedent over any ongoing maintenance activity. The tension arises due to the technicians perceiving this activity as semi-skilled and beneath their level of expertise. This tension between maintenance and other areas of the business is also evident in other areas of the management structure, despite the relative stability of performance metrics.

Interviews were conducted at four different levels within the business and included discussions with the Operations Director (OD), Operarions Manager (OM), Mantenance Coordinator (MC) and Maintenance Team Leader (TL).

4.5.1 Senior Management Engagement

The engagement of Senior Managers within Plant 4 appeared relatively high when discussed at interview. OD indicated a keen interest in maintenance development, discussing the crucial part Maintenance must play in a successful plant. Further discussion revealed that OD previously held the plant manager role at Plant 4 and maintenance development was one of the strategic responsibilities of the position. Furthermore, this historical engagement had led to a keen interest in current maintenance performance.

The discussion with OM reflected the present engagement levels with senior management staff. OM believed the prominence and importance of maintenance within the business would be maintained and improved with the engagement of senior staff. TPM was named as being a current initiative within the plant, involving primarily maintenance staff but eventually production staff. Interestingly, although OM alluded to need for business leaders to engage with the implementation of TPM, a continued discussion revealed the TPM project was the sole responsibility of MC.

Finally, the strategic objectives assigned to the site through the parent company were cascaded from the OD to each individual tier of operation within the plant. Eventually, this emerged at the operational level of maintenance. The achievement of these objectives was planned and discussed in a meeting between OM and MC. In this meeting, the plan to achieve the objectives was identified. MC revealed this plan would be the basis for any ongoing appraisal of department and personal performance.

4.5.2 Skills and Training

Interviews revealed there were differing opinions on the level of skill and training currently held by the maintenance team. OM concluded there were variations in the range of skill within the maintenance team, which directly resulted in poor performance. Further discussion revealed this was directed at progressing maintenance apprentices who were operating as newly qualified technicians. According to OM, these skill levels were lower than more experienced staff and affected maintenance performance "***Newly qualified technicians, that were apprentices performing at a lower level. Low knowledge and skills let team down***.". TL presented a differing perspective, reinforcing the problem that some tasks the maintenance technicians were required to complete each day were below their skill level and demoralising. These involved tool changes on press machines, and low-level maintenance work on the press tools. TL insisted the department ***"feels frustrated the team can't focus on things they feel are important.***" Both OM and TL agreed these could be categorised as semiskilled activities, yet they were part of the responsibilities of a maintenance technician.

The training of maintenance staff was discussed with MC, who considered a training matrix utilised by the department for the upskilling of staff. Interestingly, the training matrix was developed by MC and was not a tool commonly used by the business. The training analysis was used by all contributing members of the department and focussed on existing and future plant equipment. TL confirmed the use of the matrix and seemed satisfied with the effectiveness of the tool.

4.5.3 Staff Resources

MC discussed frustration with the resourcing of the team leader position. The department contained one, who worked day shift. In the opinion of MC, a team leader on each shift was required, to assist in any critical decisions during busy periods.

MC and OM reflected on the importance of the maintenance apprenticeship programme, due to previous recruitment difficulties. MC added that the programme helped remove the negative attitude of previously employed staff. According to MC, this was alleviated by progressing apprentices to technician level. This model developed candidates who, in the opinion of MC, possessed the correct attributes both in character and skills. Currently, 5 of the 9 employed technicians had previously been through the plant apprenticeship training programme.

4.5.4 Perception and Production Integration

This area of discussion provided great depth and was contributed to by all interviewees. The attitude of maintenance staff was heavily discussed, and OD reflected on this issue, calling the attitude a '***mind-set'***. OD highlighted personal satisfaction that current maintenance staff possessed a positive mind-set and were '***empowered and like-minded'***. MC defined mind-set as both '***character and personality'*** and identified the importance of these traits and their influence on the external perception of maintenance. Conclusively, MC emphasised the likelihood of a negative mind-set directly influencing performance levels.

OM agreed with the importance of mind-set, describing it as '***culture***'. OM contradicted a view held by OD, insisting the current maintenance function still possessed a negative mind-set and lacked some degree of ownership for their responsibilities. The lack of ownership was exemplified with the unwillingness of technicians to fully engage in the tool change activity described in Section 4.5.2. According to OM, this reluctance projected a poor image of the department and affected team morale. During the conversation, examples were provided by OM of poor cultural practice and included technicians '***visiting jobs in pairs'*** as well as appearing to be '***just sitting around the workshop*'** during a recent visit. The frustration of OM with the maintenance function continued, revealing irritation that the department were scared to open themselves up and share information with partner departments, such as production and quality. Conclusively, OM called maintenance '***a closed shop*'**.

Factors which contributed toward these negative perceptions emerged through discussions with MC and TL. MC believed that the appearance of the plant running normally on a day to day basis, led to the business wide conclusion that operationally, everything was fine. Consequently, this resulted in difficulties for MC in gaining support from senior staff for additional resources. MC attributed this partly to the efforts of the maintenance department lacking a final product or having any final, visual impact for work completed. Friction between maintenance and internal stakeholders also existed with the production department, relating the widely held ethos of '***production is king'***. TL altered the focus, believing there was a '***blame culture'*** which resulted in friction between maintenance and senior managing staff within the plant. This resulted in the maintenance department receiving censure if something went wrong, yet importantly, receiving very little praise if a high-profile job was completed successfully.

The discussion on managing a negative perception continued, as MC acknowledged the influence of appearance. This included the appearance of the maintenance operatives as well as the work area. MC believed the outward presentation of maintenance technicians heavily influenced any impression made on other employees and considered technicians who were smart and presentable as being crucial. The alternative was that technicians looked like '***grease monkeys***.' In addition to technicians, the organisation and cleanliness of the maintenance work area was discussed. MC acknowledged the issue of staff ownership, highlighting the neglect of maintenance technicians in fully adopting the manufacturing policy of applying 5S to all work areas. As a result, the department workshop was often left in a disordered fashion. Conversely, TL confirmed from previous experience, presenting a professional and well-ordered department to all stakeholders improves both reputation and working practices.

The depth of discussion within this area provided individual opinions on how some of these negative perceptions could be altered. OD reflected upon a positive cultural change which had been experienced within the plant, whereby business KPI's were reviewed with all departments. This review identified the contribution each department made towards the KPI. In doing this, it was anticipated that the ownership of each department and their contribution towards key indicators would improve. Moreover, respect for that contribution would emerge from other, partner departments. OM also reflected on previous practice, alluding to positive work carried out by other business functions. This involved the continuous improvement department instigating process improvement initiatives. Part of this process would involve the engagement of all stakeholders when seeking to implement a solution. Other stakeholders may include Quality, Production and even Maintenance. OM insinuated this was the opposite of current practice by the maintenance function, who tended to operate in a unilateral manner. OM reflected that it was the attitude of multi department engagement towards problem solving which needed to be more prevalent for the maintenance department in the future. TL provided further insight, citing the need for an improved level of communication between maintenance staff and other parties. Part of this improvement would include an increased level of respect and professionalism.

4.5.5 Performance

There appeared to be relative satisfaction when discussing the performance of the maintenance department. OD remarked the historical maintenance strategy was overly reactive, but that had now altered towards a more proactive plan. Whilst there was general agreement from OM, there was also a contradiction when discussing the split of strategies across two separate production lines. OM revealing that whilst predictive techniques such as vibration analysis and thermal imaging were used on one line, there continued to be an over reliance on a reactive plan on another. TL shed some further light on the split strategy, revealing that the predictive maintenance activities were completed by external contractors and not by employed maintenance staff. This led to OM providing a '***performance rating of 6/10***' for the maintenance department. Confusingly, this performance rating was provided with OM also indicating some degree of satisfaction with headline KPI's, including 84.5% OEE and 94.5% machine uptime. OM indicated a critical frustration with maintenance performance resided with maintenance rework of completed tasks. This rework was due to the process or component consistently failing. Once more, OM credited this as a "**lack of ownership"** by maintenance technicians in not completing some form of root cause analysis on repeating failures.

Discussion with both TL and MC revealed the strategy development of the maintenance department was directed through the parent company version of the

TPM initiative. The criteria for achievement was measured through a Bronze, Silver and Gold progressive standard with the plant currently achieving a Bronze award. The Bronze standard requires the involvement of production operators executing housekeeping and cleaning tasks. TL revealed that similar initiatives had previously increased operator ownership for their process, though this ownership had yet to occur at Plant 4.

4.5.6 KPI's

There were varying opinions on KPI's which emerged during interviews. Both OM and particularly MC had a close focus on key indicators and metrics. This was not the case with TL. Both OM and MC discussed the relevant KPI's for the maintenance function as including; machine downtime; MTBF; MTTR and preventative maintenance completion rate. In addition, OM included OEE as a maintenance KPI – MC did not. Interestingly, OM described a plant wide monitor system which displayed a live feed of indicator status. OM described this as a new development which would help present the importance of plant indicators. Further discussion revealed this live feed did not include maintenance KPI's.

In contrast TL had "***little involvement with KPI's***" or the metrics which contributed towards them. TL was involved in the recording of specific information such as downtime but as confirmed by MC, this was a manual process and open to error. The maintenance department had no CMMS to assist in this process to the continued frustration of MC. The manual recording and calculation of indicators was processed by MC, who despite being required to report these on a monthly basis, maintained a daily calculation routine.

4.5.7 Supply Chain

OD discussed the relationship the site expected to maintain with its own supply chain, reviewing the audit procedure completed prior to any supply contract. OD described the expected maintenance standards with suppliers, which included resilience planning for production equipment as well as fundamental maintenance procedures. Audit failure would result in an action plan with the opportunity for remedial work to amend discrepancies. OM responded to questions on this matter looking downstream in the supply chain, indicating there was little to no support from the OEM regarding sharing of maintenance best practice.

4.5.8 Budget

The annual budget for the maintenance department was approximately £650,000 per annum, which did not appear to be an issue between participants. As part of the conversation, MC discussed a personal frustration at what appeared to be a lack of trust from the plant when wishing to buy maintenance equipment. MC described a recent purchase request for preventative maintenance equipment yet described the "***difficulties with decision makers agreeing to providing additional resource if plant is running ok.”***

4.5.9 Buffer Stock

Both OM and MC acknowledged the use of buffer stock within Plant 4, citing 30 hours' worth of product being held to alleviate production failure. The use of buffer stock was discussed as a well-managed process and was not used for alleviating maintenance issues. To mitigate excessive buffer stock, MC signposted the advantages of maintaining a robust critical parts list as well as a through resilience plan for each production process.

4.5.10 Summary of constraining and enabling factors:

Table 4.5 A summary of constraining and enabling factors for Plant 4

Category	Constraint	Enabler
Senior Management Engagement	✓	✓
Skills and Training	✓	
Staff Resources		✓
Perception & Production Integration	✓	✓
Equipment and Spares		
Performance	✓	
KPI's	✓	✓
Supply Chain		✓
Maintenance Shift System		
Budget		
Buffer Stock		✓

There was an increase in enabling characteristics with Plant 4 and the previous experience of OD having responsibility for maintenance appeared beneficial. The use of an apprenticeship scheme to alleviate recruitment issues as well as make a positive impact on the department culture is valuable. Moreover, the understanding of the importance of department commitment, presentation and attitude demonstrates empathy with how a difficult working relationship may be eased by appearing to recognise and associate with widely held organisational standards. The inclusion of Buffer Stock is an acknowledgement of the importance of developing a robust spare part management system. This includes the evidence which demonstrates a relatively complete critical spares list and emergency breakdown procedure which maintains production levels in the event of a critical process failure.

4.6 Summary of cross Plant categories:

Each of the four case study participants presented a differing constraint profile during the investigation, yet the importance and reason for these constraints becomes more apparent when understanding the context of the situation. This chapter will conclude with a brief summary of the key features of those situations, which will contribute towards the next stage of this research.

4.6.1 Senior management engagement

The degree of engagement with the senior management team varied across all four sites, yet this engagement consistently had an influence on maintenance performance and management. Plant 1 appeared to have a supportive senior management team, encouraging maintenance strategy development. This was with a caveat, as further discussion revealed the resourcing of the development plan was limited, with a large proportion of the implementation being assigned to the maintenance engineer. Plant 2 experienced differing issues, as the poor performance of the maintenance function led to the department being held with little regard at all levels of the business. A fractured relationship between operational staff and senior managers also appeared to be evident in Plant 3, with views on maintenance development varying between staff. Discussions with most participants indicated a lack of belief in the department and ME believed this resulted in a continued lack of investment.

The negative aspects of senior management engagement could be countered with the positive levels of engagement with Plant 4. Discussions revealed the previous maintenance experience of OD influenced the expectation that a successful maintenance function, needed to have continued support from senior managers.

4.6.2 Skills and Training

The importance of considering the correct skill attainment of maintenance technicians – as well as an appropriate training plan, became apparent during interviews. Plant 1 seemed to be experiencing some legacy issues from previous ownership – which resulted in a drain of staff and skills. This, combined with no training plan for the department, appeared to result in the technician team demonstrating little autonomy when completing tasks and exhibiting an over reliance on more capable staff. The traditional, discipline focussed maintenance technicians in Plant 2 led to numerous problems, including the department being under resourced. This was despite progressing technicians being trained in multi- skilled maintenance. To compound the issue, difficulties in recruiting technicians had given rise to a drop in the entry standards of new staff. Clearly this has resulted in a lack of specialist knowledge in the department.

The skill base of maintenance technicians in Plant 3 was very much focussed towards reactive work, with all interviewees describing this as a strength of the department. Subsequently the maintenance strategy was reactive, although most staff acknowledged the need for more proactive activities. The training of staff to improve the skill set of technicians was inhibited by both the supply contract and ongoing legislative requirements. The annual cost down expectation of 5% by the OEM resulted in a reduction in training opportunities according to ME. This was compounded by the need for continued updating of staff licences in areas such as forklift driving, grinding and scaffolding courses. Indeed, these updates accounted for approximately 40% of the training budget and restricted any additional development.

Although Plant 4 used an apprenticeship programme to alleviate staffing issues, senior staff believed progressing apprentices did not have enough experience to make a genuine impact on maintenance activities. Although this may improve as the graduating apprentice gains more experience. Possibly of greater concern, is the workload attributed to maintenance technicians which appeared to cause friction in the department. The tool change tasks completed each day was described as semi-skilled and demotivating for technicians.

4.6.3 Staff resources

Staff resources were not identified as a problem for 3 out of the 4 plants, but Plant 2 had specific issues. This was irrespective of possessing the greatest number of technicians across all 4 participants. The department was acknowledged as being under resourced as a reflection of the vast array of differing production equipment, as well the extensive number of sites. This appeared to provide an ongoing challenge to how the maintenance function performed.

4.6.4 Perception and Production integration

Reviewing the perception of the maintenance department by external members of the organisation as well as the type of working relationship held with the production function, offered an opportunity to understand some of the issues each maintenance department was experiencing.

The introduction of operator led maintenance activities in Plant 1 was discussed with some degree of scepticism by senior managers, who firmly believed there would be cultural issues at that level preventing any degree of success. This perception was countered by the experiential evidence attained by the maintenance engineer who implemented a similar pilot scheme. Feedback suggested this sharing of working practices brought the maintenance and production department closer together. This closeness presented itself in the form of an improved understanding from operators of maintenance activities and their link to improved production conditions. What did appear consistent was the conflict between departments due to the manual recording of breakdown information.

The maintenance department from Plant 2 appeared to have some serious issues in the working relationship with external stakeholders. The differing values, working practices and performance of maintenance technicians negatively influenced the perception and subsequent relationship held with key organisational personnel. These differences appeared in several ways, including a lack of urgency in work completion or little engagement with any key performance indicators. The opportunity to alleviate this through operator led maintenance was not available, apparently due to the transient nature of the production workforce. The lack of opportunity for integrating the working practices of production and maintenance was evident at Plant 3 but for different reasons. Interestingly, the most senior manager at the site insisted production would not be capable of any low-level maintenance tasks and were to concentrate upon their simple, production focussed tasks. This was in direct conflict with the opinion of other senior managers. This lack of clarity at a senior level clearly influenced the strategic direction of the maintenance function.

The importance of recognising factors which influence how the maintenance department is perceived and engaged began to emerge at Plant 4. The maintenance department appeared to understand the positive influence new staff may have on a function. This was demonstrated by qualified apprentices becoming established technicians through the company apprenticeship scheme. A discussion with MC also highlighted the significance of the attitude and outlook of technicians when discussing external perceptions of the department. Crucially, MC understood the negative influence a poor attitude could have on maintenance performance levels. The theme of projecting a positive image became more tangible with interviewees reflecting upon the importance of a tidy, well presented work area. This would mirror the standards established in production and improve any image issues.

4.6.5 Equipment and Spares

Procurement and commissioning activities seemed to have a dramatic influence on the condition and readiness of equipment and spares at most of the case study plants. The low-cost purchasing strategy of Plant 1 ensured varying machine manufacturers existed throughout production, so standardisation was impossible. The increased variance in equipment and parts also had an impact on the currency of technician training. Significantly, this variety resulted in a huge impact on the maintenance budget. These difficulties also continued at Plant 2 where the business model presented significant difficulties to plant maintenance. The ability of the site to produce high volume product for automotive assembly as well as batch and unit production for automotive spare parts, resulted in a vast array of production equipment. This presented extensive difficulties for asset management and resulted in a lack of critical part identification and storage. Combined with the increasing age of the production equipment, this proved a significant barrier for maintenance performance.

The age of production equipment emerged once more at Plant 3, with a similar purchasing strategy to Plant 1 having a comparable, damaging effect. Moreover, the large proportion of production machinery having to operate beyond the suggested life cycle, also resulted in spare part management becoming a negative influence on maintenance performance.

4.6.6 Planning and Performance

Any discussion of maintenance performance with senior managers from Plant 1 immediately led to a review of OEE. This relative satisfaction with 85% belied the fact that maintenance clearly still had room for a great deal of improvement. Developments were under way to emerge from a mainly reactive strategy, yet this was still proving difficult. The implementation of PLM was in the early stages, yet a lack of accurate, electronically recorded data resulted in the ineffective planning of tasks. This was perpetuated by an unwillingness by staff to engage with the installed CMMS system. The reported underperformance of the maintenance function at Plant 2 also appeared to be heavily influenced by a lack of accurate information and planning. Any preventative maintenance was superficial, random with the overriding strategy being reactive in nature. Combined with the range and age of equipment this was a strain on resources. Furthermore, the lack of accurate information inhibited the ability to move away from this style of working. The issues reported in Plant 1 and 2 also presented themselves in Plant 3 to varying degrees. A willingness to move from a reactive stance to a more proactive plan was there, yet not fully supported by senior managers or infrastructure. The OD acknowledged the need to move from a reactive plan but was resistant to using any other staff to assist technicians. At a more operational level, the ability to plan for a more effective strategy was compromised by the manual and inconsistent recording of data.

Plant 4 halted the trend of negative planning and performance issues. The site had advanced towards a more proactive strategy and was continuing to do so, although strategy issues remained. Interestingly, OM expressed satisfaction with plant OEE and machine uptime statistics yet was still critical of maintenance activities. Once more, this appeared to be as a result of a lack of accurate information. This gap in the maintenance strategy and subsequent lack of analysis, resulted in repeated failures at component level on certain machines.

4.6.7 KPI’s

The definition and use of maintenance metrics and indicators offered some consistent themes. Senior managers would consistently identify OEE as the primary indicator of maintenance performance, irrespective of the case study site. At a senior level, little else appeared of importance. This seemed to be as a result of it being the only indicator reported to group level in relation to maintenance performance. At department level, maintenance KPI’s were often redundant and inaccurate. This included the completion of preventative maintenance tasks, despite the recognition by interviewees at Plant 1, 2 and 3 that the preventative tasks were both superficial and poorly planned. Once more, Plant 4 reversed this theme and increased the range of KPI’s used by the department. This was despite it not being a reporting requirement, internally or externally. Despite this proactive approach, the information which emerged from this extended use of KPI’s was unreliable. Plant 4, as with all other plants could not utilise an electronic data recording system for maintenance activities. As a result, analysis was open to error.

4.6.8 Supply chain

The relationship between the case study participants and the OEM appeared formal and tense across all 4 plants. There was no sharing of best maintenance practice between the OEM and their Tier One supplier. Conversely, the engagement with the OEM increased significantly if contractual issues became apparent. These contractual problems could be quality or delivery in nature and resulted in an increased focus and strain on the supplier. Plant 2 expanded on this, explaining the long-term impact of an OEM intervention at maintenance level. This often resulted in unwanted department changes being insisted upon by the OEM. Interestingly, Plant 2 reflected upon a regional Automotive Alliance group as a platform for support amongst OEM and supply chain members. Unfortunately, Plant 2 regarded such a platform from a business perspective and displayed a reluctance to engage and divulge sensitive information to potential competitors.

4.6.9 Budget and Buffer stock

Plant 1, 2 and 3 all bemoaned the impact a reduced budget had on their ability to improve, yet all interviewees agreed the headline figure was substantial. Poor maintenance planning and infrastructure resulted in outgoings which reduced the budget capacity for maintenance improvements. A clear example of this could be seen in the lack of equipment standardisation diversifying the range of spare parts required. This was a common theme and a heavy cost to each plant. Moreover, Plant 2 provided further examples, whereby a rigid maintenance shift pattern resulted in overtime payments which once more, reduced the available budget. The consequences of this type of maintenance management inhibits the capacity of the department to step out of the damaging reactive work cycle. The importance of understanding these issues are highlighted by the industrial environment of automotive production. The annual cost down requirement of the OEM appears to be normal and expected, yet Plant 1 and Plant 3 discussed their difficulty in managing this. Consequently, it seems to have a having a severe impact on their ability to release funds for maintenance training and recruitment. These activities appear to be one of the first to be removed to facilitate this reduction. Plant 4 did not seem to have a major issue managing the annual maintenance budget, possibly due to the more advanced development of the maintenance function.

The underperformance of maintenance appeared more tangible when reviewing feedback from Plant 2 and 3. Although it seemed a sensitive issue, all Plants admitted the use of '***break glass stock'*** to support a demanding delivery schedule. Yet Plant 2 and 3 acknowledged the volume of stock at any one time was inflated to mitigate the potential failure of the maintenance plan. The monetary extent of this burden was understandably difficult to ascertain, although Plant 3 highlighted the gravity of the issue by revealing the value of additional stock was '***Tens of millions of Euros'***. The realisation of this drain on cash flow may provide the plant and other suppliers with impetus to reflect on current maintenance plans and subsequent change.

4.6.10 Cross Plant summary of maintenance constraints.

Table 4.6 A cross Plant summary of constraining factors

Category	Plant 1	Plant 2	Plant 3	Plant 4
Senior Management Engagement	✓	✓	✓	✓
Skills and Training	✓	✓	✓	✓
Staff Resources		✓		
Perception & Production Integration	✓	✓	✓	✓
Equipment and Spares	✓	✓	✓	
Performance	✓	✓	✓	✓
KPI's	✓	✓	✓	✓
Supply Chain		✓		
Maintenance Shift System		✓		
Budget			✓	
Buffer Stock		✓	✓	

4.6.11 Summary of maintenance enablers from case study participants

Table 4.7 A cross Plant summary of enabling factors

Category	Plant 1	Plant 2	Plant 3	Plant 4
Senior Management Engagement				✓
Skills and Training				
Staff Resources		✓		✓
Perception & Production Integration	✓			✓
Equipment and Spares				
Performance				
KPI's				✓
Supply Chain				✓
Maintenance Shift System				
Budget				
Buffer Stock				✓

Table 4.6 and Table 4.7 present a summary of constraining and enabling factors which have resulted from the data presented. These factors are a result of the categorisation process discussed in Section 3.5 and will be used, alongside the concluding statements from the literature review in Chapter 2, to develop a tool to assist in addressing these damaging issues preventing maintenance performance in the automotive supply chain.

The development of this tool will be discussed in Chapter 5. Furthermore, Chapter 6 will include a description of the emerging results from these field tests, with a cross case comparison.

5. Development of the maintenance Gap Analysis Tool

5.1. Introduction

Chapter Four provided a detailed account of the key issues which emerged from the four case studies. From this, several constraints were identified which were impacting the effective delivery of maintenance strategy. These were:

- Inconsistent Senior Management Engagement with Maintenance
- A lack of skilled technicians
- Ineffective training of staff
- A lack of autonomy from technicians
- Restrictive staff deployment plans.
- Negative perception of the maintenance department
- Poor spare part management
- Ineffective planning techniques
- Manual recording of maintenance information
- Limited use of performance indicators

Additional, important detail was also included in Chapter Four. This includes the damaging use of buffer stock, which appeared to have a detrimental effect on the organisation. Feedback indicated the use of buffer stock was as a result of maintenance failures. Therefore, the need to address maintenance issues becomes very important as it could alleviate the need for holding expensive, excessive stock.

The negative impact on maintenance performance of these identified constraints led to the development of the Gap Analysis Tool.. This was due to the observations and data which emerged following the case study work. This information established there were both individual and common problems within the case study participants, yet all had a working maintenance plan. On that basis, this research will look to test the presence of constraints as well as good practice on the understanding there is a functioning maintenance department.

The chapter will begin with a summary of propositions developed from the literature review in Chapter 2. Furthermore, the field work completed in Chapter 4 has led to a series of additional propositions which will be used for the development of the Gap Analysis Tool. Consequently, the discussion will review the construction and development of the tool prototype. Figure 5.1 provides a representation of workflow and the relationship of these activities.

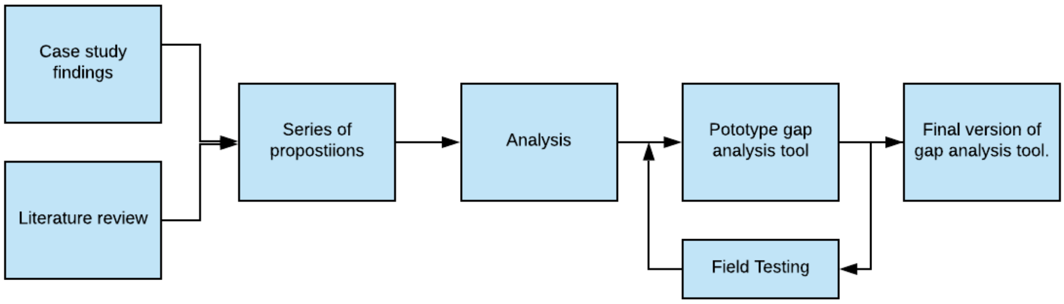

Figure 5.1 A representation of Gap Analysis Tool Development

5.2. Key points from Literature

Chapter 2 reviewed a wide range of scholarly work regarding maintenance management and factors which contribute towards a successful maintenance strategy. During this review, it became clear that the working practices, beliefs and values of an organisation have a substantial impact on the success of the maintenance function. As a result, organisational culture formed part of the summary. The literature search also included academic work which applied to maintenance practice within the automotive industry, specifically the supply chain. This proved challenging and led to an identification of a gap in scholarly work. Consequently, the key areas of interest were assembled from the remaining literature and led to a series of propositions being formed. These may be examined in Appendix 3 and are summarised in Table 5.1.

This proposition list may be summarised into key areas of investigation. These areas can then form the basis for a tool which will investigate the status of the maintenance function of a Tier One supplier in the automotive manufacturing industry. The key areas are categorised, with indicative information alluding to further content.

Table 5.1 A summary of propositions emerging from the literary review

Category	Proposition
Senior Management Engagement	• Senior management participation is essential for strategic maintenance development.
Training and Skills	• Training for maintenance staff must be appropriate, relevant and timely and accordance with the working environment.
Staff Resources	• Staff resources and skills should be flexible and aligned to maintenance strategy requirements.
Perception and Integration	• The perception of key stakeholders can be influenced by the cultural artefacts displayed by the Maintenance function.
Equipment and Spares	• The equipment and spares management system must support efficient and effective maintenance activity.
Planning and Performance	• A comprehensive work order planning system is needed to ensure the quality assurance of completed work.
KPI's	• The identification and accurate application of relevant performance measures, is a key characteristic of a successful maintenance strategy.
Budget	• Adequate financial and human resources are required to support and drive the maintenance strategy.

The construction of propositions has been aligned with the categories of constraints which emerged from the case study review. In this manner, it is anticipated the development of the tool will become transparent. As can be seen, the categories and key points from literature demonstrate commonality between literature and this research. Moreover, the literature has highlighted the importance of considering the culture of the organisation and the impact it can have on maintenance performance. This is represented in Table 5.1 yet is categorised under '*Perception and Integration'*. The content of this area is focussed upon working relationships, as well as factors which affect how the department may be perceived by other members of the organisation.

5.3. Key points from case study participants

Chapter 4 presented a full appraisal of the research carried out with four case study participants. Furthermore, this was categorised into a series of constraints, with each partner developing a profile of constraints, or enabling factors, which influence maintenance performance. The context and rich data which informed each characteristic, was then used to amend the proposition list developed in Section 5.2. Most of the information from case study partners, once analysed, acknowledged the majority of key points developed from literature. This can be noted from the detail in Appendix 3. As can be seen in Appendix 3, the proposition list is coded to reflect the origin of the proposition – such as Interviews, or observation. The proposition list developed from case study feedback is shown in Table 5.2.

Table 5.2 A summary of additional propositions emerging from case study feedback

Category of Constraint	Proposition
Training and skills	• Training should be completed when scheduled to ensure staff skills and morale is maintained
Maintenance shift system	• The maintenance shift system can support production more effectively if it runs in parallel to production
Perception and Integration	• A high level of production availability improves the perception of the production department • Discussing maintenance priorities in formal manufacturing meetings increases understanding of maintenance impact.
Equipment and spares	• All critical assets must an identified secondary plan for production and maintenance activity
Budget	• Effective budget management is critical to the performance of the maintenance department
Buffer stock	• Buffer stock is a regular feature within the automotive supply chain. • A poorly performing maintenance department will lead to an inflated level of buffer stock

The inclusion of this additional information confirmed the relevancy of the propositions which were developed in Table 5.1. Importantly, the analysis of case study information provided context from the automotive supply chain. Consequently, this ensured the development of the tool was rich in recognised academic work as well as contextualised, case study research.

The case study feedback included amendments such as the shift pattern of maintenance technicians, yet also supported the identification of a key symptom of a poorly performing maintenance department. The misuse of buffer stock was highlighted through feedback from Plant 2 and 3, yet buffer stock was consistently used in a controlled manner by Plant 1 and Plant 4.

The development of the Gap Analysis Tool would look to recognise the presence of buffer stock, yet it is anticipated reducing any increased levels of stock would be achieved through recognition and subsequent improvement of poor maintenance practice.

5.4. Analysis and Development

The combined series of propositions, derived from literature and case study data, was now at the stage of development where it could begin to focus upon Research Question 3:

3. *What is the most effective method of developing a successful maintenance strategy which will accommodate issues from Q2?*

This stage of development was carried out by two pieces of field work, which were completed in two separate organisations. The first organisation (Site 1 ltd) was operating in a different industrial environment. The feedback from this test was synthesised and helped further refine the tool. The second test was completed in the automotive supply chain and based upon the updated tool. Each test was completed with employees who had not previously been exposed to this research.

5.4.1. Field Test One

Stage one of the development came with an opportunity to confirm the relevancy of the findings and propositions through a field test. This field test was conducted by transposing propositions from each constraint category and developing them into a similar question. An example of this transposition is provided:

P1. As stakeholders, leadership should be engaged in the development of the maintenance function.

Q1. Who establishes the aims and goals of the department? Are they approved by senior managers?

The test for this stage of the research took place as a semi-structured interview, with the Engineering Manager and Maintenance Controller of a local food processing organisation (Site 1 ltd). It was anticipated this would look to provide insight into the findings. Moreover, this would aspire to improve the validity of the research and its potential application within a general manufacturing environment. The questions with brief notes representing the responses of both attendees are presented in Appendix 4.

At the outset, the Engineering Manager (EM) was direct, professional and business-like. Beginning with the category '*senior management engagement*', EM acknowledged the importance of leadership engagement when aspiring to improve the maintenance function. EM related that accurate data and systems were essential to facilitate this engagement. Furthermore, the data could then be used to inform key strategic decisions. Data, as well as the importance of KPI's was a common theme throughout the conversation. EM was direct about KPI's, insisting the identification and application of specific indicators needed to be linked to business objectives. Furthermore, maintenance focussed KPI's should be selective and focussed. The conversation included the importance of using indicators as a method of driving maintenance performance.

The issues experienced by the automotive industry in recruiting and retaining well qualified staff resonated with EM and the Maintenance Controller (MC) within the food industry. The suggestion of an apprenticeship scheme was met with approval as a means of addressing part of this problem. Conversely, the discussion also included a cautionary description of the potential impact of a poorly managed apprenticeship programme.

Case study findings provided several examples of poor relationships with partner departments which inhibited the performance or development, of the maintenance function. On this topic, EM indicated that perception '***was everything'*** to a department and provided examples of how important it could be in an audit or supplier visit.

This exercise presented an opportunity to compare key findings emerging from this research with an external, objective participant. The discussion provided acknowledgment of the importance of each category which had been formed but also compounded this information with additional, valuable detail. No further categories emerged, but information which would inform the tool development are highlighted in Table 5.3. This information is not exclusive, but provides an indication of the depth and value of discussion:

Table 5.3 A summary of additional information from Field Test 1 supporting key constraint categories

Category	Additional Information
Senior Management Engagement	• Senior management engagement is crucial in maintenance development. If management do not engage, maintenance will never improve.
Training and Skills	• Training and skills very important, ensuring identification of specific roles needing specific training.
Maintenance shift system	• Handover and communication issues emerge if maintenance runs a distinct shift pattern to production.
Staff Resources	• Autonomous maintenance for operators very important as it releases capacity for maintenance technicians. • An apprenticeship scheme is important to maintain key technical staff levels, although the standard of completed
Perception and Integration	• A positive perception is very important, it ensures the department is making a good impression and instils belief in the function • M/C availability can improve perception with production, but
Equipment and Spares	• Any issues with equipment and spares can be remedied by a high level of stock and warehouse management.
Planning and Performance	• Staff engagement within maintenance can refine planning and performance.
KPI's	• Select focussed indicators, informed from accurate data which are linked to a department objective. • Include metrics which provide indication of department cost efficiency and production availability to attract senior management engagement. • Utilise MTTR and MTBF to more accurately predict any required buffer stock.

5.4.2. Field Test Two

Using the literary and case study propositions, as well as the information gained from Field test one, the tool underwent a final stage of refinement. Field testing stage two reverted to engaging with the Automotive Supply chain. The purpose of this was to ensure any emerging feedback was in the context of of the automotive manufacturing industry. It was anticipated this would increase the value and operational capability of the tool.

Table 5.4 provides an example of the latest development due to field testing stage one. The proposition developed through this research was tested through a question. The response would allow the person carrying out the test to categorise this response through a succession of options. The content of the options was based upon the information gained from literature or case study participants, describing forms of good to bad practice. An example of a proposition and the question testing that proposition is demonstrated with P4 and Q4.

P4. Training is planned, implemented and documented regularly for the maintenance function

Table 5.4 An example of a test question based upon Proposition 4

Q4	Is there a training plan for the department? a) Yes, it is planned at the beginning of each financial year, reviewed regularly and documented for audit purposes b) Yes, it is planned at the beginning of each year and reviewed at the end. c) It is planned each year, but rarely followed. d) Training tends to be requested on an ad-hoc basis

.

The style of question in Table 5.4 with the associated answer structure was a common theme throughout this version of the tool. Although it was recognised that further work was required to ensure the tool was a useful item within the automotive supply chain.

Once more, this field test took place as a semi-structured interview. The interviewee was an experienced Quality Engineer (QE) with a Tier one supplier. This participant was selected as the tool had begun to resemble a series of questions which tested gaps in maintenance practice with the respondent. This was as opposed to attempting to review the entire spectrum of maintenance activities. A series of questions were asked of QE relating to the version of the tool seen in Appendix 5. These questions included wording, style of question and scoring method. The experience of QE within Quality management and automotive manufacturing was particularly useful to the development of the tool. The feedback provided by QE was based upon personal and professional experience when executing or engaging with automotive quality audits in the supply chain.

The field test was based upon the format of the tool, as opposed to the evidence collated to that point. The currency and validity of the evidence had been evaluated through the rigorous methodology of the investigation, as well as Field Test 1. As a result, the feedback was not collated and aligned with the categories identified in Table 5.1, 5.2 and 5.3. A summary of the discussion may be found in Appendix 6 and key points are identified in Table 5.5.

Table 5.5 A summary of feedback from Field Test 2.

Tool Category	Feedback
General Comments	• Questions are relevant and good areas to evaluate. • In automotive industry everyone has a target and kpi, so a scored gap analysis would mirror that. • Audits are poor if they hide what is being looked for. Audits are looking for evidence of conformance. • Person carrying out audit is someone who is not necessarily a quality person. • Audit as word is intimidating.
Report format	• Each section could have a minimum required score. • Gap analysis is more sellable as a useful tool. A state of the nation tool, which provides outputs. • Number of questions for tool is absolutely fine. Not about how many questions. It is more are all the questions relevant?
Wording of questions	• The tool appears as an audit presented in the form of survey. Providing options and allowing opinion. • Remove option for opinions on a question. • Reword questions with 'what am I trying to find out' in mind. What is the answer telling me?
Scoring	• Scoring method required. Removes opinions and makes it a score. Then can apply targets. • Evaluator should decide what the score or answer is to the question based on the evidence provided. • Evidence for scoring is crucial. • Audit tends to be open ended, informal and based on discussions with several key members of staff. Questions asked are open ended. Results of discussion leads to the auditor completing the scoring for each question or category.

Field test two provided constructive feedback in two main areas, which supported the final stages of tool development. Firstly, a change to the tone of the 'question' was required. As indicated in Table 5.4, the question allowed the respondent to return an answer of yes or no, as opposed to a more revealing answer prompting discussion and the opportunity for further detail. As can be seen in Table 5.4, the style of question had to change to be able to identify from any response, if the respondent had evidence proving the business engaged with an activity or characteristic. An example of this transition can be seen below:

The original question: *Are the training needs of the maintenance department identified?*

This was altered to: *How is a maintenance training requirement normally identified?*

The change in clearly minimal but requests a different answer from the respondent. The question also drives at how any training requirement is identified and what method is used.

The second main area to emerge from Field test 2 is the use of scoring for each point of investigation. Clearly, this system allows benchmarking and provides a platform for improvement. Moreover, as identified in Table 5.5, operating with metrics within the automotive industry is widespread and common (Wireman, 2004, 2010; Kelly, 2012). Decisively, a scoring system provides a clear and transparent system to improve from poor maintenance practice to good maintenance practice. Reflecting on the work of both (Hayes, R and Wheelwright, 1984) and (Pintelon, Pinjala and Vereecke, 2006), the use of four ascending categories to characterise maintenance performance was acknowledged as being suitable. Within the tool, the four stages will be represented by four characterisations of specific maintenance practice. Starting with an example of good practice and ending with an example of poor practice.

Finally, the experience of QE emerged when discussing the name of the tool under review. Audits are used in the automotive industry, yet that name may provoke a negative perception of the activity. Subsequently, the researcher titled this tool as a Maintenance Gap Analysis Tool.

5.5. Summary of Tool Development

The additional field-testing was invaluable to this research. Field test one acknowledged the findings from the case study data as being genuine maintenance constraints in a manufacturing environment. The external validity of the findings from the automotive supply chain have been improved by reviewing the key constraints with a manufacturing operator outside the automotive environment (Colin Robson, 2002; Gray, 2017). Furthermore, this stage of testing supplemented case study findings with additional, useful feedback.

Field test two provided a useful insight into the tone and content of version 5 of the Gap Test tool. Moreover, the introduction of a scoring system linked to appropriate evidence, offers an improvement the tool. Importantly, the Gap Analysis Tool will deploy techniques which are widely used within the automotive supply chain. This includes industry standards such as IATF 16949 which was developed as a quality management system for automotive manufacturing. This is now an ISO recognised standard and being certified is an expectation in the automotive manufacturing industry. The standard is managed through an audit based approach (Yeh, Pai and Huang, 2013)

Finally, the prototype was tested with Plant 1, Plant 3 and Plant 4. The prototype can be seen in Appendix 7.1. The results and discussion of these tests can be seen in Chapter Six.

6. Gap Tool Testing

6.1. Introduction

Chapter Five reviewed the development of the maintenance Gap Analysis Tool. The development, through two field tests, was incorporated into a prototype Gap Analysis Tool which can be seen in Appendix 7.1. This prototype was subsequently tested in Plant 1, Plant 3 and Plant 4. This Chapter will present the findings of the three tests, as well as a discussion of the results.

The Gap Analysis tool, once analysed, provides a significant amount of information on the status of the tested maintenance function. Results from each test have been presented and summarised in a diagrammatic manner. The diagrams are in two forms; A radar diagram and a characteristic score diagram. The radar diagram provides an overview of maintenance performance as a result of the test. Following this, the characteristic score diagram provides specific detail on performance in tested areas. Figure 6.1 summarises this information.

Name	Gap Analysis Tool
Purpose	Scored audit questions with examples of judgment criteria
Application	Conduct Gap Analysis Test for maintenance practice.
User Group	Auditor; Maintenance & Senior Management Team

Name	Radar Diagram
Purpose	Communicate an overview of Gap Test results
Application	Visually present results for each category within the maintenance department.
User Group	Senior Management; Maintenance management team.

Name	Characteristic score diagram
Purpose	Provide individual maintenance characteristic scores from the Gap Test.
Application	Allows specific targeted approach to improving maintenance practice.
User Group	Senior Management; Maintenance management team.

Figure 6.1 Summary of test result applications

6.2. Executing the Gap Analysis Test.

The process for completing the Gap Analysis with an Industry participant is shown in Figure 6.2.

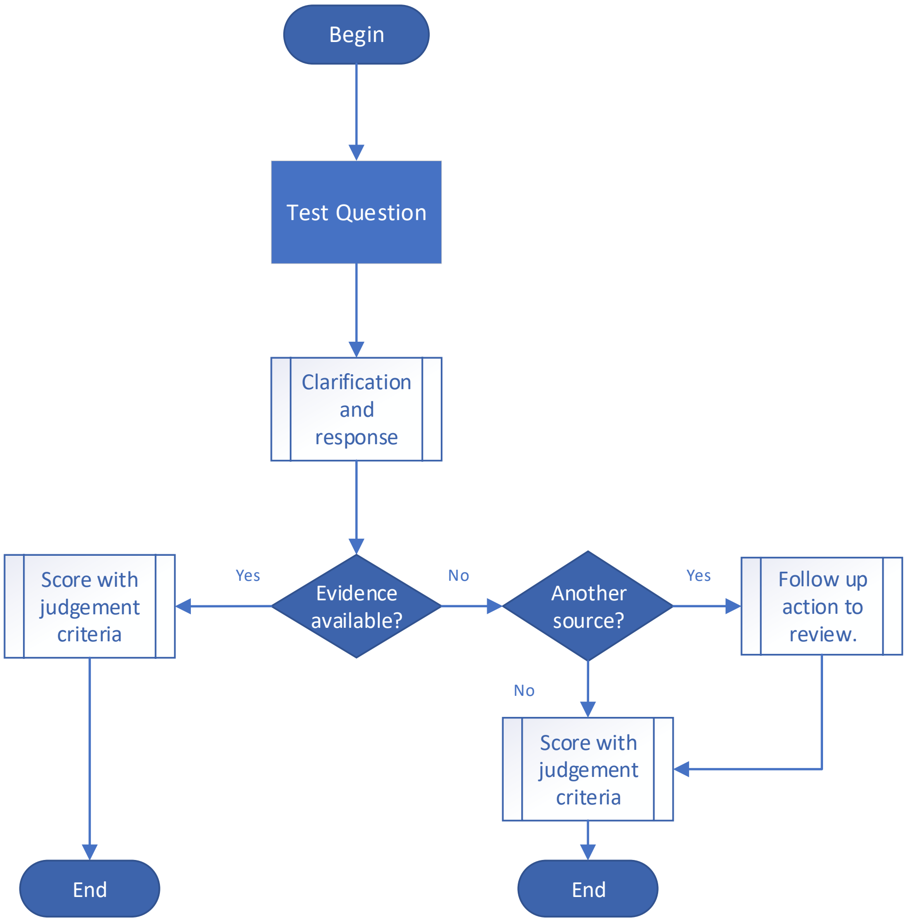

Figure 6.2 A flowchart representing the process for using the Gap Analysis Tool.

To assist in understanding the flowchart, an excerpt from the tool including the evaluation has been included in Table 6.1. This is taken from Plant 3 and is a question within the 'Skills and Training' category.

Table 6.1 An excerpt from the Gap Analysis test taken from Plant 3.

Category	Question	Criteria/Evidence	Judgement	Score	Notes
Skills and Training	Is there a training plan for the department?	Training records Maintenance skills gap analysis Training plan records	a) Yes, it is planned at the beginning of each financial year, reviewed regularly and documented for audit purposes b) Yes, it is planned at the beginning of each year and reviewed at the end with no follow up plan. c) It is planned each year, but rarely followed. d) Training tends to be requested on an ad-hoc basis	a) – 4 b) – 3 c) – 2 d) – 1	No plan in place. Little training previously taken place. Currently under review.

As can be noted from Table 6.1 the question regarding a training plan has been scored as 1. The notes column reflects detail taken at the point of the test and is based upon the conversation which took place. Included within Table 6.1 is also a list of possible evidence which may be included as a guide. Furthermore, the judgement criteria are not explicit and are solely there to act as a guide for any subsequent judgement. As may be seen, the criteria reflect the sliding scale of the score.

Figure 6.2 demonstrates the process of conducting the Gap Analysis Test is relatively straightforward. The questioning is completed with a nominated maintenance expert employed by the plant. The nominee must be able to:

a) Understand the terms used within the question
b) Identify the appropriate evidence which would support the response.
c) Demonstrate enough experience to be able to appreciate the current performance of the maintenance function.

6.3. Gap Analysis Test results

This section will provide an example of results from the testing process. This provides an indication of the feedback presented to the individual plant. In addition, the charts and diagrams provide summary results and individual detail. To be concise, the full set of results across all three plants are contained within Appendix 7.1;7.2 and 7.3.

A sample of a question which has been answered using the tool is shown in Table 6.2. This excerpt is taken from the 'Integration' section and summarises the question, subsequent discussion and eventual scored outcome for a point of investigation. The 'Judgement'; 'Score' and 'Notes' section have been annotated to reflect the discussion which took place.

In a small proportion of responses, the judgement criteria would not directly match the answer and evidence provided. This was expected and any subsequent scoring was completed based on a comparative characteristic to the response provided. Table 6.2 also includes the average for that category. It is this average which informs the radar diagram shown in Figure 6.3. This radar diagram is representative of each category score and reflects Gap Analysis results for the maintenance department. Finally, where two questions which inform one characteristic are scored differently, the total is based upon the average of those scores. Where this is not a whole number, the lower number is used. This is to assist with the tool being used to drive improvement wherever possible.

Table 6.2 An excerpt from the Gap Analysis tool following the test at Plant 3.

Category	Question	Criteria/Evidence	Judgement	Score	Notes
Integration	How is the impact of the maintenance schedule discussed with other departments?	Meeting minutes Email traffic Process documents for schedule generation	The schedule is communicated electronically and discussed at daily meetings. The schedule and plans are discussed at most meetings The schedule and plans are discussed informally. No discussion takes place	– 4 – 3 – 2 – 1	Only plans discussed are PM's…discussed informally with production coordinator.
	Is the location of the maintenance workshop suitable for access and contact?	Manufacturing floor plan	Workshop is in an ideal and accessible area, for immediate contact. Workshop is in an area poor for contact, requires improvement. Workshop requires major improvement for accessibility. Workshop is inaccessible and contact is difficult.	– 4 – 3 – 2 – 1	Located in between press shop and fab shop.
	Does the workshop reflect the operational standards set by the surrounding work areas?	Standard operation procedures for workplace maintenance Conformity documentation	Work area is maintained to outstanding standards. Regular inspections are held and documented for adherence to 5S standards. Work area maintained and inspected at the end of each shift. No standards for efficiency or inspection used. Work area can remain untidy throughout the working day, but is cleaned during quiet periods. Work area goes for long periods in an untidy state.	– 4 – 3 – 2 – 1	Verbally, says YES, but only weekly audit carried out.
	How would you describe the way in which the performance of maintenance is communicated?	Visual inspection Communication records	Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are live. Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are updated regularly. Primary goals and metrics are displayed to relevant staff. Primary goals and metrics are reported to senior managers upon request.	– 4 – 3 – 2 – 1	Targets and metrics displayed in Simon's office only. Not outwardly produced or shown. No briefing of maintenance improvements to any staff. Action point!
Average score				2.25	

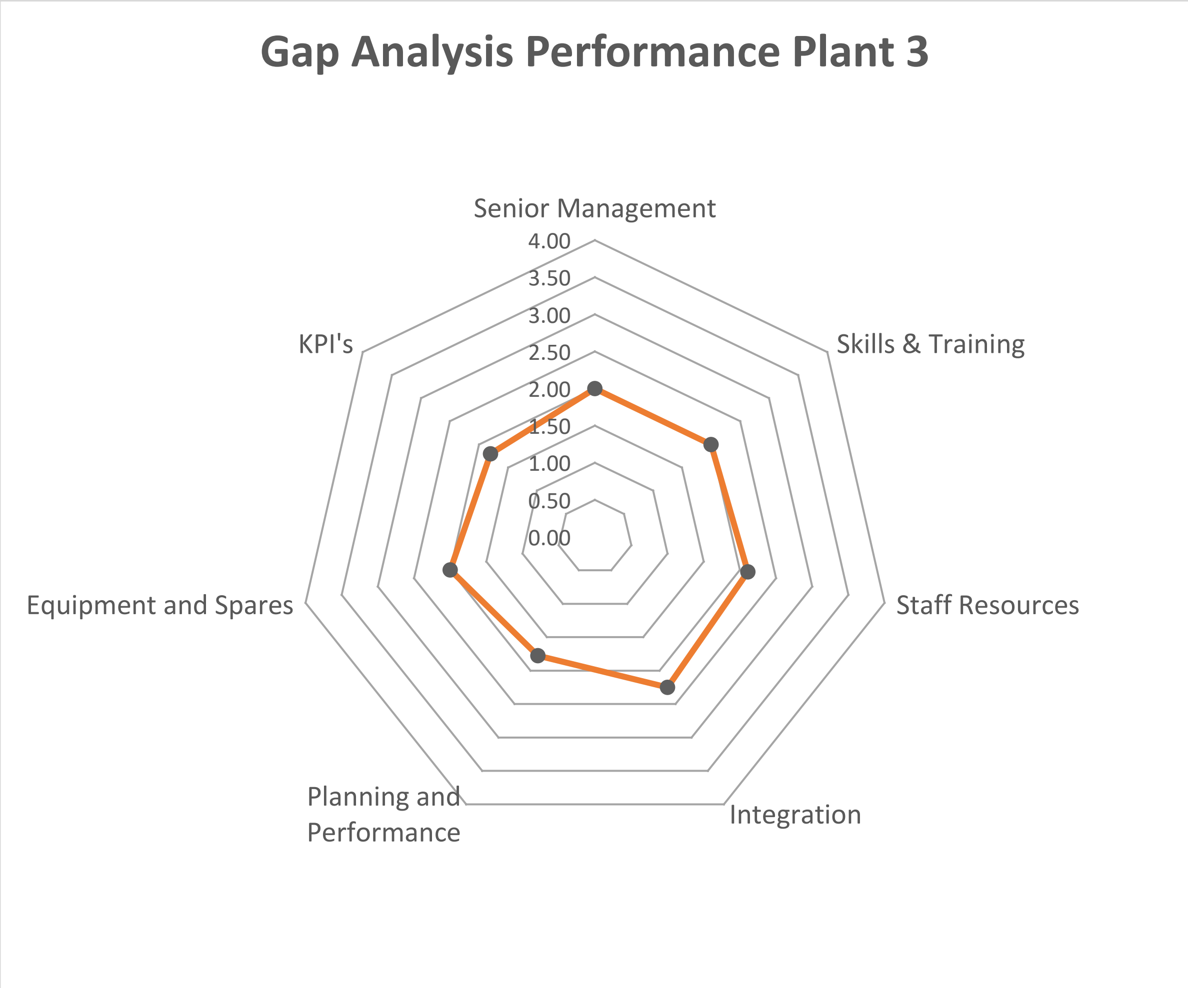

Figure 6.3 A radar diagram representing the category scores for Plant 3.

Finally, where there are scores which demonstrate gaps in maintenance practice – further information would clearly be beneficial. Therefore, the detail which informs the score becomes crucial to offering a route to improvement. Moreover, areas of good practice would be more clearly signposted. Figure 6.4 collates this detail into a colour coded characteristic score diagram, representing Gap Analysis results for the case study partner.

Section 6.2.1 discusses the results from each category within the Gap Analysis Test for Plant 3. Due to the volume of test points, the discussion will centre upon key areas within each category. Result and summary diagrams for Plant 1 and Plant 4 can be seen in Section 6.2.2 and Section 6.2.3 respectively. Section 6.3 will provide a summary reflection on all three tests, with Section 6.3.1 reflecting upon the operational issues experienced when deploying the test.

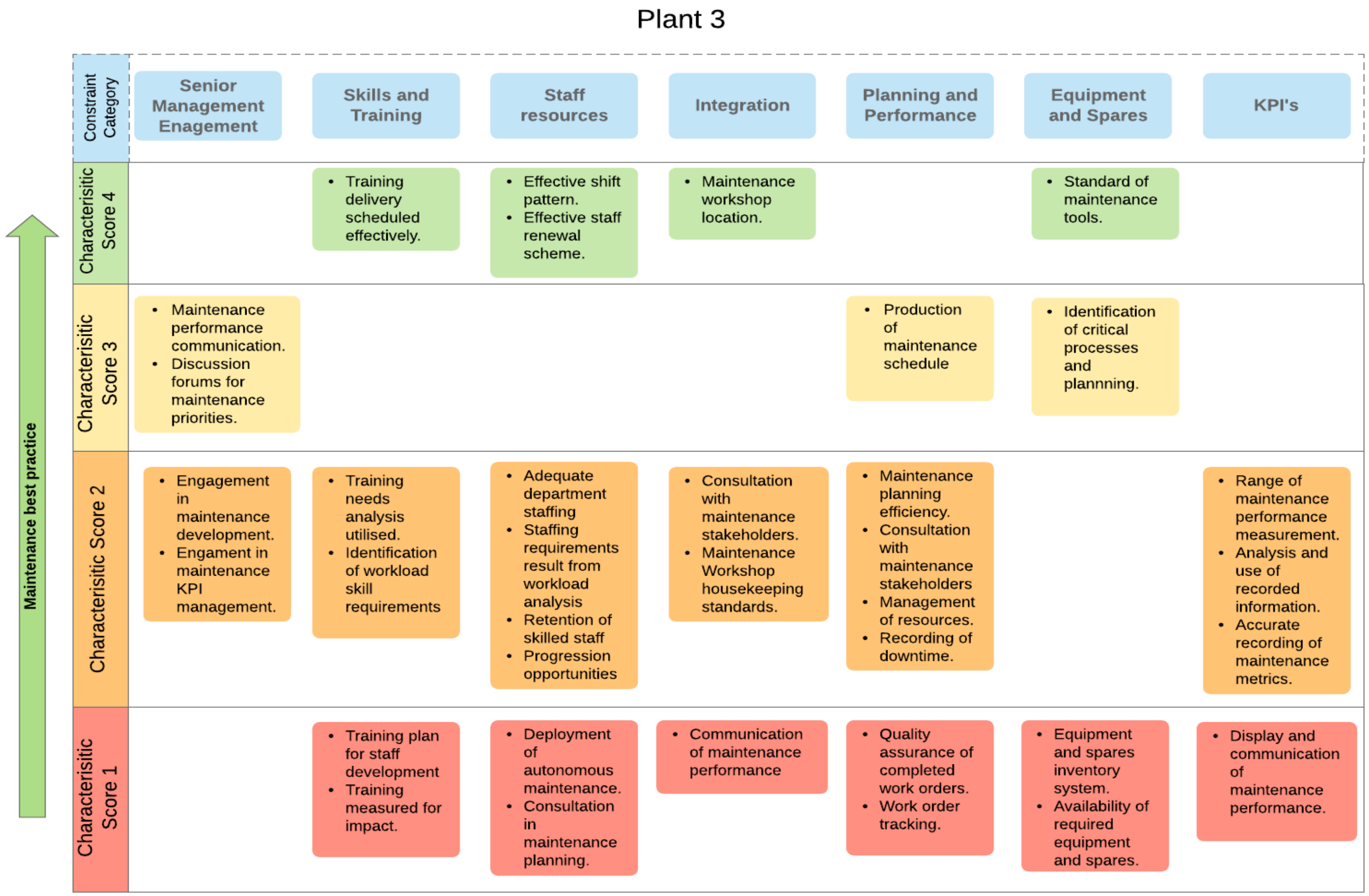

Figure 6.4 A characteristic score diagram representing Gap Analysis results for Plant 3

6.3.1. Plant 3 Results

Case study feedback from Plant 3 indicated the site was experiencing continued issues within the business. These issues included a difficult manufacturing environment, with continued financial constraint. Additionally, the maintenance function was operating in a reactive manner, with ageing, unreliable machinery. This resulted in repeated breakdowns and difficulty with spare part management. As a result, the development of the maintenance function as well as the performance of the department appeared to be an issue within the business.

6.3.1.1. Senior Management Engagement

Reference to Figure 6.5 will provide an indication of the performance of the business within this category. Discussion will be based upon the category score.

Score	Characteristic
3	• Maintenance performance communication.
	• Discussion forums for maintenance priorities

The communication of maintenance performance with the Senior Management team was given on a weekly basis. In addition, the structure of production meetings encouraged identification and discussion, of maintenance priorities daily. At a superficial level this appeared encouraging, as consideration of maintenance tasks by the Senior Management team is clearly needed for the department to be able to operate and develop. Furthermore, the regular discussion of maintenance priorities within production meetings demonstrates the value placed upon maintenance priorities by the manufacturing unit.

Score	Characteristic
2	• Engagement in maintenance development.
	• Engagement in maintenance KPI management.

The engagement by Senior Managers in the development of the maintenance function requires some improvement. The test indicates any senior management interaction is passive and inconsistent. This was based upon feedback by the nominated expert, who identified that future developments for maintenance tended to be at middle management level. Importantly, these were focussed upon operational tasks, as opposed to strategy improvement plans. Furthermore, the extent of Senior Management interest in performance was evident through the weekly communication briefing. The extent of the interest was of concern, with the report being informed by break down rate and completion rate for preventative maintenance activities. This is a narrow view of maintenance performance information and metric information is limited.

6.3.1.2. Skills and Training

Score	Characteristic
4	• Training delivery scheduled effectively

The delivery of scheduled training was identified as being effective and delivered as planned. The perspective of this inquiry is to review the ability of a department to coordinate workloads to allow the delivery of staff training. The inability to deliver this may lead to a concern with planning or department workload. Whilst this evidence was encouraging, subsequent testing revealed some worrying issues.

Score	Characteristic
2	• Identification of workload skill requirements.
	• Training Needs Analysis utilised.

Testing revealed a distinct gap between the skills and experience of the maintenance technicians and the skills required to address the maintenance workload. No examination or analysis was completed by Plant 3 to assure the department they had staff with the required skill set to address current or future tasks. Recruitment was completed by continuing the historical ratio of Mechanical or Electrical maintenance technicians. This led to a vulnerability in technicians being incapable of completing work orders. Furthermore, little was done in the way of a skill assessment of staff. This was completed on an annual basis through a staff appraisal system. This system provided the opportunity for staff to submit requests for training. This is of merit, but clearly the desire for specific training may not be linked to a clear department need.

Score	Characteristic
1	• Training measured for impact.

The results showed a requirement for improvement was recognised when reviewing the justification of training requirements. There was no evidence or system in place to understand the impact or benefit staff training had with the department or the wider business. This may not seem overly unusual, yet it is an additional gap in a category which is clearly underdeveloped for the function.

6.3.1.3. Staff resources

Score	Characteristic
4	• Effective shift pattern
	• Effective staff renewal scheme

Plant 3 engaged with a shift pattern which reflected the working schedule of the production facility. A separate area of good practice within this category emerged through examining the renewal of skilled technicians. In an industrial environment where staff recruitment was challenging, the continued use of an apprenticeship scheme with the subsequent employment of qualified apprentices, is of merit.

Score	Characteristic
2	• Adequate department staffing.
	• Staffing requirements result from workload analysis.
	• Retention of skilled staff.
	• Progression opportunities.

The scoring of these characteristics demonstrates the amount of development work required to improve the maintenance function in this area. Due to a lack of workload analysis, it was difficult to demonstrate the adequacy of staffing. Evidence of inadequate staffing did emerge in a specific area of maintenance – production tooling. This was due to a deficiency of staff availability for specific shifts. This was evidenced through the late completion of tasks specific to that type of work order. To compound this, the apparent requirement for additional staff was based solely on the experience of the nominated expert and historical staffing levels - as opposed to a workload analysis. What emerged was a lack of any detailed information recording system which could inform analysis and staff planning.

Finally, the ability of a business to retain staff can be linked to several key enablers. These enablers include career progression opportunities (Campbell and Reyes-Picknell, 2015). The appraisal system for Plant 3 did not include any aspect of structured career development. As a result, this gained a low score.

Score	Characteristic
1	• Deployment of autonomous maintenance.
	• Consultation in maintenance planning.

A requirement for improvement was once more evident within Plant 3, in two specific areas. The first was the deployment of autonomous maintenance. This is aimed at measuring and justifying the use of production operators to complete low level maintenance tasks. This test point is used to examine if autonomous maintenance demonstrably increases the capacity of the department. The score of 1 was awarded due to the complete absence of any operator/autonomous maintenance activity. The second area achieving this score was ‘engagement and consultation with maintenance technicians for planning or scheduling of tasks’. The benefits of engaging with staff are known to increase team identity, which in turn will increase staff performance (Tsang, 2002; Smith, 2003; Lloyd, 2010; Campbell and Reyes-Picknell, 2015). Moreover, utilising the knowledge base of technical staff and adapting plans accordingly would help develop the static and repetitive plans which are in place at Plant 3. The Gap analysis Test revealed this was not considered at all by the department.

6.3.1.4. Integration.

The category of Integration is responsible for examining the working relationship between the maintenance function and other, stakeholder departments.

Score	Characteristic
4	• Maintenance workshop location

The accessibility of the workshop is important as it may directly influence the level of engagement with external stakeholders (Tsang, 2002; Campbell and Reyes-Picknell, 2015; Shanmugam and Paul Robert, 2015; Schein and Schein, 2017)**.** The maintenance workshop was centrally located, and this was observed during a tour of the maintenance and manufacturing facility. As a result, the accessibility of the maintenance function by operational stakeholders could be achieved quickly. Furthermore, the activities of maintenance staff were clear and observable. This promoted the opportunity for cooperating staff to sympathise with maintenance working practices (Brown, 1998; Keyton, 2010) – an area identified in Section 4.5.4 as providing barriers to maintenance practice.

Score	Characteristic
2	• Consultation with maintenance stakeholders
	• Maintenance workshop housekeeping standards.

'Integration' provided several action points which required improvement. The discussion of maintenance priorities with partner departments was identified as being valuable during interviews at both Plant 2 and Plant 3. The value was recognised as promoting understanding and cooperation with the production unit. Yet, the Gap Analysis revealed the maintenance work schedule and subsequent priorities were only discussed informally with the production coordinator. As a result, this narrow and localised communication reduced the opportunity for maintenance priorities to be discussed on a more extensive and recognised basis.

Although the maintenance workshop was in a primary location, the operational standards observed during use were of concern. Whilst the production area surrounding the maintenance workshop were operating to a 5S standard, the maintenance work area was adhering to no housekeeping standard or system. As a result, there were no records available to reflect any audit on housekeeping within the department – unlike the production area. Moreover, any review of the appearance of the workshop was completed simply by inspection on a weekly basis. The impact of these differing working practices across two co-dependent departments is recognised as being a demonstrable inhibitor to the perception of maintenance within a business. This is recognised by Campbell and Reyes-Picknell, (2015) as well as through rich data gained from Plant 2.

Score	Characteristic
1	• Communication of maintenance performance.

The inconsistent tracking of maintenance performance as well as the complete lack of any outward display of performance statistics, led to an identification of poor practice. This feature, as well as the poor housekeeping standards of the workshop, provided artefacts which demonstrate the beliefs and values of the department. These artefacts contrast with those of cooperating departments, who displayed clear housekeeping standards as well as well communicated performance statistics. These differing artefacts allude to the maintenance function placing little value on maintenance performance and external communication (Dixon et al 2019, Brown, 1998; Kumar *et al.*, 2013; Schein and Schein, 2017). Observation of the workshop revealed the performance information was displayed, on a wall in the maintenance supervisor's office. Further investigation revealed the displayed information was inaccurate and obsolete.

6.3.1.5. Planning and performance.

Score	Characteristic
3	• Production of the maintenance schedule.

The importance of the organised planning of maintenance activities is discussed by Wireman, (2010); Campbell and Reyes-Picknell, (2015) and Plant 3 demonstrated aspects of good practice. The maintenance work order schedule was generated by the Maintenance Supervisor, who demonstrated previous experience and knowledge in producing an efficient schedule. The effect of this was limited, due to the schedule being restricted solely to preventative tasks. These tasks were identified in section 4.3.6 as being visual without any physical interaction. Conclusively, the positive impact of scheduled preventative work was difficult to establish.

Score	Characteristic
2	• Maintenance planning efficiency
	• Consultation with maintenance stakeholders
	• Management of resources
	• Recording of downtime

As a result of the Gap Analysis Test, maintenance characteristics emerged which required strategic action by the business. The efficiency of the planning system as well as the management of the required resources was identified as requiring improvement. The detail of the maintenance planning process only included the allocation of time towards the completion of a task. Tools and equipment were not part of this plan. Moreover, it was identified that the recording of time to complete any task was a manual process. Conclusively, there was little evidence presented to substantiate responses in this category.

The communication of planned maintenance activities with the affected production area was only completed in an informal manner – if the opportunity arose. Clearly, this lack of communication has the potential to create misunderstanding between these two areas of manufacturing.

Score	Characteristic
1	• Quality assurance of completed work orders
	• Work order tracking

Reviewing the quality assurance process of the department led to a score of one being awarded. This aspect of the review focussed upon the quality and suitability of completed work orders by the maintenance function. Wireman, (2010); Campbell and Reyes-Picknell, (2015) recognised the importance of this feature as part of maintenance performance management. Plant 3 completed no formal or informal work order review once any task was complete. Furthermore, there was no recording system for the type of maintenance task within the work order process. This included any reactive or urgent tasks. As a result, Plant 3 had an inability to monitor, assess and plan their resources for any future development.

6.3.1.6. Equipment and Spares.

Equipment and Spares contained good and poor practice and this section reviews the state of maintenance tools, the spare part system and critical process identification.

Score	Characteristic
4	• Standard of maintenance tools.

The importance of maintenance tools and equipment is recognised by Wireman, (2010); Campbell and Reyes-Picknell, (2015) as directly affecting both performance and morale. The good practice identified within the Gap Analysis test emerged from verbal feedback from the nominated expert. The recording system which would substantiate this was non-existent. The answer was taken at face value based upon the nominated expert being an experienced maintenance practitioner and discussing maintenance tools as being available when required and of good standard.

Score	Characteristic
3	• Identification of critical processes and planning

Critical process identification and emergency planning was investigated and it was clear from the document produced, that critical analysis of each process was in evidence. Furthermore, an insurance plan was part of this activity. It was recognised that this was ongoing and required regular review.

Score	Characteristic
1	• Equipment and spares inventory system
	• Availability of required equipment and spares.

Evaluation of these characteristics resulted in a particularly low score. Although this category revealed critical processes had been identified, the availability of the subsequent critical parts was not satisfactory, with key parts unavailable. The nominated expert revealed the maintenance function was unsure as to what spare parts were held on site at any one time. This was directly linked to the complete absence of any inventory system for spare parts and consumables. When probed further, it was revealed that there was no store person in place or any substantial system for recording items which were removed from the stores. Consequently, the timely reordering of any spare parts was ineffective.

6.3.1.7. Key Performance Indicators

Score	Characteristic
2	• Range of maintenance performance measurement
	• Analysis of recorded information
	• Accurate recording of maintenance metrics

Maintenance performance management in Plant 3 revealed some fundamental issues in the method of recording and use of maintenance information. The range of metrics used by the department was extremely limited and consisted of budget efficiency and the percentage completion of preventative maintenance tasks. Other metrics, such as break down rate were held by the production facility and were not freely available to the maintenance function. As a result, the analysis of any maintenance related information was superficial. Due to the limited nature of the maintenance related information, analysis was only completed on preventative task completion. Recording was completed manually and in isolation by both the production and maintenance function. Whilst this is fundamentally flawed, the willingness of both departments to record and compare the data for accuracy is of a small degree of merit.

Score	Characteristic
1	• Display and communication of maintenance metrics

Further poor practice was recognised for the display of maintenance performance information. Despite the limited nature of maintenance indicators, Schein and Schein,

(2017) recognised the importance of displaying targets and performance to other employees. This promotes transparency and understanding of the function. Observation of the work area revealed performance graphs did exist but were located with the office of the maintenance engineer. Furthermore, the detail on the graph was out of date. As a result, the display was obsolete.

6.3.2. Plant 1 Results

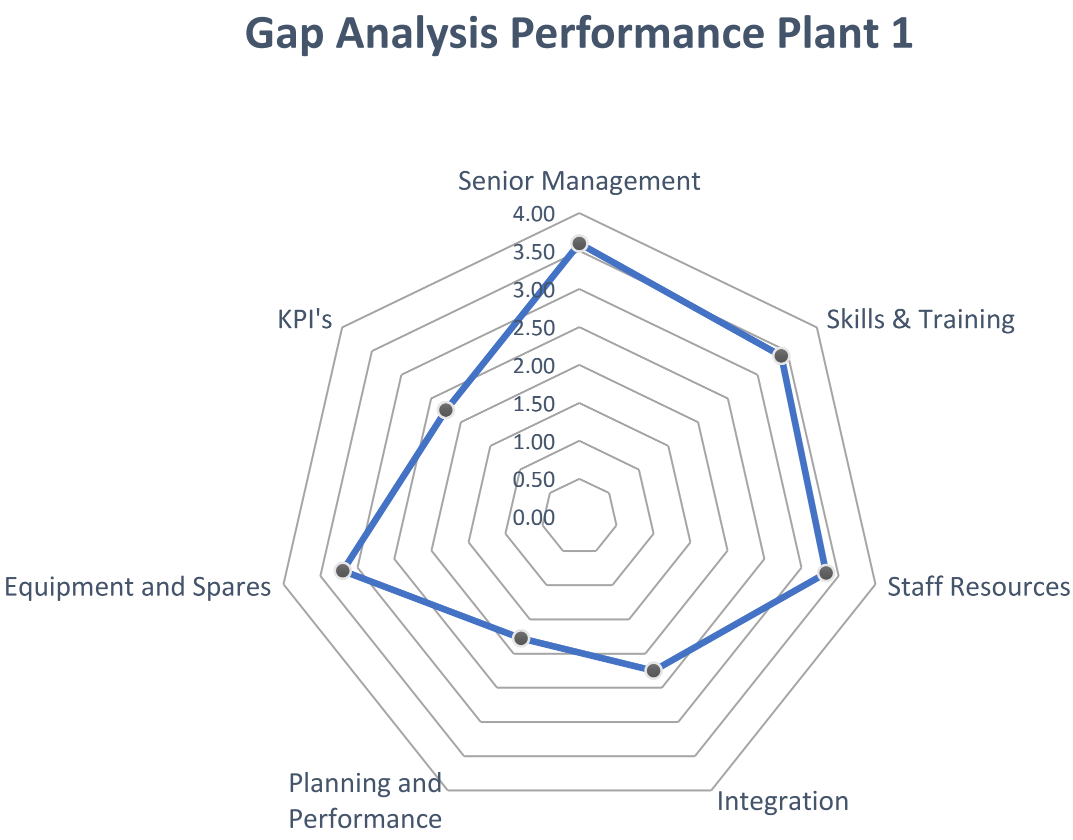

Figure 6.5 A radar diagram representing the category scores for Plant 1.

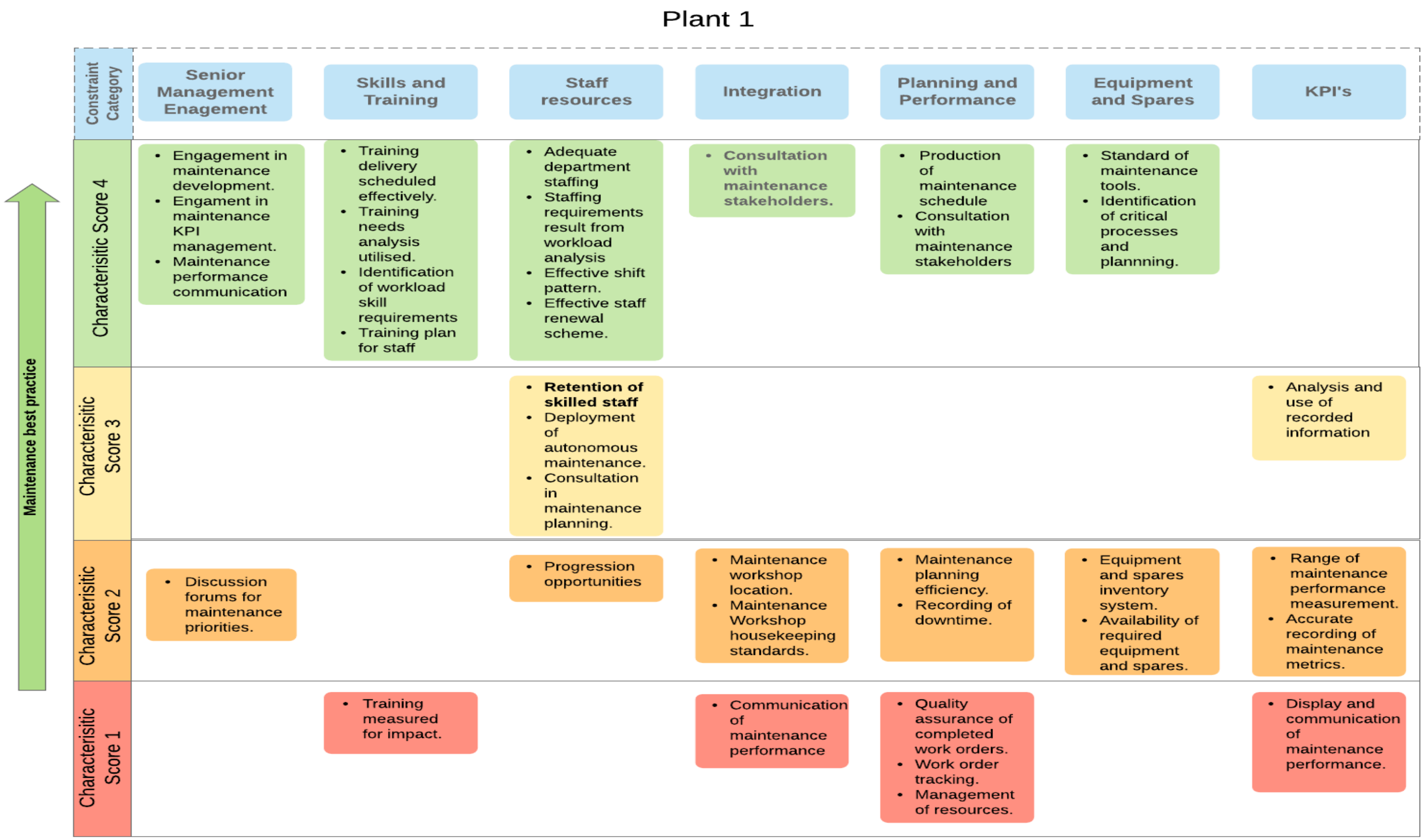

Figure 6.6 A characteristic score diagram representing Gap Analysis results for Plant 1

6.3.3. Plant 4 Results

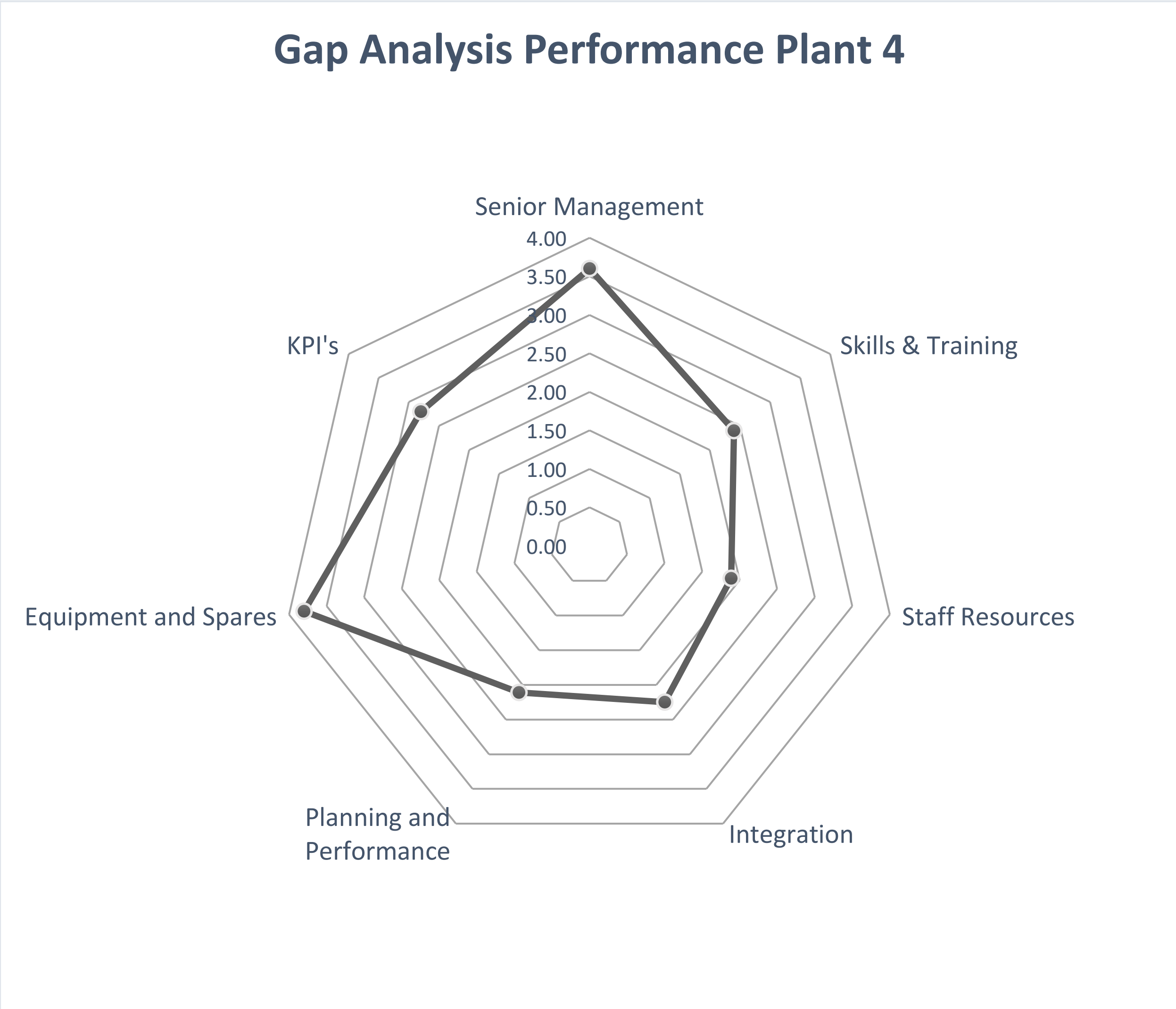

Figure 6.7 A radar diagram representing the category scores for Plant 4

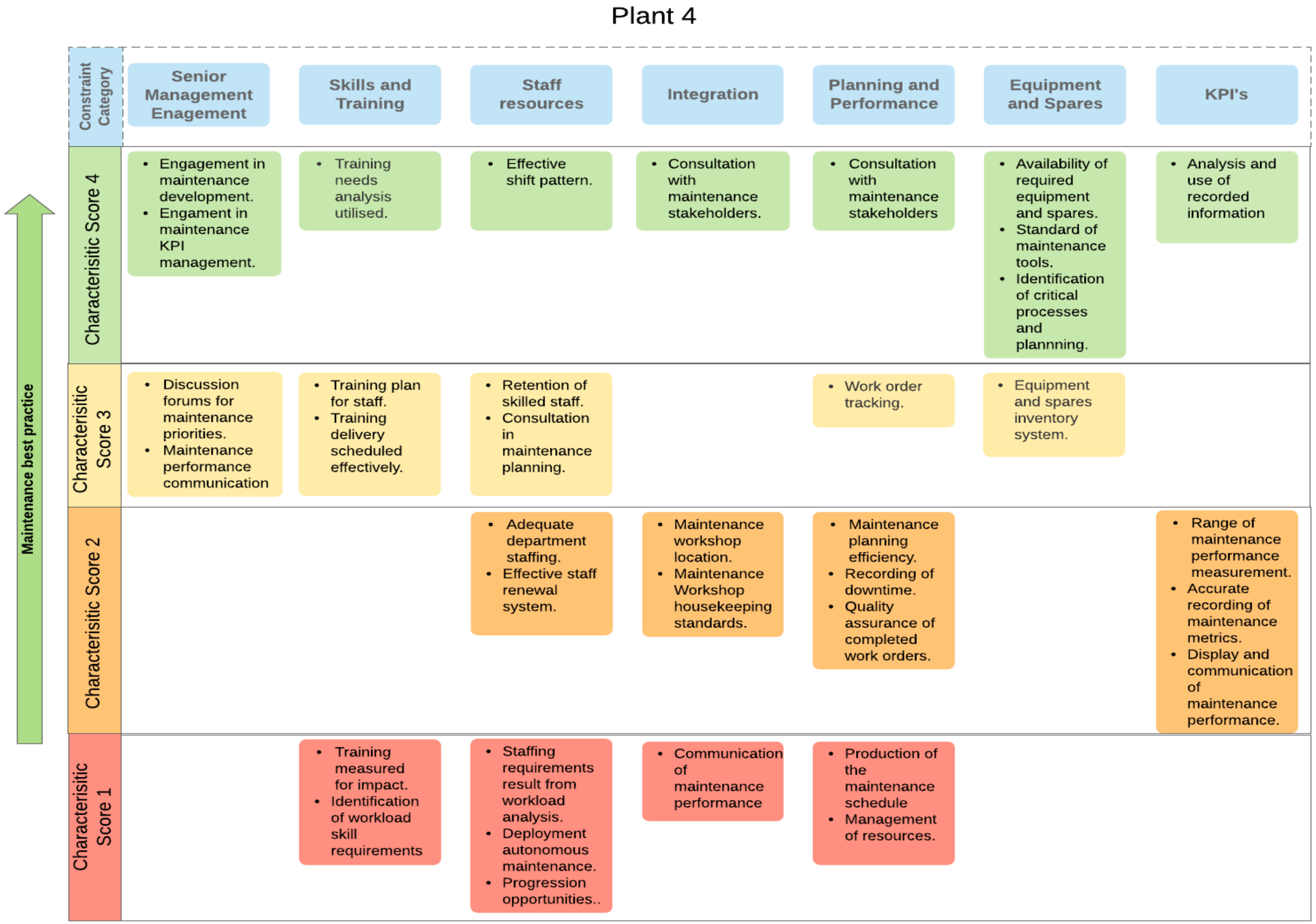

Figure 6.8 A characteristic score diagram representing Gap Analysis results for Plant 4.

6.3.4. A comparative view of collective Plant results.

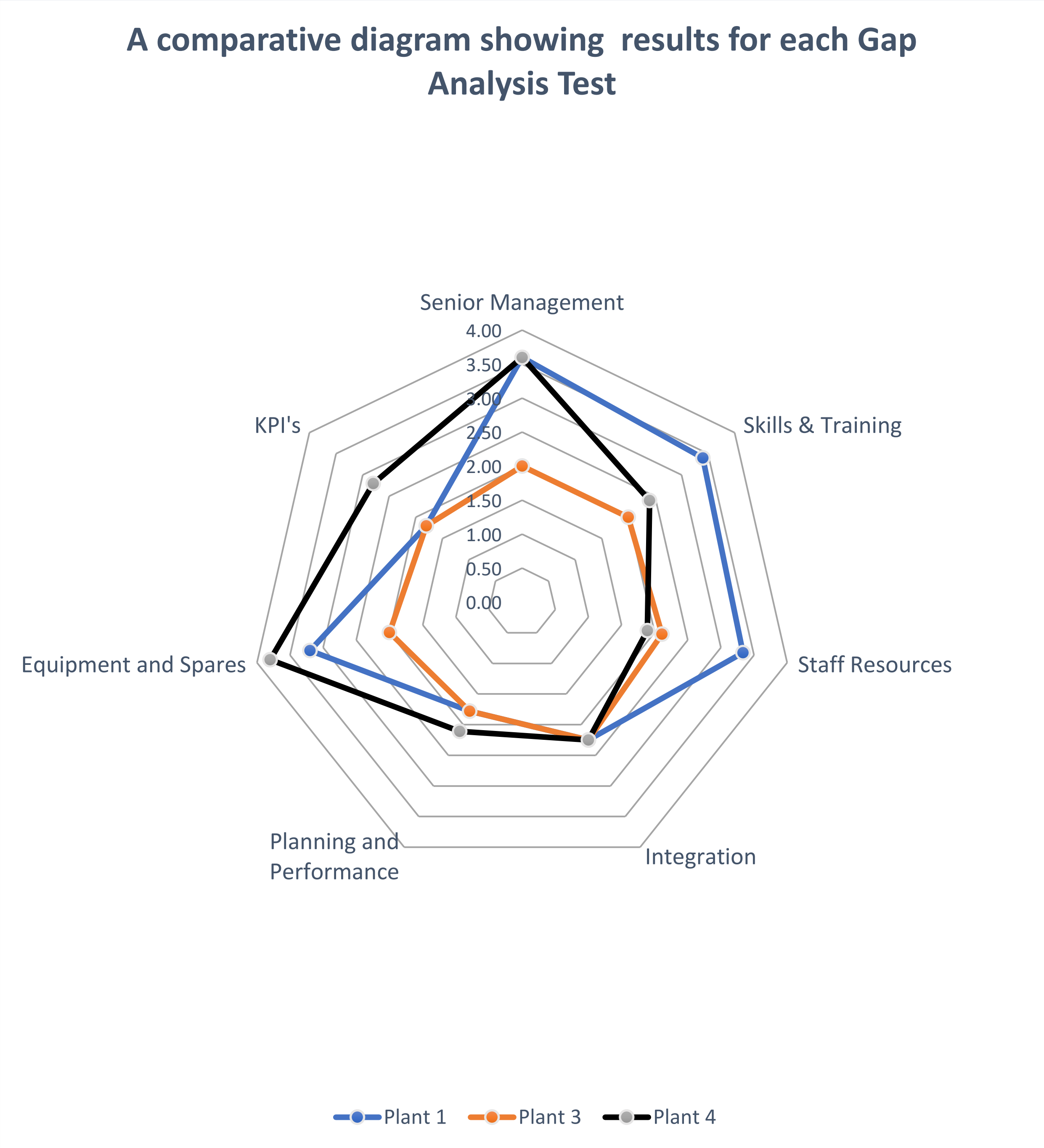

Figure 6.9 A comparative diagram representing Gap Analysis Test results.

Table 6.3 A quantitative overview, presenting the average score in each category

Category	Average score		
	Plant 1	Plant 3	Plant 4
Senior Management	3.60	2.00	3.60
Skills & Training	3.40	2.00	2.40
Staff Resources	3.33	2.11	1.89
Integration	2.25	2.25	2.25
Planning and Performance	1.78	1.78	2.11
Equipment and Spares	3.20	2.00	3.80
KPI's	1.80	1.80	2.80

6.3.5. Operational use of the Gap Analysis Tool

These findings have been collated as a direct result of field testing the Gap Analysis Tool. This testing process has been beneficial as it will provide a response to the research question. Furthermore, the testing process has provided the opportunity to understand the tool from an operational perspective. Based upon all three field tests it is appropriate to draw conclusions. This will help facilitate the usefulness of this tool in the future. Comments in Table 6.4 are aligned with the process flow chart for the Gap Analysis Test detailed in Figure 6.2.

Table 6.4 A summary of reflective comments based upon the deployment of the Gap Analysis Tool.

Stage No.	**Description**	**Operational Comments**
1	Commence Test	• The test must be carried out with an experienced maintenance operative. Employment experience within the test site is important as any response must be informed by existing evidence.
2	Test Question + Clarification	• The test question required clarification at times, due to the wording. This was deliberate to expose some further detail of maintenance practice. As a result, the practitioner carrying out the test should be familiar with the aims of each category and question.
3	Response	• The response of the nominated expert was often clear and could be scored easily. Several times the response had to be clarified for understanding by the administrator. As a result, prior knowledge and experience of maintenance practice is essential to expedite this test. • The requirement of evidence to validate a response must be a constant requirement for this test.
4	Evidence	• The evidence base for a response varied from test to test dependent upon the category. Clearly, due to the question some items were specific such as a display of data. Others, such as a training needs analysis came in different forms.
5	Scoring	• Grading criteria were sourced from literature and case study information. They were formed to reflect a sliding scale of good and bad practice for each question. As a result, the response may not align directly with the categories provided. Subsequently, a fair alignment and score must be given by the administrator. • Where two separate questions relate to one proposition, giving an average score which is not a whole number, the proposition is scored the lower whole number.

The need for an experienced respondent for the Gap Analysis test is clear. Plant 3 received a low score in aspects of ‘Planning and Performance’ as the respondent was new to the business and acknowledged doubt as to the existence of evidence. The administrator should also be familiar with the aims and objectives of the test. The feedback received in Section 5.3.2 describes the importance of the wording of any question, along with the prior knowledge of what information is the administrator requiring.

The need for evidence to inform a response is essential and would not be alien to personnel within the automotive supply chain. Rich data revealed the requirements of the local OEM included that any Tier One suppliers must meet the International Automotive Task Force (IATF) 16949 standard. This standard supersedes the more widely known TS 16949 standard which is commonly required within the automotive supply chain. IATF 16949 is a quality management requirement and is conducted as an evidence-based audit. As a result, the nominated expert of each Plant was comfortable with the Gap Analysis Test method of evidence-based scoring.

The scoring of each question and category is based upon the response, the evidence presented and alignment of that evidence with the scoring criteria of the tool. Clearly, it would be difficult to achieve criteria which matched the operating characteristics of each Plant. The criteria have been collated through previous research and are scored based upon the response and subsequent judgement of the administrator. As a result, judgement can be subjective. Therefore, it is crucial the administrator is both impartial and professional.

6.4. Discussion.

This section summarises the prominent characteristics which emerged from testing all three plants. Figure 6.9 provides a useful overview of Plant performance from all three tests.

6.4.1. Senior Management Engagement:

The importance of Senior Management engagement in maintenance development is well recognised throughout literary work, yet the depth of this engagement appears to be a more pressing issue. Gap Analysis scores from Plant 1 and Plant 4 were good but were unsatisfactory from Plant 3. A closer look at this category across each plant reveals that Plant 1 and Plant 4 displayed more strategic involvement in the development of the maintenance function. Indeed, Plant 1 had improved from an initial identification of low engagement at the data collection stage, to a situation where there was structured strategic development of maintenance within the business. Conversely, Plant 3 identified engagement from Senior Managers was more commonly at an operational level.

The translation from positive engagement into tangible outcomes for the department, was less apparent. Although clear strategic direction was provided by the Executive in Plant 1 and 4, this did not translate into improving maintenance development or performance in either plant. Consistent issues emerged around the business providing satisfactory infrastructure for the maintenance function to be able to develop and operate at an optimum level. Examples of this can be seen in categories including ‘Skills and training’, ‘Staff Resources’, ‘Planning and Performance’ and ‘KPI’s’. These examples have led to an infrastructure deficit for any advanced maintenance planning or recording of data.

6.4.2. Skills and Training

The identification of any training requirements for maintenance technicians revealed varying levels of practice. Plant 1 demonstrated a clear and structured methodology to address training needs, with an ‘I, L, U’ system to identify skill proficiency of staff. Moreover, the Root Cause Analysis (RCA) completed by the function on any major breakdown also informed the skill requirements of maintenance staff. This strategy was not executed by Plant 3 and Plant 4, thus reducing the effectiveness of any subsequent training. Plant 4 completed a training needs analysis process for staff – yet the needs were not based upon the business requirements and were centred upon generic characteristics. Moreover, there was no link between the training plan and what was required by the plant and maintenance workload. As a result, the effectiveness and benefit to the business was reduced. Plant 3 demonstrated inadequate performance with no training analysis completed or any process to support effective training management.

6.4.3. Staff resources

In general, each plant displayed a varying degree of satisfaction with staffing levels despite some complaints. Further investigation revealed issues at a more human level. Each individual Plant identified a lack of any structured career management for technician staff. This included restricted progression opportunities. Moreover, deficiencies became further apparent when examining the extent of staff resources for low level maintenance tasks. Plant 1 deployed a certain level of autonomous maintenance which was not in place at either Plant 3 or Plant 4. This helped Plant 1 provide additional resource to the maintenance function. In contrast, Plant 3 and Plant 4 indicated there was a complete absence of any organised autonomous maintenance by production staff. The conflicting opinion of Senior Managers when discussing a progressive maintenance strategy for Plant 3 had a long-term effect on the maintenance department. Section 4.4 describes the complete opposition from the Operations Director to the use of production operators for any autonomous maintenance tasks. This conflict remained when the Gap Analysis test was conducted – with no additional resource provided available for low level maintenance tasks. The lack of autonomous maintenance continued to be noted in Plant 4. This was disconcerting, as a strategic directive for the maintenance function was the implementation of TPM for the site. This polarisation between high expectations and ineffective resourcing, had a detrimental effect on the ability of maintenance to move forward as well as the morale of the department.

6.4.4. Perception and Integration

Evidence of differing working practices leading to operational friction, emerged through investigating the display and communication of department performance. The communication of maintenance performance could be characterised by information display charts either being out of date or simply not used at all. Furthermore, this was in direct conflict with how the manufacturing function managed their performance display area. Within the production facility, performance charts were up to date and available for all staff to engage with. This difference is a tangible disparity between the production and maintenance department. The regular displays in production versus the irregular or missing displays in maintenance is an artefact of this disparity (Kumar et al., 2013; Schein and Schein, 2017).

Furthermore, a common issue across all sites was the difference in operating standards between maintenance and production. Within Plant 1, 2 and 3, Production cells utilised the 5S technique to manage the work area. This was monitored through regular, cyclic audits each shift. Although the maintenance unit appreciated the value of this, they admitted they did not follow the same procedure and could not evidence any real housekeeping standards. The seemingly innocuous difference can negatively affect the perception of maintenance and ultimately working relationships.. This can be clearly linked to the frustrations of the production manager in Plant 2.

Areas such as workspace, performance communication and staff engagement were seen by the organisation as an operational characteristic. Yet discussion in Chapter 2, Section 2.6 identifies these areas as observable, tangible artefacts that can have a deeper effect on the ability of the department to function. Importantly, specific artefacts which represented the values and working practices of the maintenance department were identified as being different to that of the production unit. This includes the appearance and management of the maintenance work area, as well as the display of performance information. This can promote mistrust and lead to a lack of empathy for maintenance practitioners. This is especially true when understanding the dynamic performance strategy which governs the production unit. The KPI approach to manufacturing which is prevalent in the automotive supply chain was simply not in evidence within the maintenance function. Indeed, for all case study Plants, performance information was not displayed anywhere for organisational staff– unlike Production.

6.4.5. Planning and Performance

The ability of the maintenance function to plan effectively was recognised in testing as being weak and requiring improvement. This was found in areas such as work order identification, tracking and the associated resources required to complete any task. The symptoms identified during the Gap Analysis test led back to a single, underperforming area in each plant – the poor management of information. This emerged in several ways, including the inability of the maintenance function to plan work orders. This comprised of the required resources, or the accurate recording of task completion and down time. There was no use of any recognisable, automated data management system for the planning or recording of maintenance tasks. Each individual plant recorded information by a manual method. This could be through time sheets or entering the information by hand into an excel spreadsheet. Although each recognised the importance of accurate data, there was no infrastructure to support this. Conclusively, this is an area of major improvement for all three Plants. The accurate recording of downtime information would improve the accuracy of important business KPI's – including OEE. Moreover, a lack of accurate information provides no foundation for any maintenance performance improvement.

6.4.6. Equipment and Spares

All three Plants acknowledged the importance of a critical spares identification system. Yet this recognition was potentially worthless in Plant 1 and Plant 3, due to the lack of infrastructure to support an accurate inventory system. In both instances this presented itself as the plant having no inventory recording system or consistent staffing of the equipment and spares area. As a result of these operational features, the probability of any required spare part being available when required was negatively affected. Conversely, Plant 4 recognised the importance of the process, by having a bar code tagging system which identified the part and its subsequent removal from the store area.

6.4.7. KPI’s

The use of KPI was consistent across Plant 1 and 3 with a low score of 1.8 for the category. Plant 4 performance was marginally better due to the enthusiasm of the nominated expert, who calculated additional information for personal interest.

The damaging lack of infrastructure noted in Section 6.4.5 had a deeper impact on performance management. As a result of the manual recording of performance information, any metric informed by this data could be considered inaccurate and potentially misleading. As well as this gap leading to difficulties in performance management, it created additional friction between the manufacturing unit and the maintenance function. This revealed itself through both units having their own manual, recording system. This was consistent across all three plants and led to dispute. Moreover, the accuracy of crucial performance information, communicated on a regular basis to the parent company and the site OEE, was open to debate.

These findings will now be assimilated into a coherent response to the research question of this thesis. Furthermore, appropriate conclusions will be established, and suitable recommendations submitted.

7. Conclusions and Recommendations

7.1. Introduction

Chapter Six presented and discussed results from the Gap Analysis Test conducted with Plant 1, Plant 3 and Plant 4. This included diagrams which presented trends and identified specific performance issues. An example of both may be seen in Figure 6.4 and Figure 6.5. Furthermore, a comparison diagram between all Plants was presented in Figure 6.9.

The results identified all three plants as having fundamental gaps in their maintenance strategy – in crucial areas. What has become further apparent, is that the individual constraints/categories identified in this research have a common point of origin – a lack of infrastructure. This infrastructure facilitates maintenance operation, performance and development and the gaps are having a damaging effect within the automotive supply chain. These gaps include;

- The manual recording of all production and maintenance information
- No Maintenance management system
- Inconsistent identification of training for maintenance staff
- Incomplete and inefficient maintenance planning.
- Incomplete or absent equipment and spares inventory system.
- Inadequate MPM strategy

Although the majority of constraints identified and tested by the Gap Analysis tool are recognisable within the context of manufacturing maintenance, organisational culture emerged as an important ingredient and interconnected the findings. Organisational culture is an enabling characteristic and the results demonstrate this has not been appreciated by any of the Plants tested.

Section 7.2 will synthesise the Gap Analysis Test results to answer the research question of this thesis. Subsequently, as a result of this research, recommendations will be presented in Section 7.5 with the contribution to knowledge identified in Section 7.6.

7.2. Response to the Research Question.

A reminder of the Research Question is identified below:

How can an automotive supplier overcome constraints which limit the implementation of an effective maintenance strategy?

This will be answered more specifically by the following questions:

1. *What are the features of 'state of the art' or 'best practice' maintenance strategies within the automotive manufacturing environment?*
2. *What are the constraints identified within the automotive supply chain which prevent maintenance strategy implementation?*
3. *What is an appropriate method of improving an existing maintenance strategy which will accommodate findings from question one and question two?*

The principal question was broken into three-part questions. The identification of the response to each individual question can be summarised in Figure 7.1;

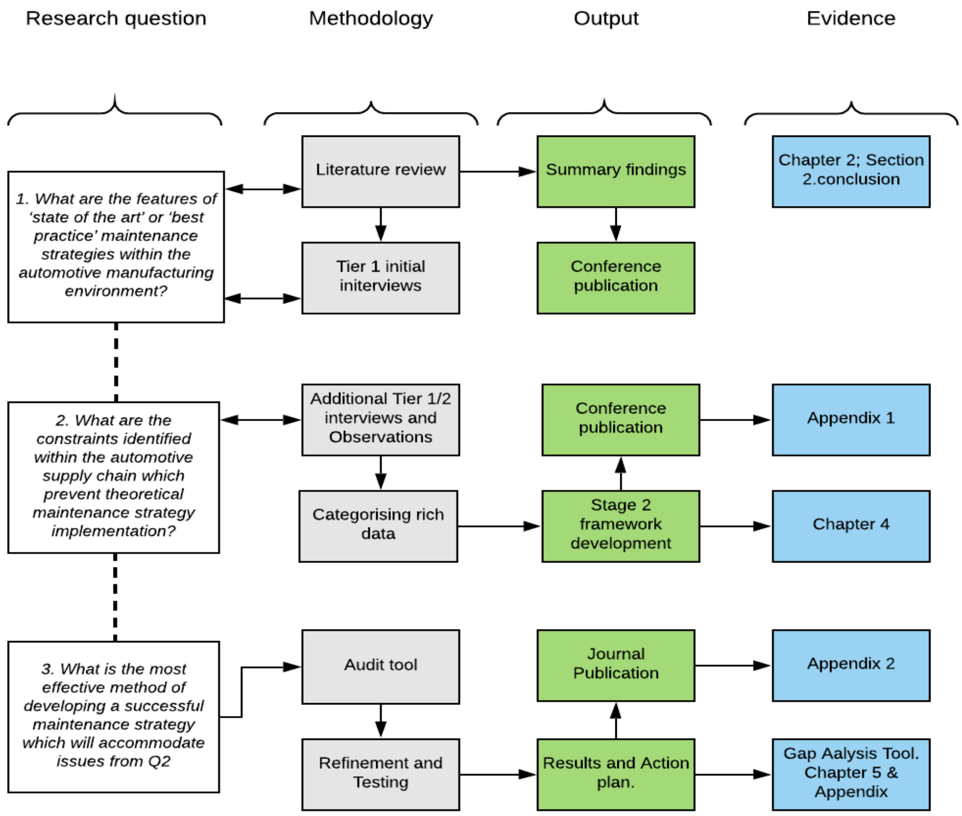

Figure 7.1 A diagram representing the response source for each research question, with associated outputs.

7.2.1. Response to Research Question 1

What are the features of state of the art or best practice maintenance strategies within the automotive manufacturing environment?

The literature review in Chapter 2 heavily influenced the response to research question one. To compliment this, information was extracted from the rich data gained during the case study work. This was due to the lack of literature on maintenance in the Automotive supply chain. Developing a response to Question one also established a gap in literature.

The characteristics identified as best practice in maintenance management from Chapter 2 are summarised:

1) Maintenance strategies must accommodate individual features of the operational site. This includes the manufacturing environment, site history, geographical placement and workforce demographic.

2) The selection of KPI's must be informed by the objectives of the business. Also, the MPM system must benefit from senior management engagement and include the human element of maintenance.

3) Predefined indicators for an organisation will fail to fulfil the strategic potential of a measurement system.

4) The maintenance strategy must link and engage with the human element. The human element includes workforce engagement; staff motivation; staff skills and training.

5) Effective SCM is crucial to the performance of the organisation in a lean manufacturing environment.

6) Organisation and department culture can affect maintenance performance

7) Understanding and using maintenance strategy enablers can influence a positive department culture.

These broad characteristics were then used to develop propositions which formed the basis of the Gap Analysis Tool. The propositions from the literature review are described in Table 2.5.

To provide background for these propositions and enabling characteristics, records were reviewed from the rich data established during the case study work. This review supplemented the enabling characteristics from Table 2.5 and included;

1) Combined production and maintenance initiatives improves the working relationship between the partner departments.

2) Effective use of an apprenticeship scheme can help alleviate issues with staff resources

3) Senior Management engagement with maintenance development may increase if managers held some, previous maintenance experience.

4) Maintenance department appearance, attitude and commitment are important for organisational acceptance.

5) Buffer Stock management is possible with successful, critical part analysis and robust process planning.

Through these areas of literature and data analysis, emerged characteristics which were important for a successful maintenance strategy within the automotive manufacturing supply chain.

7.2.2. Response to Research Question 2

What are the constraints identified within the automotive supply chain which prevent maintenance strategy implementation?

To provide industrial context for this investigation, a case study approach was applied. This considered four tier one automotive suppliers, located within the North East of England. The categorisation of the rich data which resulted from this case study work, led to a series of constraints which are listed in Table 7.1.

Table 7.1 A cross Plant summary of constraining factors

Category	Plant 1	Plant 2	Plant 3	Plant 4
Senior Management Engagement	✓	✓	✓	✓
Skills and Training	✓	✓	✓	✓
Staff Resources		✓		
Perception & Production Integration	✓	✓	✓	✓
Equipment and Spares	✓	✓	✓	
Performance	✓	✓	✓	✓
KPI's	✓	✓	✓	✓
Supply Chain		✓		
Maintenance Shift System		✓		
Budget			✓	
Buffer Stock		✓	✓	

These categories were a product of the rich data gained from case study participants. As a result, this important detail informed the additional propositions which are contained in Chapter 5. The combination of literary work as well as rich data, led to a platform of propositions which facilitated the development of a maintenance Gap Analysis Tool.

7.2.3. Response to Research Question 3

What is an appropriate method of improving an existing maintenance strategy which will accommodate findings from question one and question two?

This question was answered through the development of a maintenance Gap Analysis Tool. The tool was developed primarily to be used with members of the automotive supply chain. In addition, it is to be applied with the premise that the business has an existing maintenance strategy. Chapter Five provides a detailed account of the process which led to the growth and advancement of the tool and is summarised concisely in Figure 5.1.

Figure 6.3 presents a visual representation of the average score a business may attain for each category. The simple radar diagram allows a profile to be developed for maintenance performance which provides an overview of the status of the maintenance function. Further detail is provided through a review of either the test tool itself – Appendix 7.1 provides an example of this, or the characteristics diagram shown in Figure 6.4. As well as providing an acknowledgement of the presence of constraints within each category, the characteristic diagram represented in Figure 6.6, demonstrates a detailed itemisation of the status of those characteristics. Furthermore, each scored characteristic provides a defined vertical route for how improvement and good practice will be achieved. Although this diagram does not outline the precise manner of achieving a characteristic score, consultation with the trained person administering the test could provide specific advice.

In this manner, the Gap Analysis Tool provides a specific, industry focussed tool which will measure the presence of key features of maintenance practice. Furthermore, the scoring process for each characteristic provides a benchmark for the site and subsequent route for improvement. Conclusively, the tool does not look to radically change the incumbent maintenance plan but develop and improve it.

7.3. Outputs and Conclusions

7.3.1. Outputs

This research has provided a deeper understanding of maintenance practice within the automotive supply chain. This has been completed primarily in a qualitative manner and consequently specific, human centric findings have emerged. Case study reluctance to release metric information provided an opportunity to gain increased depth from the qualitative feedback. As a result, this research has benefited from a profound understanding of the issues. The benefits present themselves in several forms, yet tangible outputs are summarised below:

1) The review of literary work and maintenance management, cross referenced with the automotive supply chain, has revealed a dearth in published literature. This research presents a new addition to this field.
2) This research has produced several publications representing the development of this investigation. Dixon *et al.*, (2017); Dixon *et al.,* (2019) identifies the importance of culture within an organisation and how it is embedded in a structured maintenance strategy.
3) Identification of automotive supply chain constraints which prevent effective maintenance strategy development.
4) A Gap Analysis tool which will identify the presence of maintenance constraints within an automotive supplier and offer a route to improvement.

7.3.2. Conclusions

Research completed with four case study partners and the subsequent testing of the Gap analysis tool, has provided a valuable, comparable series of findings. These findings now form the basis of concluding remarks which reflect the results of both the case study work and Gap Analysis Tests:

1) Organisations within the automotive supply chain are dominated by industrial outputs. Within automotive manufacturing, these outputs are cost, quality and

on time delivery. This has a direct and often detrimental influence upon all aspects of the business, including maintenance. Due to the synchronous or JIT production strategy, as well as the high volume of part production, the resultant business environment is restrictive and claustrophobic. This has a damaging effect on maintenance development.

2) Inhibitors to maintenance development can emerge in an explicit form – such as limited access to machinery for maintenance tasks. Conversely, the inhibitor may present itself in a more subtle manner – such as the senior management attitudes to maintenance KPI's or the reluctance to deploy production operators to maintenance tasks.
3) During this investigation, there has been no evidence of suppliers considering site-specific dynamics and the human element when developing their maintenance strategy
4) A deeper understanding is needed by any manufacturer in the automotive supply chain of the aggressive and dynamic production led environment. This understanding must include the operational effect it will have on departments which support production – such as maintenance.
5) The aims and objectives of a Tier One supplier can inhibit maintenance performance. Rich data from Plant 1 revealed detrimental issues with equipment and spare part management. This was partly due to the equipment procurement process being led by the finance function – with no maintenance involvement. As a result, cost became the primary driver for buying new parts. This led to multiple issues with performance, quality and standardisation. Moreover, equipment and part diversity became a damaging characteristic.
6) The maintenance function within the Tier One partners appear to be suffering from a lack of infrastructure. This can be demonstrated by the manual recording of maintenance information. Each Tier One supplier acknowledged the automation of this process was crucial yet had no plans to address this. Plant 1 possessed a CMMS system but did not use it due to a reluctance from maintenance technicians.
7) Interaction with supply chain partners is limited to quality, cost and delivery of the order. Whilst the importance of these three characteristics is not under

question, literature suggests a more relational SCM approach has more benefits for everyone in the supply chain. Currently, the SCM can be described as contractual, aggressive and with very little sharing of best practice.

8) Communities of practice do exist within the supply network investigated, yet this does not appear to have a direct influence on either maintenance performance or development. Rich data suggests this may be due to the competitive nature of suppliers at Tier One and the subsequent reluctance to share sensitive information.
9) Case study information revealed that the predominant maintenance strategy is still reactive, with some areas of further development. This is despite the recognition by interviewed staff that more advanced techniques would benefit the department and organisation.
10) Constraints to maintenance management have also emerged from the sphere of organisational culture. These constraints are immediately obvious in the form of artefacts which highlight differing working practices and values. These differing practices can result in a lack of trust and poor working partnerships.
11) These artefacts along with their importance, must be understood by the maintenance department. A positive working relationship with partner departments is influential for maintenance performance. Clearly, the primary partner of maintenance is the manufacturing unit.
12) Recognising and adopting suitable good working practices from the production unit should be considered by the maintenance function. These include the communication of maintenance performance and workshop standards. This will potentially remove an unnecessary and evident barrier.

7.4. Comparisons with literature.

Chapter 2 provided a foundation for this research by identifying key characteristics which constitute a successful maintenance strategy. Although there was very little published work focussing on the automotive supply chain, the review of maintenance practice was useful. The findings and associated data emerging from this research provided some degree of agreement with scholarly work. What also emerged was specific differences with items of maintenance literature.

The importance of holistic, business wide engagement in developing a maintenance strategy is acknowledged in literature (Tsang, 2002; Wireman, 2014), yet this research has found no evidence of this happening. This research has identified that due to the production method and demands of the OEM, each supplier is very heavily focussed on manufacturing, quality and delivery. Yet this focus is to the detriment of maintenance management. The organisation expects maintenance to fully support and facilitate production effectiveness, yet there is superficial engagement by the organisation and the leadership team.

This low level of engagement has been demonstrated in this research when reviewing data related to maintenance KPI's. Indicators in each plant are described as limited and dysfunctional. MC from Plant 4 maintained records which were additional to the information required by the leadership team. This was solely to facilitate capital expenditure requests and was not formally reported. The evidence from literature is clear; failure from the business to explore and use site specific KPI's for maintenance performance management will lead to maintenance deficiencies(Muchiri et al., 2011; Parida et al., 2015). The evidence gained from this research acknowledges this perspective and offers the conclusion that there is a substantial issue with each case study partner in this area. Moreover, the dynamics of this industry appear to have had a direct and negative influence on the MPM system used by each business. This influence is to the extent whereby the MPM system is ineffective, misleading and prevents maintenance development. This may be evidenced by each plant confirming the organisational focus on OEE; on time delivery and product quality. This focus has led to a dereliction of MPM.

Berges, Galar and Stenström, (2013) identify the need for establishing KPI's which report on the human element of maintenance performance. This research endorses that proposal but recognises the difficulty in establishing such additional KPI's, when fundamental problems with the incumbent MPM system are still to be addressed.

The importance of the relationship between businesses within the manufacturing supply chain is discussed as being crucial Hill, T and Hill, A, (2009); Wit and Meyer, (2014b) to the performance of the individual organisation. This research has identified that in the automotive manufacturing supply chain, the relationship is contractual and not relational. There is no technical support from the OEM or sharing of best practice in the maintenance function. Conversely, the only communication of maintenance performance with an OEM and a Tier One supplier, is often as a result of an enforced intervention by the OEM. This intervention occurs when a continued production failure results in a line stoppage at the OEM site. As a result, the OEM can intervene and deploy maintenance technicians to resolve the issue – to their satisfaction. This enforced intervention, confirms the directness and contractual relationship that exists within the automotive supply chain. As a result, the Tier One businesses can be reluctant to share technical maintenance information with external organisations. As identified by Hill, T and Hill, A, (2009), this dynamic is difficult to change.

A direct result of this supply chain dynamic is the use of a buffer stock to mitigate an intervention. Plant 1, Plant 2 and Plant 3 revealed that buffer stock was used to provide a safety net due to the unreliable performance of the maintenance plan. To this extent, the degree of buffer stock is a direct indicator of the trust placed in the maintenance plan by the organisation. The level of stock can also signpost the state of the relationship with the OEM. Plant 1 revealed the buffer stock to be in the region of millions of Euros.

One of the most revealing aspects of this research was the importance of the department and organisational culture in affecting maintenance performance. Although recognised by established authors such as Brown, (1998); Keyton, (2010); Schein and Schein, (2017) in being influential in business performance, the influence of culture on maintenance and the automotive industry is limited in literature. The clear differences in working practices between production and maintenance was evident in several ways, but included methods and content of communication, workshop standards and cooperative projects. As a result, these differences appeared to create a certain degree of friction and established unnecessary and problematic relationships. This was very much in evidence in Plant 2 and to a certain degree, Plant

1 and Plant 3. Although some of these artefacts may be classed as superficial, they are important and a visual representation of values. These values apply to both the organisation and the maintenance function. Bititci et al., (2006); Pakdil and Leonard, (2015) stress the importance of organisation leadership understanding and addressing this, yet evidence of any understanding of this is absent in these manufacturing sites. If there are clear differences in values between partner departments, such as production and maintenance, then the business can suffer. This research demonstrates that this is not acknowledged or addressed by Tier One suppliers in the Automotive Supply chain.

7.5. Recommendations for maintenance management within the automotive supply chain.

This research has recognised several constraints which prevent the successful implementation or development of a maintenance strategy. A Gap Analysis tool has been developed and tested to identify the presence of these constraints within a tier one automotive supplier. As a result of the development and testing, this research has a series of recommendations in specific areas of maintenance management, for the automotive supply chain.

7.5.1. Enhance the maintenance infrastructure

The lack of infrastructure noted throughout this investigation is a concerning issue affecting the maintenance function and its ability to be effective. Moving forward, the specific features which require redress have been identified as:

7.5.1.1. Improve KPI management

The specific focus on production outputs has led to a limited selection of KPI’s being used in each plant. As a result, each plant has a reduced capacity to identify and measure improvements. Considering an appropriate and increased suite of KPI’s would provide a focus for maintenance improvement as well as demonstrate alignment with methods used in production management. Moreover, addressing the manual method of data management is of upmost importance.

7.5.1.2. Plan and track effectively

The planning required for maintenance tasks was found to be inconsistent and lacking in detail. Predictive maintenance tasks were completed but plants were unsure as to their effectiveness. Also, the manual recording of down time information led to inaccurate and ineffective plans being produced. Addressing these issues will take some investment yet reviewing the suitability of a CMMS would be beneficial. To compound this, two out of three plants operated with an unsatisfactory spare part and inventory system. This resulted in operational deficiencies. Implementing an effective store and inventory system is a necessity when an organisation is operating at this level and in this environment.

7.5.1.3. Prioritise skill management

The systems for supporting the development of maintenance technicians is inconsistent and would profit from some sharing of good practice. Plant 1 utilised basic but effective training management. This included a skills analysis of each technician, combined with an ongoing review of maintenance workload requirements. These two components then informed an effective training plan. Other plants appeared to focus upon standard, regulatory training. The introduction of a more considered, site specific method of skills management would be beneficial to staff and performance.

Staff development of maintenance technicians is an important employee investment and can be extended to include progression opportunities. Across each plant, the Gap Test evaluated that a dramatic improvement was required to the career management of technicians. The lack of human resource management in this area is stark and could lead to less visible problems, such as motivation and poor morale.

7.5.2. Operations management

7.5.2.1. Improve operational monitoring

The performance monitoring strategy established for the maintenance function was identified as being regular and with specific frequency. However, the content of the performance report included limited and inaccurate information. The superficial nature of the MPM systems identified in this research, provides limited data for department development or specific areas of improvement. It is acknowledged that the required suite of reporting metrics often come from the parent company, yet additional site-specific indicators should also be considered.

7.5.2.2. Address communication methods

The existing methods of communicating maintenance information has underlying issues which have caused discontent across case study participants. Within the scope of this research, the inconsistent communication of maintenance performance was particularly prominent.

All production cells, including the overall manufacturing unit were required to display and update, relevant metric information. This display was open to other production units as well as visitors to the site. Apart from Plant 4, there was no requirement for the maintenance department to do this. Plant 4 had space to display their metric information but it was out of date and lacked visibility. This oversight can have damaging effects on the perception of the department. The alignment with the practice of other, partner departments is important.

7.5.3. Review cross department dynamics

The organisational priorities of the business evidently have an operational effect on department performance. Plant 1 and Plant 3 were inhibited as a result of organisational priorities. The strategy of the organisation positioned the finance function to be the primary influence and facilitator, in the purchase of any new equipment. As a result, the focus was cost, as opposed to any design for maintenance consideration. Furthermore, a specific remedy to this situation in Plant 3 was the increased use of buffer stock – to mitigate this and other maintenance failure situations. Evidently, a review of these cross-department dynamics is substantial and not to be completed lightly. Yet the evidence gained through this research has highlighted the damaging implications of not understanding organisational dynamics and consequences to the maintenance function. An attempt should be made by the organisation to interconnect the business priorities, between cooperating departments. A disconnect had occurred in these Plants, leading to substantial financial impact.

7.5.4. Understand the cultural spiral

This research has identified the importance of the human element of maintenance practice and its position in the wider context of a department or business culture. Furthermore, it has acknowledged that although changing the culture of a business can be a lengthy process, there are areas that may be addressed. Rich data and Gap Analysis results identified operational differences between departments in the following areas:

- Methods of communication - internally and externally.
- Maintenance technician involvement in planning and development.
- Maintenance operational standards.

Acknowledging and addressing these deficiencies provides a compounded benefit. This includes the performance of the department and the relationship it holds with other stakeholders. Identifying and aligning key artefacts which represent the beliefs and values of the organisation, including those of the production and maintenance function is of value. This includes performance reporting or housekeeping standards. These artefacts and characteristics are important within the automotive manufacturing industry. Differences in values and working practice can be magnified as a result of the high pressure and aggressive industrial environment.

Adhering to the recommendations of this research may prove beyond some organisations due to resource issues. What is possible, is an understanding of the importance of the strategic and operational characteristics which constitute a maintenance function in the automotive supply chain. It is these characteristics which define how the department is perceived and the subsequent working relationship with other departments. Through understanding this, change can emerge.

7.6. Contribution to knowledge

The completion of this research has presented findings which are novel and an addition to the existing body of knowledge in maintenance management. These findings are found in Chapter Two, Chapter Four and Chapter Seven.

Chapter Two reviewed varying perspectives of maintenance management, as well as specific techniques to address and improve maintenance inefficiencies. Although, maintenance management within the automotive industry was discussed, it was recognised that the majority of literary work was focussed upon general manufacturing. In doing so, it became apparent that there is a gap in published research regarding maintenance management in the automotive supply chain. The importance and relevance of this gap became clear during the case study work. Finally, although there is extensive literary discussion on organisational culture and the link to the success of a business, there appeared to be no cross connection to maintenance. It is anticipated this is an important contribution to knowledge.

Chapter Four reviewed the data which was assembled from field work with four case study partners. Each partner had varying levels of maintenance performance, with a cross section of inhibitors preventing development. What emerged was an assimilation of constraints which contribute towards poor maintenance performance. On a deeper level, Chapter Four also discussed a technique used within the supply chain to accommodate poor maintenance deployment. The use of a buffer stock to guarantee continued, on time delivery to the OEM is well practiced within a JIT environment. Yet the degree to which it was used in Plant 1 and 2 demonstrated that poor maintenance performance was placing a severe financial burden on the business.

Literature identified the importance a holistic, business wide approach to maintenance management – including the importance of considering site specific dynamics. In contrast, the research presented findings which revealed maintenance practice within the automotive supply chain is operating with neither of these key development techniques. Moreover, the rich data revealed that as well as the working culture of each organisation inhibiting maintenance, the organisation was oblivious to factors which contributed towards this. As a result, addressing these issues was included in the resulting Gap Analysis Tool.

The development and testing of the maintenance Gap Analysis Tool is presented as an output which is novel. This output has been developed and tested with automotive supply chain partners and offers a specific tool, to measure and improve a maintenance plan in the automotive supply chain.

The tool is designed to review areas of maintenance performance which have previously inhibited maintenance development at Tier One level. Furthermore, the tool does not look to investigate all areas of maintenance practice, simply ones which have emerged as being influential during this investigation. This includes aspects which look to address the cultural practice of the department and that of the organisation. Importantly, the format of the tool is recognised throughout the supply chain, through quality assurance audit processes such as IATF16949. Conclusively, the tool can be used as a lever to implement change.

To summarise, the contribution to knowledge has been identified as:

1. This investigation has contributed significantly to the body of knowledge in maintenance management, with a specific focus on the automotive supply chain. This may be evidenced by the identification of inhibitors which limit maintenance strategy performance and development in the supply chain. This is supplemented with a significant piece of research identifying the importance of organisational culture in the field of maintenance management.
2. These inhibitors have an organisational impact in addition to causing maintenance issues. This impact has been identified in the form of an increased buffer stock to mitigate maintenance failures.

3. A bespoke Gap Analysis tool was developed and tested to identify the constraining factors limiting maintenance strategy effectiveness in automotive supply chains. The tool embraced existing knowledge regarding maintenance strategy frameworks and included contextual, specific issues emerging from the rich data.

This contribution is further supplemented by the peer reviewed conference and journal publications listed below:

Dixon, D. *et al.* (2016) 'Improving automotive supply chain performance through maintenance strategy development.', *EuroMaintenance 2016*. Athens, Greece.

Dixon, D. *et al.* (2017) 'The Role of Cultural Development When Improving Maintenance Practice in the Automotive Supply Chain', in *COMADEM 2017*. University of Central Lancashire, p. 8.

Dixon, Derek, Robson, Kenneth and Baglee, David (2020) The development of a maintenance gap analysis tool for use within the automotive supply chain: A case study perspective. International Journal of COMADEM, Vol. 24 Issue 1, p71-72

7.7. Research limitations

The collection of rich data was approached through a case study method which included semi structured interviews. This was predicated by the reluctance of participants to release any substantial performance metrics. Moreover, the research question required the need to understand the context and depth of the problem. This is fully explored in Chapter three.

Despite this, the author recognises that this approach uses a finite number of case study partners and semi structured interviews which limits the research sample.

7.8. Further research

The Gap Analysis tool was developed to be used within the automotive supply chain. Continued field testing in the supply chain would improve the functionality and allow a deeper understanding of the validity of the findings. In addition, understanding the ability of the Gap Analysis Test to be used in a modular fashion would improve the depth of the tool.

The formation and refinement of the tool was partially completed with contributions from a maintenance expert in the food processing industry. This contribution acknowledged the relevance of the constraints as well as the content of the Gap Analysis tool. As a result, the ability of the tool to be applied and used in the supply chain of an alternative sector or a general manufacturing environment would merit further consideration.

Furthermore, the emergence and influence of organisational culture on maintenance working practices was a refreshing discovery. This influence is crucial in the context of improving maintenance performance and development. Although scholarly work in this field is extensive, this is not the case when applied to maintenance management in the automotive supply chain. Certainly, the observed high intensity of the manufacturing process within automotive supply, including the financial restrictions of being a Tier One supplier, ensure this workplace can be a very stressful environment. As such, extending the understanding of all contributing factors to organisation and department performance is vital.

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Appendices

Appendix 1.1 Initial Meeting Notes Plant 3

First meeting with Executive manager, Tier One Supplier

Summary

- EM has agreed to facilitate meetings with the plant managers of Plant 3.
- Going to get back in touch with regards details for first meeting
- Meet plant managers.
- No issue with interviews or transcribing the interview...

Maintenance feedback

Still a conflict between production and maintenance.

Keep varying amounts of buffer stock to accommodate maintenance breakdown.

This is based upon the length of time for the biggest maintenance activity (if there is a breakdown), so the buffer is utilised - allowing the maintenance activity to carry on without it stopping the line.

Plant 3 is 24hrs of stock

OEM owns 41% of Plant 3 which makes the relationship 'difficult'

Metrics required for evaluating maintenance are from Parent company and include standard ones such as MTTF. I get the impression they do not get a great deal of investment for maintenance...

They do advocate PM as part of the expectation of the workforce (operators) but do not enforce it rigorously. 'It is something we should do more...' Agreed that there is a lack of knowledge and application with certain parts of the work force.

EM indicated that engineers (and operators) can find it difficult to work in between OEM and themselves. OEM Engineers can be completely proceduralised and 'mechanical' i.e all faults can be rectified by following an SOP, whereas Plant 3 engineers are expected to solve problems and be imaginative....**I think there is something here....**

OEM also have the option of coming into the factory and imposing themselves upon the supplier, to what extent I don’t know yet. This is not something Calsonic do...where they are looking to foster a softer relationship with their suppliers, and share best practice. This is in its infancy

Have considered outsourcing and at the stage 2 years ago of establishing a partner for a new machine, but did not follow it through…kept it in-house.

Interested in vibration analysis as a method of CBM, but knows very little about it….

Appendix 1.2 Initial Meeting Notes Plant 2

Meeting 1 – Plant 2

Time: 10:00

Present: Derek Dixon (DD) – SL and Researcher at UoS

MM – Senior maintenance manager, Design, Engineering and Projects.

Notes:

DD – Can you please explain a little about Plant 2, the products and operations please?

MM – Plant 2 is mainly a Tier One suppier. A vast range of products. A multitude of parts that cover body and white and trim and chassis parts, interior and exterior trim. The main processes being injection moulding – the range of machines being 30 tonnes to 2000 tonnes. The 30 tonnes machines will do small components such as end caps. We have varying types of moulding processes. We also paint – we have 2 paint plants now. We did have 5 but we have taken that down to two. We make an array of metal parts which can be cold formed or cold extruded, or pressed and bent and trimmed. Assembly is either automation or manual assembly. We also have an aftermarket accessories market. Little things like kicking plates with LED lights on.

DD – which particular parts provide you with the most pressure – and that could be linked to quality?

MM – In terms of processes it kind of ebbs and flows. Now we would say the metal parts, this is where the majority of pressure or concerns come from quality. A lot of that is as they are high visual parts. These chrome strip parts are for the Qashqai and it's the first time OEM has built a car with a chrome strip. Paint is always a critical process, as the cost of the part means you've got to get it right first time.

DD – is there any reason why you went down from 5 to 2 paint lines?

MM – the business needs and for the cost i.e if you don't get it right and the cost if you don't. Also, a difference of opinion with the customers where despite we meeting quality standards it's always the next level up. Plus both paint lines are more than twenty years old and it's a manual painting process, which brings its own limitations.

DD – the production system that you run is it normal just in time or is it bespoke?

MM – it's a mixture really, the customer base is OEM1, OEM2, OEM3, OEM4 and OEM5. Each has their own stipulations with regards to minimum stock orders and quantities. We do some cat 3 stuff for OEM, where we only have a set amount of hours before the car is built. They would say ok, we're gonna build 20 black cars today, 3 red and 3 white and we would sequence some of our parts in – such as back door finishers. We used to sequence for Honda as well believe it or not, even though its in Swindon and 5 hours away. We used t sequence covers there as well. The other guys we have 2 or 3 shipments every day. There is also 'milk rounds' going on other shipments which are a mixture of not just Plant 2 parts but parts from other Tier One's such as X and T, so it's a mixture.

DD – What is the current MS?

MM – Right now it's very much predominantly reactive – a number of reasons for that. None more so than the sheer number or pieces of plant on the site, I think there's 1500 pieces of kit on the site – there may even be more than that. We have a planned maintenance schedule we call it TPM but it's not really TPM, but it's stuck. We do have our planned PM's which are seen as an overcheck. We have mechanical maintenance, electrical maintenance, press tool and injection moulding. It starts, the guys get their PM sheet – there's a schedule there and they are issued weekly and monthly. It happens ad-hoc because the machines are never actually shut down for a set amount of time for the planned maintenance. So a list of ten jobs which go out for the week, the guys have the jobs and they work with production to find out when the lines gonna be down to do the maintenance. We record the results of that weekly and publish a report monthly, to find out if we're on plan or do we need to put some catch back hours in do we need to put an overtime check in.

DD – so you measure to see if those planned activities are completed?

MM – Yes, that's how we work on if we've changed the plan or not.

DD – do you measure how effective that plan is or the success of it?

MM – No, only very broadly in terms of – we now have machinery performance data so we can now go back over a year and see how a machine has been performing, but we don't tie it in with planned maintenance.

DD – Do you carry our preventative maintenance?

MM – we do some preventative maintenance, we do oil sampling. We'll do some specific planned maintenance with some of the large injection machines where we'll pay for a contract to come in and that type of thing. It's very limited what we do as preventative maintenance to be honest.

DD – Is the strategy different in other areas?#

DD – on the shop floor you'll have operators. Do you involve them with any maintenance activities at all?

MM – they have a daily maintenance procedure that they go through in terms of the basic up keep of the machine. Also as part of our production meeting, it is a forum for these guys to say their machine is underperforming or I think there's a noise coming from it. The main production meeting is 8:30 and before that there are 2 sub meeting(s) – the metal parts facilities and mould and paint shops. At these meetings they will say there is an issue with a particular machine and the maintenance guys will ask when can you give us a spot to look at it…when is it next down?

DD – how does senior management (SM) view maintenance.

MM – a necessary evil I would say. My background is as a mechanical maintenance technician, and I've been here since I was 22. That's definitely how I see it and I definitely believe it. The maintenance budget, when I build that I look at what contracts we are doing and why. What have been our problem machines and components, but one thing that is clear to me is that you set the maintenance budget but as you go *through the year it's something that very quickly gets eroded away. So if it's a planned spend then people just think well, let's just react to it as and when we need to. But my strategy and budget was built around what is the absolute minimum we need to do, not putting contingency in, thinking of critical spares but also regular PM and making sure we keep on top. You want to keep away from the unplanned spends being so high.*

DB – You set your own plan, you are autonomous?

MM – Yes, there are twenty plus categories and I have 3 that I feed into, including 'maintenance spend' which includes labour and overtime.

DD – there was always a big clash with production – is that still the case?

MM – it's not conflict, I would say the difficulty comes with production having the confidence to say – you can have the line then – and sticking to it. Also our ability to react as well as that. As an example, the metal parts that are made, a lot of the machines making those parts are reaching their peak loading. The days of having spare capacity with production could flex or hide a little bit to cope with a higher scrap rate. Now, when we're going and saying we need the line for 8 hours and they suggest a date. When you go on that date they say no, we need to run and make the product. They're not doing out being awkward – it's out of necessity. It could be a change in order or a breakdown, so its catch back. There are 101 reasons for it. There are no clashes; I actually think most of the production guys would prefer the machine to be in better working order as it makes their job easier.

DD – recruiting technical staff can be an issue…is it?

MM – Yes, definitely. I've just lost a really good guy to Supplier X as it was really close to his home. One of his feedback points was he thought there were better career opportunities (at Supplier X) which was a little disappointing. In terms of recruiting yes, the same. As well as getting in a good CV we have our own testing process. We have varied results there, so in terms of the guys telling you what they can do and what they can actually do is sometimes different…

Pass rate used to be 75 – 80% but we relaxed that a bit for people who have the right attitude. But we even have a struggle getting those people now.

DD – what do you think is the issue there?

MM – I think it's to do with chasing the money. From what I hear and reading between the lines, being so close to OEM as well. They're sucking up a lot of the resource and they're even recruiting people from overseas now. High turnaround of staff at technician level at OEM as well. They're used to making the money there as well. I know that OEM are struggling, as are Unipress.

DD – do you recruit multi skilled or go by discipline?

MM – I leave it open. Multi skilled is best as you get a bit of both but even then they are better at one discipline than the other. Were a bit old fashioned in that the mechanical and electrical divide – it's a little bit old shipyard mentality that we've been trying to break down a little but you also get certain skills with that where they can go and do other things, such as in the tool room.

DD – What I've noticed over recent times, is that manufacturing companies often keep a certain amount of semiskilled staff as agency, in case they have financial issues. Do you? Does it have an effect on your maintenance activities?

MM – Don't ask me to give you a ratio, but it's quite a high number. I would say at the minute it's pretty noticeable that the first line maintenance over recent years has slipped – there's no doubt about it. The production staff is so lean it's all about making the parts. The production manager Paul, is instigating a 3S activity – not 5S. Let's start cleaning the machines and doing the basics and doing a daily check. So you can see a step change across the factory now. Paul is the better one to ask about the agency, but my opinion is – absolutely. The days when we had near 100% of our production staff being Hashimoto staff, my opinion is there was maybe more ownership of the sections and a little bit more pride than what people are these days. If they saw a bit of oil on the guard they would wipe it off, where now they would leave it. The agency staff in general, they come in at 8 in the morning, you may be lucky if they come in at 8 o clock the next day. The mentality is different, some of them are really trying to find *work and we recognise that. The guys who really work hard we can reward with f/t contracts but you do have a level of agency that only want to come in and clock in for the day and they may be doing something different tomorrow.*

DD – do you look to offer influence over your supply chain, do you share your best practice?

MM – No – honest answer. Component suppliers are vetted through our purchasing department. There's a supplier approval process, we don't from a maintenance perspective look at anything at the suppliers. We don't look at the facility we don't look at their equipment. When we're buying steel we don't think about their process or how reliable it is. That comes from the purchasing side. Recently it's something that we've started dialogue that we need to involve our technical guys in, somewhere where we're getting a component but maybe the component has come from a press tool. {Discusses context of supplier where they had issues with Chinese supplier, where a check would have over some issues they ended up having with the customer}. We definitely need to think in the future, probably looking at how important that component is using critical path but we certainly need to get involved technically with some key components.

DD – What sort of suppliers do you have (local/international)?

MM - More local…there has been a big drive on the past 5 years to localise – when I saw local I mean Europe and we're pretty healthy with that. I want to say 80 / 20 but don't quote me on that. There is some obsolescence as well where there is just some things that can't be imported anymore (so local is a must is inferred).

DD – So you haven't noticed a particular quality issue coming though from a supplier?#

DD – do OEM influence you much – sharing best practice?

MM – we haven't really although we did try to kick that off last year. I met my equivalent at OEM last year and I think I was more interested in their best practices than they were interested in mine. It never really got off the ground though; you set off with the *best of intentions. Your priorities become the here and now and it's hard enough prioritising the next 3 months. It's something I'm keen to do and I think it would be worth getting the Tier One's together without the OEM and sharing best practice. I think when the OEM is there is a chance it could pick holes in things and create a risk to their supply chain or take it down an avenue where they're looking for a cost down.*

DD – what is the percentage split of your supply to the OEM? Does it change?

MM – yes it does. This year's its 50% to OEM, 20% Honda and then it filters down and is broken up. Next year it will be just less than 50% OEM, maybe 20% OEM5 and then OEM2 10-15% and then it filters down for the rest.

DD – is that something you guys actively do, not put all of your eggs in one basket?

MM – Absolutely. Many moons ago we were all OEM, then late 90's early 2000's we got the Honda business but Chris is all about diversifying the business. Last 18 months we have secured Renault which launches this year. MMW we have spoken about…1 programme launches this year and another next year. They will then become our second largest customer next year. .

 # - Question not asked.

Conclusions:

- Reactive MS only.
- No clear thought around preventative maintenance and planned maintenance
- Clear lines of demarcation for maintenance tech. discipline…mech/elec.
- 'Shipyard mentality'
- No planned downtime for maintenance. Achieved 'ad hoc'
- Healthy supply split to OEM's. 50% to OEM…
- No interaction with their suppliers, though recognition that in some instances it is required.
- Synchronous production in only some instances, in others stock is held (I think)
- Planned maintenance is scheduled, but only measured against completion.
- No measures of effectiveness of maintenance activities

- Engagement of operators still to be confirmed.
- Senior management view it as ‘a necessary evil’
- Maintenance budget set, then eroded away of the year and seems to consist of labour and overtime costs
- Recruiting technical staff is an issue, as well as (to a lesser extent) retaining them.
- Agency workforce has a detrimental effect on the performance of the production staff and possibly maintenance. Substantial ratio I think…(to be confirmed)
- No sharing of best practice or reviewing of any practice for suppliers
- Recognition that it may need to happen…
- No sharing of best practice from OEM though recognition that they may/would be willing. Reluctance there again…
- Very keen to move forward, work together and share best practice.

Appendix 2.1 Transcript Plant 1

Meeting 1 – Plant 1

Present:

Derek Dixon (DD) – SL and Researcher at UoS

ME – Senior Maintenance Engineer

MM – Production manager

PM – Plant Manager

Acronyms:

PM – preventative maintenance activities

PLM – production led maintenance.

Notes:

DD – Can you please explain a little about Plant 1, the products and operations please?

PM – Joint venture). Plant 1 then bought out Kansei and the joint venture was between Plant 1 and Magna. 6 years there was a buyout process to dissolve a joint venture. Predominantly an injection moulding plant, also make soft ip's - vac forming and injection foam and high gloss paint also.

Interesting that you're looking at maintenance as the dissolving of the joint venture took 2 years. During that period no investment took place and there was a big skills drain, and now we're paying the price. I've worked on this over the past 12 months, and ME has worked here for 4 years and been senior engineer since April 14. We've spent the last 12 month trying to recover the situation. A lot of crucial machines (Inj. Moulding) is 26 year old and shelf life is around 20 year old. We're very interested in your thoughts on maintenance

- Joint venture
- Lost a lot of skilled technicians when the joint venture ended
- Still feeling the impact of that.
- Products are foam based, injection moulding and paint.

DD – What is the current MS?

ME – A planned maintenance schedule, also an annual servicing schedule based on manufacturers recommendations. The effectiveness of the planned maintenance has been called into question of late as it was proved to be very generic…lubrication and greasing etc. There is very little condition monitoring at present which is where we hope to get to. We have 4 different manufacturers of moulding machines downstairs.….

PM – Going back 12 months, the PM schedule and activity was very sporadic. Production was running flat out at the time so production never gave maint. the time. Now we have the maint. dept in the routine of doing the PM's (they should) we are now looking back at the quality of the PM's. We're doing PM's at the moment but whether they're effective or not is debatable.

DD – Do you judge or measure how effective your activity is?

MM – Maintenance was managed by how many breakdowns we had. We had 161 PM's to do in a month, a vast majority of which were against assembly jigs which had no critical effect on production…so what was their worth? So, ME has been working on a schedule that's effective. So manufacturing would take a machine out of production for a maint. activity.

What we're also looking to do now is what we're calling Production led Maintenance (PLM), where the operators complete housekeeping and basic cleaning duties. This is in its infancy. The operators are responsible for cleaning the machine and reporting to maint. anything they think is out of the ordinary. The next level is in a years' time is the operator is performing the PM activity. Maint. guys do that at the moment.

ME – there are 5 cells in the mould shop. What we're looking to do is get a system going where we can roll it out to the whole shop floor. So there is 1 cell per day, the *whole cell stops for 1 hour and they have a checklist that I have designed and the operator goes through the checklist..clean, check jigs. They can also report things on the sheet. The sheets are returned to me and a lot of things that may be missed are being found through it..or had to wait for a monthly PM. It started at 90 work orders per week, with small things such as lights out etc. and now they're starting to look harder and go into a greater level of detail.*

DD – Has starting this process off led to the start of a culture change?

PM – this is our biggest challenge of the plant. Even going back to MKL, there is a big change in mind-set required…not just maint. but within manufacturing and the whole plant. The strategy for FY15 starting next month, 80% of it is to get people thinking differently.

MM – We're pushing it forward now and its teetering, but if we stop pushing it would fall down. We need to keep pushing it on.

Just to go back to maintenance the average PM activities are down to 46 a month. This is based on a red amber green system, which is based on criticality. This feeds into downtime analysis, which ME is feeding into the downtime analysis for the mould machines.

DD – so the main measure of your maint. activity is machine uptime (or downtime)?
PM – Yes.

- At the moment instigating PM activities with maintenance staff, and in one particular area with operators.
- Call the PM activity with operators PLM (Production led maintenance)
- Changes made within the past year and the pilot scheme with operators performing PLM as recently as November.
- Previous planned maintenance activities were generic and very much lubrication and general actions.
- No visibility of PM activities when touring shop floor.
- Culture and communication is an issue with embedding maintenance improvement involving all personnel.
- 1 hour per cell per day is given to staff for PM activities…heavy investment!

DD – retaining technical staff can be an issue…is it?

MM – it's probably higher than other indirect staff. But there is a lot of opportunity for maint. staff out there.

PM – Very good maint. techs are very hard to keep hold of. If you're not careful then you have Nissan paying very well for technical grade staff, so you can end up with mediocre people.

ME – We'd be lying to say we don't have weaknesses within the team and possibly having skills in area's which were right 10/15 years ago.

MM – just going back to losing skills with MKL dissolving, we haven't got any injection moulding experts. There isn't anyone in our team that has experience of injection moulding, just people who have grew up with it (maint.)

DD – from that aspect is there any sort of strategy for professional development for staff?

MM – to be honest no, and there isn't a training plan for staff.

PM – we have a diverse range of equipment with a lot of different manufacturers. There's been no standardisation of any equipment, such as PLC's, hydraulic and pneumatic equipment. We have a big job to identify who needs training on what to cover the whole plant, the whole time.

ME – Especially with the number of men we've got.

DD – How may do you have?

ME – 3 a shift, across 3 shifts. They cover overtime also - which is weekends. 9 maintenance technicians and 1 apprentice (who is leaving). We've just taken on a maintenance engineer as well and I've got a facilities engineer who looks after the buildings – all report in to me.

DD – With regards to the diversity of the equipment, how does that affect your team?

ME – it's a nightmare. I've got to have enough spares to cover all the kit we carry. At least enough knowledge to make an attempt to diagnose the fault.

DD – do you have to take an active part in the activity?

ME – We have to all help, the whole team. A lot of the gear is salvaged as we can't get the spare parts anymore. I dare not get rid of anything. In an ideal world every PLC would be a Siemens…it would be easy but that is never going to happen. ***We have specially made pieces of kit to do specific tasks.***

- Mentioned that staff were relatively loyal, but OEM were a threat from a pay point of view. Stated that the team had some weaknesses based upon that.
- CPD and staff training did not feature as part of their ongoing strategy.

DD – what aspect of maintenance do you have to report on to your parent company?

MM – Globally wise its OEE. OEE feeds into cost, but we (maint.) report into Japan into global breakdown analysis and pick some key machines report on run time/loss time and how many times it breaks down. What happens with that data is it goes onto the global square and…

DD – do you get much feedback on that coming back down…

MM – no..we get some benchmarking stuff from other plants.

DD – best practice or 'these are some targets to hit'

MM – they would share it with us if we asked… we're not there yet.

PM – A lot of the global kpi's that there are from other Plant 1 companies are claiming that they are very good at OEE but they may just measure them differently. There is a specific template that leads to how it should be calculated, but whether they follow that is questionable.

DD – What I've noticed over recent times, is that manufacturing companies often keep a certain amount of semiskilled staff as agency, in case they have financial issues. Do you? Does it have an effect on your maintenance activities?

PM – our turnover is not high. Overall its 4%. Around 20% of our direct workforce is agency but we pay very well at that level.

MM – Agency are keen to buy into new things and they haven't got the hang ups of working here for 8 or 10 years.

ME – a big difference has been that MM is in charge of maintenance and manufacturing which has helped.

PM – That is something we did last year – put maint. under manufacturing and before that they didn't really report to anyone.

MM – they still have conflict (prod. and maint) but my mindset has changed as now I understand how difficult the maint. job can be but I also understand that if you don't carry out maint. then the production dept has no chance.

PM – I moved over to plant management last year and my background was engineering and manufacturing which helps.

- Only have 4% staff turnover as pay at operator level is good. They quite prefer to work with this group of staff as they don't have inherent culture issues and 'hang ups'.

DD – there was always a big clash with production – is that still the case?#

- Not so much, as operations manager MM has previously had maintenance management experience as has PM – the plant manager. So the appreciation of what is required is there…
- *Though ME did say that there is still conflict with the machine down time and what is attributed to maintenance. In short the maintenance activity is not measured.*

DD – You've made some improvements recently, what are you considering next? *Question answered within another response.*

- The MS appears to be piloted in the injection moulding area, and the wish is to improve that and put it out to separate areas.

DD – how is your maintenance activity measured? *Question answered within another response.*

- Machine up time or down time. OEE is measured, but does not seem linked at all to maintenance?.

DD – Do you get the time to do PM activities? *Question answered within another response.*

- 1 hour per day!
- They seem heavily insistent on this…

DD – Is the strategy different in other areas?#

Due to the PM pilot scheme…yes!

DD – how does senior management (SM) view maintenance.#

DD – do you look to offer influence over your supply chain, do you share your best practice?

Low level feedback from group on the only interaction being a quality product – on time.

DD – How do you do with a supplier to you stopping your production?

PM – I can't remember an issue with a local supplier we've had issues in Asia though.

When we supply into Plant X, when we despatch parts it's probably about 3 hrs until that part is on the car, so that's 3 hours of stock we hold. But for our local suppliers, we probably hold 3 days of stock – so it's got to be a major breakdown to affect us. For international suppliers we probably hold 4 – 6 weeks of stock.

DD – What is the ratio of the supply chain – local to international?

AS – 40% local to 60% overseas (Including Europe)

What level of interaction is there? Is it technical or commercial?

- Very little interaction, just an expectation of a quality on time product.
- To mitigate risk, buffer stock is held to varying degrees.

How many suppliers do you have?

- Not specifically asked, but 60% international and 40% local.

DD – So you haven't noticed a particular quality issue coming though from a supplier?#

- Question not really asked…

DD – does the OEM share best practice?

PM – OEM have their major breakdown report – Reliability Needs analysis (RNA), they were happy to come out and train us with that. They were open about that and I'm sure they'd do it again. They don't really ask us for any maint. metrics unless it's a critical process where we could easily stop them. Unless it's a unique supply, such as for the model 1 car where we're required to hold a breakdown stock. But also expected to hold breakdown frequency of the process, but not particular other information. As soon as you do stop the line they're all over you, but if you're not causing them any problems, they don't tend to ask any questions.

- They are interested in a specific process which they feel is a risk to them if there is a breakdown or stoppage. They require detail on certain metrics of that process on request.
- PM indicated that they would help on training and development if asked, but they didn't seem keen on this…
- They had previously came in and trained some of their staff on one of their own techniques Reliability Needs Analysis (RNA), but all the staff left.

DD – For how you implemented the MS, how did you communicate this to everyone?

MM – we knew we would have an issue with this, so ME took it upon herself to speak to 140 operators ,in small groups in anything of up to 10. She covered all cells on each shift – in the mould shop. Explained the checklists, and what the expectations were and the promise that all items reported would be acted upon. This took 3 weeks. This happened in week 47 last year (2014).

AS – The feedback from the shop floor was very positive on the communication.

ME – Slowly but surely the small things which make their lives a misery, such as their fan and light not working were fixed. Now they may notice that their machine smells funny and they're looking more deeply. Now were looking to roll it out to the paint and foam areas.

MM – We've never committed to providing the operators with an hour to do these activities before, normally it might be done at the end of the shift. Plus with ME communicating it, that got people buying into it. Also it's down to us…the first time we say to an operator they're not getting their PLM time is the day it dies. They will tell me when they don't get their PLM time…they will say their coordinator didn't give provide it so they couldn't do the activity. They sometimes do the PLM hour within 2 or 3 days instead of over 5 but that's ok…

DD – who had to green light the hour and the PLM 'time'

PM – it was all of us…

DD – did you set out particular targets or was it a blind investment.

MM – last year we did a lot of work on freeing up process time, reducing scrap by running machines at the right cycle time. This freed up production going from 7 days into 5 days. We haven't got a measure though.

DD – how do you think the strategy will fare if you are required to increase production?

PM – that's what we want. This time last year we would be worried, but everybody wants it now. Because we have things being more efficient.

MM - Its only pockets of everyone wanting it though.

PM – Communication has been an issue between production and maint. in the past…gaining access to machines.

In the past there was a production scheduling system that was scheduling based upon 85% OEE. Last year the OEE was around 75% so it's hardly surprising that there were issues.

Conclusions and points:

- Very keen to work together and move forward
- Recognise their deficiencies
- Not interested in supply chain processes or maintenance
- A lot of impetus comes from the senior maintenance engineer (ME)
- They are interested in CBM
- Never mentioned a CMMS
- No real metrics in place for tracking the maintenance performance
- Use OEE but no link to maintenance as a measure?? Linked to cost within their reporting mechanism…
- Culture an issue for really pushing maintenance into realms of PLM (with shop floor)
- No true feedback and communication with parent company
- They do not trust the benchmarks provided to them from other businesses within the group.
- Budget is very restrictive
- Training or CPD for maintenance staff not in place
- 9 maintenance technicians in total. 3 per shift.
- Current allocation of 1 hr per day is when there is a low volume of production. Would it still hold if OEM ramps up?
- **No measure of what they want from the hour.**
- Their way of dealing with supply chain issues is to hold a buffer stock…no communication of best practice.
- Piloted a PLM strategy in a non-crucial area….an indication that they possibly don't measure risk (to production).
- They recognise their need to model their own risk analysis for planned maintenance activities.
- Varying degree of machine age and quality. Maintenance plays no part in the procurement of kit…so no opportunity to engage with standard equipment for each incoming machine. Such as PLC's, pumps, motors, robots. Varying machines mean bigger stores and parts etc.
- Communication of MS came from Senior Engineer (ME) not Senior management…bad thing?

- Admitting that their new strategy is dependent upon the operators getting an hour to do PLM activities. If they don't get it, then the MS would fail.
- Want more production as they are more efficient but they have no real measure of maint. performance! How do they know it's efficient?
- OEM only interested in certain metrics of process which they deem critical…nothing else!

Appendix 2.2 Observation Notes Plant 1

Plant 1 Observation – with Maintenance Engineer (ME),

Bullet point quick conclusions:

- Morning meeting attended by maintenance. All functions report. Attended by Manufacturing manager (MM). Errors and issues aggressively pursued. Relatively cordial atmosphere. No real issues with maintenance here…
- Maintenance reports on how may PLM's carried out or missing by each individual area at morning meeting. MM pursues missing PLM's - reminds meeting of meaning of them and their benefits.
- Several reports generated by ME indicating frequency of PLM on each individual piece of kit in the business.
- ME identifies critical parts as well as critical machines…alot rests with ME.
- Reports are aligned with business objectives.
- Maintenance budget is £1,000,000 pa
- There is a CMMS system which is used inconsistently and infrequently, but produces a planned maintenance schedule.
- Maintenance has KPI's which are aligned with business objectives but tend to be based around cost, BDR (break down rate) PM and PLM completion.
- Each individual production area has, the below. These are the 5 pillars of the strategic parts of the business and maintenance has no different. BUT maintenance does not have a display board like this.

- Reports are sent to Parent company and a return is sent with a happy face or a sad face (i.e. if not hitting their benchmark). If you get a sad face then you must complete an action plan.
- Conversation with Plant manager (PM) indicated that the TS audit is a 'health check' and does not drive business improvement. It checks to see if you have things in place such as critical parts list as well as preventative maintenance plans. It does not check if they are effective! It purely establishes if there is a control on things which may affect the customer.
- PM sees maintenance progressing towards condition based monitoring but recognises that the department is still '60% reactive' so time and cost are an issue.
- Production Engineering work autonomously and do not consult with maintenance re: new lines and commissioned plant. Maintenance capacity is then used up to 'mop up' things which may have been prevented if communication had improved.
- Energy usage monitors are to be installed which demonstrate energy usage during m/c usage and when idle. The operator must not go home until he has ensured that when

his m/c is idle, it is at its baseline for usage…I.e. no background processes are running that he is unaware of.

- This will happen, though PLM activities are still being missed.
- Paint plant has multiple quality and culture issues…though culture may still be a problem elsewhere (with agency)
- Attended quality meeting with multiple attendees from maintenance, PE, paint, Improvement team etc. where quality issues were discussed.
- P Plant…has a high scrap rate due to poor PLM and housekeeping probs…

Additional Notes:

- ME has established a measurable improvement with maintenance performance over the previous 2 years.
- The impact of this has led to a high degree of influence with SM at Plant 1.
- PM has maintenance background which helps.
- A lot of the drive for maintenance improvement and development rests with ME…it does not appear to be embedded in the culture of maintenance team?
- Handover is poor at maintenance team shift handover. Little communication…which led to a comment from ME that this lack of communication can lead to increase lead time on job completion. ME was at the handover meet and no one seemed bothered!
- A huge amount of the maintenance impact is down to one person - ME, this is a concern as it then leads to the conclusion of what if they weren't there? Would the drive within the business be there?
- The maintenance technicians seem to rely on ME heavily and call ME out a lot…to check if what they have done to sort a m/c out is OK. ME doesn't mind this but does it remove autonomy and ownership.
- ME admitted that he does not let the junior maintenance engineer make commitments in meetings in his absence…so he has full control maybe?
- Does this control prevent a lack of ownership and autonomous activity by her team…and indeed the SM??
- Do they have an established strategy? It is based on a mix of reactive, planned and preventative. Is it what they need though? They mention moving to CBM and predictive, but do they have the infrastructure to support that. What do they base their strategy formation decision on? ME? Experience? Knowledge? Or a strategy formation…?

Appendix 2.3 Transcript MM Plant 2

Questions for Maintenance Manager (MM)

Meeting – Plant 2

Present:

Derek Dixon (DD) – SL and Researcher at UoS

Interview questions for MM (maintenance manager):

DD – MM, for the sake of the record, would you like to introduce yourself and talk a little about your role?

MM – Sure, my names ***MM, Senior manager*** *for design and engineering projects. Part of that remit is* ***to oversee maintenance and tool room maintenance aspect at Plant 2 Europe****. That involves setting and managing KPI's in the business, planned maintenance schedules for both facilities and tooling as well as ensuring there is enough resource to carry out those focusses as well.*

1. How do you select your Maintenance strategy?

   *MM – Erm, through a number of channels****, no one set structure if you like****. The company goes back 25 years; a lot of the early equipment came from Parent company – with critical spare parts from Japan.* ***Planned maintenance schedules were written in conjunction with our head office*** *if you like, so on the older Japanese equipment the* ***PM plans have been borne out of their experience almost and we've sort of maintained what they saw to be the critical tasks****. With more recent equipment we work with the machine supplier to determine the more critical spares, the PM schedule becomes part of the machine specification when we're actually purchasing equipment, we have that in place from day one. On the tooling side we tend* ***to set the PM schedules based on experience of similar tools or similar tooling construction****.* ***Or we will start with a plan, and we'll adjust***

	that to suit...depending upon the criticality of the product, quality, tool life if we're seeing regular breakages, *that type of thing and we'll amend it to suit.*
2.	Who are the key decision makers? *MM –* ***My side is to oversee it and make sure the guys have the targets and they understand from a company perspective what the targets are****. So at KPI level. On a day to day level it starts with the maintenance team leader, to the maintenance supervisor. Those guys will use all their experience the* ***maintenance supervisor will then be responsible for managing the TPM schedules.*** *We also have* ***an administrator in place who issues all the weekly TPM tasks and schedules to the technicians directly****.*
3.	What are the key performance indicators you use? *MM – We look at* ***the downtime performance of the production lines****. We have a lot of production lines here,* ***we have 70 plus production lines*** *or what you class as production lines. Sometimes there can be between* ***5 and 10 assets on each production line which is then broken down into 20 or 30 sub components****. So very, very quickly it becomes very difficult to manage each little piece of facility if you like. So what we do is we look at the critical lines, whether that be if they're highly loaded with capacity, or the type of product they're making,* ***or its through the customer we're supplying to****. Not that you should judge each customer differently but* ***each one has different standards*** *within themselves in term of QCD. So that's where we start it as a baseline. Its reviewed daily through production meetings, so production have the opportunity to tell us if a line is not performing within a 24hr period so we can go have a look at it. But then there is the normal shift and section performance KPI's which will measure* ***downtime, OEE, scrap and such like****. We'll look at that versus our maintenance schedule and how its performing.*

4. How is the current MS performing in your opinion?

*MM – I would say that it can fulfil the target that is set, but I would say that we're at a crossroads where **ageing equipment which is probably 25yrs plus now, the regular TPM or regular planned maintenance isn't probably getting to the real nitty gritty of the issues**. So it is actually being revised now, we're using a lot of external support to give us a boost with manpower and resource to come in and look at what's broken, lets fix it and let's look at some sustainability again.*

DD – so is your **internal resource** for doing that type of thing **limited**?

*MM – **Yes, very much so, limited by manpower**…we've got over **1100 different pieces of facility here and we've probably got over 5 times that in tooling**. The maintenance squad and the toolroom squad there are some **30 people**, so it doesn't take a lot to work out you've **not got enough human resource there to run a proper PM schedule**. So that's why we need the external support really.*

DD - What sort of strategy do you think you have?

*MM – Its **reactive borderline breakdown maintenance at the minute, due to the manpower versus the number of assets**.*

5. What are you basing your assessment on?

N/A

6. How do you mitigate the risk of the Maintenance strategy failing?

MM – We've got some examples of that actually, we've previously ***dual tooled*** *so we've actually* ***doubled the tooling*** *to allow the product to be* ***made on 2 different lines*** *and it can be made at the same time or to fit in with different production schedules, we've done that when its been a high runner when we've thought 'well if this facility goes down, then we've got a big problem' s* ***we've spread some of that loads by dual tooling****. The other thing we've done this year is identified* ***critical spares*** *that you would normally class as CapEx items. For example, an extrusion line might be made up of 20 small pieces of equipment or machinery that come together to make that extrusion line, so we've actually said this year 'OK if we've got 6 extrusion lines, what components are critical to the process but are also common amongst those lines, so if we had one spare unit, would that be able to facilitate the other six lines. So we've started actually buying in components we can keep and what we're doing is removing an old unit, putting in the new one, refurbing the old one and then moving it round. That way we've almost got a continuous improvement plan.*

DD – Something that several plants utilise is **break glass stock or safety stock**. Is that something Faltec do?

MM – ***Yep. We have break glass stock****.* ***OEM certainly insist on breakglass stock,*** *we put* ***breakglass stock in a couple of years ago where we got to a position where we were so close to missing cars never mind delivery slots****, working almost JIT when we* ***should have 2 days stock in place****. So now, that is the* ***standard*** *where we have* ***2 days safety stock in place****.* ***Customers*** *will have* ***vary*** *and obviously it depends where we dispatch to. We dispatch as far as Japan and China. But that works on a slightly different routing where we ship to the OEM then they ship to Japan. So we normally work on 2 days safety stock.*

DD – Is your calculation for how much you hold based upon how much the OEM requires? Does the information come from that direction?

*MM – We work it on an **average of the weekly take if you like and the forecast**. We work on fixed delivery schedules and we always have a mid-term forecast and that's like a 2 way thing the customer, they'll give us a schedule. We'll also look back in time a little over the last 16 weeks as maybe the forecast are just that, most of the time they're accurate and close but actually historically over the last few years the forecast doesn't actually materialise against the actual. So we look back as well as looking forward to get that balance.*

DD – So is that safety stock finished goods?

*MM – **yes**.*

DD – do you hold internal safety stock as well, in between processes?

*MM – **Yes, we do. That's our own buffer.** We try again to employ the **2 days safety stock** but it depends what the processes are. Typically the finishing process might run at 100 units an hour, but the **extrusion process** might run at 3 times that. So we may look to hold **12-24 hours' worth of stock on those lines**. **Service parts** becomes a **different** animal altogether for automotive. We've got to **keep the tooling** as service parts can go **back 15 years**, so we tend to have those **batches** with only **2 or 300 units**, but they might **last you a year**. So its dealt with separately. **Ideally** our best scenario is have about **24 hours internal stock for what we produce for our secondary processes**.*

DD – what decides that? The 24 hours or the length of time a company is comfortable with.

*MM – **The length of time it takes to change over from product to product, as we have a lot of shared facilities**. That's a **big factor, the output of the OEM**. All OEM's have different outputs, we're getting to a point this year where we're trying to **educate** the **production guys** into thinking what the **customers TAKT time is**. How many cars are they producing each hour, how does that filter back to what we're making each hour so they can get a visualisation of, if **we make 120 components, that's 2 hours of what the OEM can make**. So **every customer is different, every OEM is different**. We obviously take into consideration the scrap rates, the OEE and the downtime.*

DD- so if there is a maintenance issue, that comes into it as well?

*MM – **yes, its got to**. If you've got a **poorly performing line**, and you've got **6 hours' worth of stock** – then you're **1 big breakdown away from stopping someone**. So you've got to **look at the risks by line** almost.*

DD – That cost of the safety stock...is it cost analysed?

*MM -**Yes**, its run on a spreadsheet by our production control department and shared in our managers meeting every Thursday and obviously what we do is we have key KPI's in stock control and stock management and working number of stock days if you like. It's a KPI that's et by head office in Japan. We have a value against that and we review that value every week.*

DD – As much as possible you'd like to bring that down?

*MM – **yes, absolutely**.*

7. If answer is buffer stock…how does this fit with lean principles (depending upon production system answer!)

   N/A

8. Do you have a direction you wish the Maintenance Department to go in?

   *MM – I'd like to see, we do a lot of manual inputting and manual checks and balances. I'd like to see a much tighter tie in with regards to the **downtime accuracy**, and the **reasons for down time** and then also **link** that back to when **we maintain or improve a line go back and visit the effect of it**. **That's a missing link for us**, we don't really go back and visit the effect of it**. If it is effective**, then we have **a lot of similar processes**, we should be **horizontally deploying that across the business**. That's a missing link for us.*

DD - Does the maintenance department have objectives?

*MM – yep…both the maintenance department and the toolroom maintenance have a target of better than **97% complete versus planned for TPM across the year**. That's tracked weekly and published monthly. Also linked into the **presidential policy** which is what **all the Plant 2 plants get set from head office globally**.*

9. What is the skillset like within maintenance?

   *MM – I'll be honest its **varied**. I've been here 16 years and started as a maintenance technician and when I started here there were always guys…a bit like a football team where some guys were better at heading a ball, you know. I* *would say* ***the general skillset was higher than maybe what it is today****. I think that, we're at a position where we've had to* ***sacrifice some skillsets****, where individuals have been particularly good at one thing where we've been lacking. So, if I was looking from an electrical viewpoint…we want all our guys to be able to work on machine installations, we want all our guys to be able to fault find on conventional PLC controls and we've been in a position where* ***jobs have been hard to fill in the past****, because there is a* ***limited resource in the North East that tends to get sucked up by the big guys****, if I'm honest. Bigger than us. So you may look at* ***someone who has a really good skill set in PLC fault finding and you may know that you're willing sacrificing a bit of manufacturing experience for a bit of automotive experience*** *and maybe not having the experience of being around such a high pressure environment you know. You've got to kind of weigh that up a little and I think* ***that's where the maintenance guys are at****.*

DD – How have you find the apprentice side of things to support that?

MM – yes, we've been doing that ***6 years now*** *and we have* ***5 guys have come out of their time*** *now since we started that programme. We've* ***lost 1 electrician*** *who went to a job closer to home, to another Tier One who was a* ***big loss as he had a very good skillset****. What we've done is employ apprentices from the maintenance side we've* ***employed mechanical and electrical apprentices separately****. We* ***have introduced training for them to be able to cross over from mechanical to electrical say, but what we've found is that they always want to go one way****. Maybe on paper they get* ***classed as multi skilled but they tend to go one way or another depending on what they're comfortable with****.*

DD – Are the guys who they work with one way or the other?

MM ***– yes and that's part of the issue****, they almost get divided up by…****its hard to break it****. You have* ***apprentices who are cross trained*** *and they're* ***mentored by guys who are electrical or mechanical bias so they naturally will fall one way or another****. What we have done is we've made sure they have well rounded skills*

and cover every aspect of it whether it be through…maintenance guys have also been on fitting and turning courses as well so they have some tool room skills.
10. How is the training identified and where does it feature as a priority? *MM* ***– It always features highly on my list that's easy to say****. When I make my mid-term plan or the business plan for that year one of the key objectives that I always set is we look to make a robust maintenance plan, whether that's achieved. Cos, you know that* ***people are always going to cut back costs and one of the first costs to get cut is training****. Last year we did the best I've seen us do and we had guys trained on PLC's pneumatics and hydraulics…we did really well.*
11. What production system does the company use? N/A
12. What are the objectives of the production department? N/A
13. In your opinion, would the operators and skilled staff welcome a change that saw them carry out additional duties? MM – *I think that* ***would fit really well****, for* ***production to manage the low level*** *and have that* ***autonomous aspect to it****. To be honest about it, it would* ***just be taking us back to where we were 16 – 18 years ago****, that's what* ***we used*** *to have. We* ***lost our way with that and it was probably when we had the shift in the number of temporary production staff in****, so* ***when that ratio changed, we run a really high ratio now of temporary staff*** *and that becomes* ***really difficult to get that mind-set in place*** *and train that out and* ***make it sustainable. So that is definitely been a setback for us.***

DD- that's interesting, I was at the maintenance forum yesterday where OEM presented. They had an issue in their body shop where they had lower OEE. They wanted to improved that by improving the TPM performance of operators….the resource they placed into it was unbelievable. I don't think they have that agency capacity that a lot of Tier One's have….would you agree?

*MM- **I would agree**, but I'm sure they have their share of staff turnover. One thing I think that **OEM always** have is that they will always **naturally get the best of what's available first**. **Even temporary workers** will know that they can go to OEM and make more money. And for temporary workers are looking for quick money first, you do get ones who are looking for a job and a sustainable future...you do get those **but we tend to get the ones that are in and out. I've seen guys last a day, just don't fancy it**. I've wouldn't imagine that OEM have the turnover of agency that we have.*

*One of the things that I think helps the **OEM's** is that **they're governed by a TAKT time**. So they have a continuous conveyor, they're plant will make 60 cars in an hour. It's not an if, but or maybe, that plant will work to **60 cars an hour** unless there's **a major breakdown**. When you've got that type of set up when guys are coming in knowing they have only so long to make that component to fit before the next one comes along…I think that changes things, **alter the culture, very driven to target**. When you have processes like what we have, like extrusion, and roll forming when the **machine governs the output and we set the line speed** it will keep on making, **unlike bend and press processes** where the **output is governed by the man so his pace governs the output**. Even when you have a robot or automated process, there is still a manual element to how many parts are fed into that cell. **If that guy is not on his game or doesn't fancy it**…*

DD – that's really interesting point cos that TAKT is running at a set speed and you're driven by that…

MM – that's it, that's is your ***TAKT time****, you're driven by the machine output almost, it doesn't matter what you do you must match that.* ***It's a different driver almost****!*
14. Is maintenance a key factor in the stability of the supply 'contract'? N/A
15. IF COST is a contributing factor, on what basis do you measure your maintenance department? N/A
16. Would you alter your MS IF it could be demonstrated an improvement in cost to the business? N/A
17. What are the primary factors you would consider if you decided to change your MS? N/A
18. What sort of relationship do you have with your supply chain? N/A
19. Is best practice shared throughout your supply chain? With the OEM? Does it influence maintenance?

*MM – Hmmm, I would say that they indirectly the **OEM can have a negative effect on maintenance and planned maintenance**, by the very fact that it can be so difficult to actually get support when it comes to getting support for **facility investment** to keep their product running for their plant. For instance, lets say that OEM decide to **volume up** on Model 1 car that they're making now. We'll go through a process where they'll say OK, we wanna bring in another 50,000 cars a year. What does that mean to your plant? You'll go back and you'll say 'OK, well actually the line loading is now this, the line loading will be …that. But actually we'll then **lose maintenance time**, so actually we **need another facility** or **some investment**. And what you'll find is they say, well youre **not going to get that facility or investment** so what you'll have to do is **drive your OEE up, drive productivity up and downtime down**. Yes that's great, but you **actually need more line time** to be able to do that and you're **giving us less time to implement those improvements**. You can get caught in that and I've seen…well we're in a scenario now where **we've got some lines running continental shifts and we must run every hour and we cannot get the time to do any maintenance on them**.*

DD – Really?

*MM – So it **becomes breakdown maintenance on those machines**. So I would **say it's a negative impact actually**. The **Tier Two side** I would say is more **about the quality that they bring in**, we can control that better if we have better quality assurance of what's coming in…*

DD – do they offer any best practice downstream?

*MM **– Sporadic I would say**…to be honest I've got some good contacts within OEM's and I would say it tends to be **when you've already got a problem** and its **almost too late** and it's **in their best interest**. You get caught between that thing where…and it might not*

be the maintenance guys that share best practice with you but someone in another department will know of it and wanna share it with you cos it will help. ***OEM*** *especially are trying to set up* ***an initiative*** *around the* ***Tier One supply chain to share best practice around planned maintenance****. There's a* ***level of scepticism around it*** *about whether the Tier One's are gonna be feeding OEM with information or whether OEM are going to provide something…****it's a shame but that's business*** *really.* DD – but its so combative when people are looking to secure those contracts that people are naturally going to be defensive? *MM – a little bit and you gotta be* ***careful that you don't end up in a pool with Tier One's where you end up competing for business****. That's the difficult bit. I would say its sporadic…****I've seen it shared but never sustained…***
20. Is that valuable? N/A
21. Do you review the technical capability of upstream suppliers? N/A
22. What are your main issues with your supply chain? N/A

Appendix 2.4 Transcript PM Plant 2

Questions for PM

Meeting – Plant 2

Present:

Derek Dixon (DD) – SL and Researcher at UoS

PM – Senior Manager, Manufacturing and Kaizen

DD – PM, for the sake of the record can you tell me what your role is within Plant 2

PM – I am senior manager, manufacturing and Kaizen. Kaizen is to do with waste and improvement. This is only a small department with about 2 people in it, but my main responsibility is manufacturing.

1. How does the business select the maintenance strategy that is employed here?

*PM – I don't have any real input into the maintenance strategy, **I will voice my concerns or give my input but generally I haven't really been involved.,** that is the responsibility of senior manager MM.*

DD – But you do have some input into that?

*PM – **I do have some input as in how much I complain**. I don't want things to break, I want things repaired faster. And I'll voice my concerns if the processes aren't right, I'll complain if there's too much waiting time. Effectively, **I see them as a support department** and I will call it healthy friction, where I'll push back to the engineering maintenance department. That's where my input is…*

DD – You have a healthy feedback into the process, however it performs.

PM – Yes.

DD – What are the KPI's for maintenance that you are interested in?

*PM – In terms my measurable's and how maintenance performs**, its downtime**. And in all fairness, I split that out. I see **self-inflicted downtime where my department is responsible for it**. For instance, if we hadn't set a tool correctly and we damage it or from a skill point of view and we adjust settings we can't manage. That's an area we have to control, so I call that self-inflicted downtime. Then there is the process related downtime which is difficult to influence when things actually breakdown.*

DD – Have you guys got a way of differentiating between those two? In between the self-inflicted and the process?

*PM – We separate it out into down time codes for our production reporting. So, we know if its electrical, mechanical or tooling. **However, to answer your question of separating that out, there is no measure of it, other than the reporting that goes on within the handover or the production meetings. So its not something that we generally separate out**. If you asked me to quantify how much is self-inflicted and how much is process, I'd say one quarter is self inlicted – maybe as high as that.*

DD – What do you think contributes towards that?

*PM – Skill, training. **We have a multitude of processes within Plant 2. From Injection moulding, painting, pressing, extrusion and it depends on the level of skill and knowledge within the manufacturing operation, and maybe a lack of TPM, lack of skill, lack of care and attention, the handling of tooling**. That's a fair representation so I think a quarter of it could be at operator and team leader level.*

DD – At operator level do you have a certain amount of agency staff? Does that play a part?

*PM – **It plays a very, very big part**. We as a business has changed quite a bit over the past few years. Where before, it would be 100% permanent employees and we had very robust training, and we bring people from recruitment earlier, I think we respected the processes maybe more than we do now. I don't know if you're familiar with co – extrusion (sic), quite a difficult process and when you have all your permanent people and a stable workforce and the turnover of staff is minimal, once the business decided to bring on agency workforce – and that can work to a degree, so it became 10% agency, 20%, 30% **and now over 50% agency**. Now we call them agency but they have a permanent contract with an agency provider and we work very closely with them but at the moment our recruitment -some of it has been proactive and some reactive. Reactive because of problems in the process, poor OEE meaning extra shifts, extra hours, extra labour. We're going through a period at the moment where we're struggling to recruit people of the right calibre. So I'm working at the agency at the moment as I feel that they're not selecting the right people. So, we're going through that challenge but its also what we pay as well. So we've got a bit of an HR strategy at the moment to see how we change that for next year. So when you're introducing that level of unskilled labour – cos a lot of them are unskilled and while our processes you cant completely fool proof them or poke-yoke them so mistakes get made. So that is where we can cause our own problems.*

DD – You're not the only business that I've spoken to that has these challenges.

PM – its worked very well for us in the past, we've done it for years now but I think there's a level, I think there should be a safe ratio. I think we've went past that. I think I've made 40 people permanent this year, but the level of headcount I've got it hardly made a dent. I think the biggest change that's coming though is when we go to the living wage, off the top of my head might be another pound. So that, with some improved selection and pre-

employment vetting, I think it should all come together. We as a business cannot afford to go to 100% permanent employees, that's for sure.

DD – How is the maintenance strategy performing at the minute – in your opinion?

PM – ***Very poor. Why I say that? Because I would question the strategy****. Where we are talking about becoming leaner, we've done that in all areas of the business. I surprised myself when I did some reflection, on how many operators I had per a team leader and where I am now. As an example, I had 1 team leader for every 8 operators. I've got one for every 12 operators now. That's a 73% increase in the amount of operators but that's fine if your process is stable and reliable with good, strong OEE. And I've seen businesses have 25 operators for every team leader but where we are is we're introducing some difficult projects, we've got difficult sections and processes it gets back to the maintenance –* ***I believe they're under resourced. They cannot cope, we've got ageing equipment out there which means its getting harder. We've got a lot of different types of processes, so they're under resourced.*** *I don't think that if you look at the* ***skill set of our maintenance department they're capable of managing the level from a pint plant to an injection moulding machine to various different types of presses and extrusion lines, there's an element of that****.* ***There's only a very small number of key personnel that we rely heavily upon to get us away,*** *and another thing I think there is some serious* ***cultural issues*** *with the maintenance department. For instance, the manufacturing culture is bell to bell working, productivity, achieving tac times and targets. The maintenance department, I don't think there are enough measureables. I don't think they buy into the fact entirely that they are a support department, that we are here to make parts and that we need to be efficient and we're cost driven. In the background if I fail to make a delivery its as long as they're not getting made redundant, so I think there's an issue there.* ***If you'd have walked through the tool room to the maintenance shop, you'll see them stopping working 20 mins before the end of their shift to wash their hands ready for leaving****. If you have a breakdown in that time you have to wait of the next shift!*

*Now I don't think I'm outlining things that are any different to other businesses but for me when I'm driven by Kaizen and manufacturing **that's a difficult pill to swallow**.*

DD – It's a traditional model in a way. I started my career in maintenance which feeds my interest now,….

*PM – It would be unfair to say the whole department is like that but there is a lack of urgency. We've been here 25 years, it was 1989 and there's quite a lot of people been here that long. I think it is in their culture, will it change? The managers have to be different, but they're the ones who came through that culture, working with the same people and they're managing them now and I think there's an element of allowance given. Also, I don't think they're challenged. **There's an element of 'don't upset them' cos I need him to come in tomorrow**. So I see that. If I was to manage them I would be mindful of that but I'd like to make changes. So in terms of the strategy, I know MM is working very hard, I respect MM a lot. I don't put MM in that mould -at all, he obviously has to rely on his managers and senior supervisors, I know that sort of thing upsets him – he doesn't understand it. He's strategic, he wants to make changes, I know he wants to look at critical spares and TPM. But also, I know that the guys just want to get the line away. They don't question the root cause, its band aid, superglue, then back to the tool room. It's not 'why did it break down', 'what are you going to do different'? None of that is done in my opinion.*

DD – And you think that's a cultural thing?

*PM - **Yes**.*

DD – You mention measureables for the maintenance department, you don't think they're in place?

PM – I know MM has brought them in, have they been embraced or is it a tickey box thing? In my opinion, of course confidential , if MM was actually manging or supervising maintenance I think they'd buy into that. But unfortunately he's not and he's relying on his managers and supervisors and I don't think they really buy into that (bangs table!). and then it just becomes a graph, so when it does become overdue and it does fall behind, he ends up getting involved and focing the recovery – when they never actually got there in the first place. I feel they're not strategic in their mindsets – at Plant 2.

DD – Its interesting you say that because the reason I got involved in this research is that people have a perception or opinion that in the automotive industry that its very lean and well refined but in informal conversations I was getting that the impression that may be the case but maintenance wasn't always part of that.

PM – I'll give you an example of something a few weeks ago. OEM, three quarters of a mile away, our biggest customer, we had an ageing bit of kit, cold roll forming, it only needs to run a few hours per week, its got all the capacity in the world. Spits out 1600 parts per hour and that's for the juke. Its an inner sash, so worst case – we're not going to stop OEM. Its not a wheel arch or something. So,the machine broke down. It broke down on the Thursday and we couldn't repair it by the Friday. So our stock started dwindling. It came on our radar on the Friday from an escalation point of view. We tried to repair during Friday but then we didn't have enough parts to clear their overtime build on the Saturday. So on Friday afternoon they're getting very anxious – they're saying 'do you need our help'? No its OK, we know what we're doing in a roundabout way. So we found out that we didn't have the right sort of PLC, then we found out we didn't have the right spares, then we found out we couldn't get spares. So OEM came over, right and MD Plant 2. So they looked to see if they had compatible spares, which they did and so effectively they took over, took charge. Eventually, we ended up working round the clock right, all the way through to the next morning. I had my shift manager in on the back shift, he came in first thing Saturday morning. I said to my Production manager ' Look, *when they get that running, you've got to be ready go, no excuses, its got to be ready and another thing from a recovery point of view, peg up production and staff for the whole weekend. Not a minute warning, just be ready.' On the Saturday morning we did a complete stock check and it looked like we were going to be 30 parts short for the complete build (OEM). But earlier in the morning it looked like we were going to send the whole plant home (OEM). So they were either going to build the cars without doors, or send the whole plant home. So imagine sending 4,500 people home and the consequences, its going to Director level. So our culture is a lot of waiting time, maintenance come over, and we sort of get it away. SO when you're talking about first tier, we're not that sharp. Don't get me wrong, when I'm selling the company profile I'd tell a different story that we could do it. But the reality is different.*

So I came in on the Saturday morning and our maintenance squad was standing in the corner and the OEM lads, and there was about a dozen of them, were everywhere on this machine. So I said to my production manager, if they get this away and we're not ready to go and press parts, that's going to be a problem. But that's the difference between the OEM and us…but it gets back to the right resource, the right number of people with the skillset, the urgency, that plant cant not make a car. But over here, they'll let me wait for 30, 40 mins – sometimes 3 hours because of capacity, recovery and stock. Another thing is equipment. We didn't even have the right laptop and spares for the job,. So now we're on their radar now, for critical spares, OEE, maintenance strategy. Now MM has had proposals before in the past – he's not happy with where we're at. Right now we're not making a profit, from the customers point of view they want continual cost down year in, year out. So for every pound, annually its 5% off TDC (total delivered cost). So everything is going up, materials, labour, overheads but they want the cost bringing down. So we've got to find ways of taking cost out the part and by its nature headcount and support comes into it and is removed. But then again you tip over and too much downtime happens and too much scrap. So its getting the balance right.

2. Does OEM share best practice?
    - I do engage with them for helping us – production wise, but feel it is political and PR.
    - Don't feel it provides much cost improvement
    - If dont engage with their initiative, then they may pull business. They have in the past.

3. What is the contingency if maintenance strategy fails?
    - Having 2 days safety stock
    - Honda have 2 days at their plant as well
    - Contingency with alternative lines for some processes
    - Maintenance very reactive
    - Shut down activity very minimal
    - Spares are minimal as the cost is horrendous.

4. What are your spares purchasing policy?
    - Purchasing don't get involved really.
    - At risk in a number of areas of factory due to machine manufacturer (some from (Japan)
    - Critical spares an issue. Lack of urgency in this area from maintenance. Pushed by Paul as a matter of urgency.

5. What do you report to the parent company?
    - Monthly report
    - Productivity -which is OEE, downtime, scrap.
    - Very productivity focussed reporting

6. Do Maintenance see themselves as contributing to those KPI's?

- No. No chance. I don't believe they think they contribute at all towards that.
- I don't think they care.
- They get their overtime anyway – every weekend.
- Feels there would need to be a staffing change to change the mentality of dePM.

7. What is the production system?
    - Production system is synchronous for paint line.
    - Rest of production is batch – dependant on stock or customer.
    - Stock replenishment effectively.

8. Does Production and maintenance have different objectives?
    - All my departments have a display board on show which show the performance of the department against the targets – all the measurables.
    - Maintenance don't have that. They have a graph for is PM on track.
    - So what? What effect does it have? Where is the display for that?

9. What is the selection process for a supplier within the auto supply chain?
    - At the moment I know we're very close to being black balled due to previous problems.
    - Normally quality is 10ppm but they want us to get to 3ppm for the infinity.
    - At the minute its 25ppm – due to staff and projects.
    - They would place cost above any long term supplier relationship.

10. Tier Twosuppliers how do you select and do you share best practice:
    - Driven by purchasing dept.
    - Very few problems from supplier

• Not a great deal of experience with sharing of best practice with Tier Two.

Appendix 2.5 Transcript OD Plant 3

Questions for OD

Meeting – Plant 3

Present:

Derek Dixon (DD) – SL and Researcher at UoS

OD – Operations Director Plant 3

Acronyms: NEAA, CapEx,

DD – OD, for the sake of the record can you tell me what your role is within Calsonic.

OD – I'm operations director which covers all of the North East – which is effectively 4 locations but 3 manufacturing operations. We also have a warehouse within Doxford park. That's where all of the off-site product comes in then gets delivered to OEM. So I cover all of that from an operations point of view.

DD – that place at Doxford is relatively new as well isn't it?

OD – Its not a new building, it was a call centre that had a big warehouse attached to it. They moved out and we got the building at the end of November and we then over January, February March last year we put all the stock in. Vantec used to do it for us, but not very well. So it's a 100,000 sq ft warehouse, it has a huge office block attached to it.

*So we have about **23 million of stock** in there. That comes globally, anything non-local. So all the local stuff goes direct to line. The other stuff, UK, Europe and rest of the world comes into that warehouse the 6 days of the week.*

*At **OEM we only have 2 hours' stock** there as floor space is at an absolute premium. Really, the best place for that warehouse is OEM, but they don't have the space so…that's the 4 locations.*

1. How is your Maintenance programme designed?

OD – Erm all 3 sites are very different. You can discount Doxford as it's a warehouse operation and any maintenance done in there is done on material handling equipment and that is sub contracted through the leasing company anyway. In that plant we have no maintenance people. The differences with the 3 sites, ***this site here today is 30 years old this year and the maintenance plans and strategies have been developed over that period and to be honest are quite reactive rather than proactive****. That's built around us having a very skilled maintenance function ok, they can* ***stick a plaster on anything*** *and we really need to change. The guy in charge of maintenance has been here 26 years and knows everything inside out and it is quite engineering focussed where a lot is automated. We have* ***service contracts*** *in place with people such as ABB – outsourcing contracts, so on a 6 month or annual basis ABB will come in and service all of our* ***robots****. We have a number of service contracts which have been developed over the years, and our maintenance function does do* ***some preventative but not as much as they should****.* ***Mainly because they know the product inside out and can fix it quite quickly – which is wrong****. The problem with this plant – well both manufacturing plants really, but we'll stop on this one, new model introduction tends to bring along bespoke kit. New robot cell, new drill etc. The bit it doesn't bring along is the* ***generic pieces of kit****, such as a saw, benders which tend to make all the product and they tend to get forgotten about. So all the new model launch we tend to* ***invest around 4.5 million every year on something****…lots of things. But it tends to* ***be focussed on a new model*** *so you need a new robot cell, then that's what you need. But the bit that bends the pipe – ahh that's all right. We bend pipe anyway and that kit is anywhere up to 30 years old. And* ***CapEx is so tight, we tend then to just carry over and carry over and carry over****.* ***And that's the area where we fail a lot here, it's the peripheral equipment and also the buildings****. We'll not tend to spend money on buildings.* ***Our CapEx is quite tight, we're a OEM affiliated company,***

so all of our capital expenditure requests need to go to OEM. For example, in Europe our CapEx plans were 14 million that got reduced to 10 million..

DD – and that was out of your control?

OD – the reduction?

DD – yes

*OD – yes. Basically **from a cashflow point of view, as we have no money**. So the exhaust one, **old site**, **very experienced people and focussing on new model equipment**, that's great but not so much on the carry over and not so much on the building and **very good fixers**.*

*The old site in Sunderland, a lot of history on that site. A similar age to this site, maybe 4 years younger than this, but **the old plant invested very little in equipment, maintenance and plans**. So when we bought the company in 2008 **we bought a plant that was dropping to bits** and we bought kit that was **on its last legs**. It also **had a huge turnover in maintenance staff**, so different to this plant where you haven't got the longevity of the maintenance staff and that has been a problem for us. But **that has meant that we've had to put more proactive maintenance in because we haven't got the expert fixers**. We have in recent years invested a lot in paint and the paint plant – which we didn't have a clue about. Which bring in a lot of regular maintenance things such as changing the filters, changing the water – which we've had to learn about. Some of its contracted but some of it we've had to learn about. **At the other plant we've started to invest in new moulding machines over the past few years. The problem being that out of 32 moulding machines we might replace 2 or 3 a year. So it's a long, long process**. So the other plant, because of the nature of the product new model introduction tends to be on tooling rather than equipment because the mould machine is the mould machine. So we'll get the tooling but we'll tend not be allowed to get new machinery for new product launch. So we'll go to OEM and say OK, you want us to make these new parts and we'll go ok the tooling cost is 5 million.*

That's fine.

And ***we want new mould machines and they go NO – you've already got mould machines****.*

Hold on, they're like 20 years old

No, no – you have mould machines!

So the CapEx restriction is very, very strict there as well.

DD – Do you think those particular circumstances that you have just discussed are the norm? Or, do you think they are particular to Calsonic and these 3 sites?

OD – ***It's the norm****. I think what it is, is that we and I think with your research maybe all* ***the first tiers*** *– certainly with the OEM ones* ***are victims of their own success****. 30 years of hammering cars out. The* ***last 4 or 5 years about 500,000 cars a year is just taking its toll****. Today, OEM have a 3,500 tonne press down that broke last week and they tried to fix it and its gone down again. Line 2 is running at half speed and they're losing cars left right and centre so* ***even the OEM bit is probably just a victim of their own success****.* ***Building huge amounts of cars and not investing probably as they should have. So if that's happening at OEM – and genuinely that's happening at OEM today, you can increase it by tenfold for the first tier suppliers****. And all of the 1st tier suppliers know that none of us wants to be the next one that stops them like that, but one of us will. It'll either be us, Plant X, Plant Y, Plant Z any of those have the capability to stop them. So I think it's a good thing but it kind of,* ***probably all of us should probably have invested 10 or 5 years ago on where we're at now****. This year it'll probably be under 500, 000 cars…it'll be 480, 000 . But* ***next financial year from April is 570, 000*** *cars so its not going away and it does mean* ***actually every plant and company must have better preventative maintenance strategies****. Along with investment…*

DD – One of the things I have found and the point of my research is that so far all the plants I have been into have some issues and they can vary, but it all leads to the same point where the maintenance programme appears to be relatively ineffective. I'm also trying to identify some of the constraints which are preventing or causing that to happen. Some people are naturally defensive as well which is a challenge to overcome as well..

*OD – We have a **global maintenance diagnostic score**, and I had a **gripe** with it. I'm very honest with the plants, like I say this one here is very reactive etc.. And the problem I had is they go round and we **do our own score** and we had that **validated by Japan**. And they came across and **this plant had the worst score** – the worst **in Europe**! So I said, I'm all for improvement – not a problem. **But I absolutely can't believe that this plant is the worst for maintenance.** If you look at where we're at, were a JIT supplier. **We have to have 100% delivery** performance, we're a **7PPM plant** so the machine can't be dropping to bits and we have very, very skilled people. So how is this possibly the worst plant. You compare this to where I think is the worst, which is **Romania** they've anywhere **between 50% and 60% OEE**, they have massive problems with breakdowns and huge problems with accidents. They've had **1,000,000 euros of additional freight this year, because they can't make the delivery plan because they can't keep up with delivery as their maintenance is so poor.** So I'm all for the globalised approach and standardised approach and being able to compare, but there's clearly something wrong here. If that is telling me that, I can't go to the head of maintenance and go 'you're doing a shit job' as I know that not right. The problem on the global bit is that's fine, **are we looking at the right thing are we measuring the right thing** are we sending the right messages?*

2. Do you have an input?

*OD: - **No**. To be honest, if you look at my career in Plant 3 I started as a senior supervisor and yes my input then was to work with maintenance to help keep my kit going. Then I was manufacturing manager and that was at the time and yes there was an input. So I made sure the plant and equipment worked, so that was more strategic. So Engineering would always say 'they hit them with hammers' and I would say they don't want to hit them with hammers. They hit them with hammers cos they don't work! So that was working with maintenance and **maybe it was quite divisive but working with them then**. Then I was **plant manager** and that was probably the most input I would have…'saying, **what the breakdown rate this week'** or 'whats our biggest problem' but then **now** to be honest, rightly or wrongly **I have every little input into it**. If you look at my job, **now is to get the best operating profit in the North EAST**. Our failures in profit are around Sales and Materials and R&D costs or technical cost reduction. The pant has performed really well so I'm an Engineer by trade and I like the manufacturing bit and I could spend time with it but, its not going to get me any great benefit.*

DD Your personal objectives are different?

*OD – Now, I leave it to the plant manager's and the manufacturing managers. Now, you have **maintenance reporting to the manufacturing manager**. So you have manufacturing and maintenance. That's at all the plants. **I think that's right.** So my input now- apart from saying hello to the head of maintenance or nicking some nuts and bolts cos I need them at home…to be honest, **I would feel like I was sticking my nose in**. Although I've been honest in terms of the faults of those plants, they work very well. **I don't feel the need to**. The bits I do get involved in are the **top level KPI's** I get measured on from Japan are the maintenance scores of all the plants. Because ultimately that's seen as my area..**I would go back to Japan and say 'that's wrong,** that can't be the worst plant' so that's when I would get involved, more to defend the plants than anything else.*

3. Who are the key decision makers?

n/a

4. Does the maintenance department have any specific objectives?

*OD – By site we run with **business activity plans** and **departmental activity plans**. The problem is that each of those departmental activity plan differs in detail and I can't oversee them all. Certainly in maintenance there will be a departmental activity plan. That covers a number of KPI's which meet the needs of the business for instance, **MM who is manufacturing manager** – one of his tasks this year is to **improve the OEE in our press shop**. As it was really low and they've done a great job in that. Part of that is working with the **maintenance department to improve the downtime and changeover time**. **So within the activity plan maintenance there will be objectives to improve the OEE of the press shop** cos that's one of Ian's objectives as manufacturing manager. But the department activity plan will contain things like cross training, bringing in new apprentice's…whatever it is the department needs. So that's how it cascades. To me I have very clear plant operating profits and very clear functional budgets and then to meet those budgets or performance then it needs activity so yeah, there is a level where it drops down.*

DD – You've sort of answered one of my next questions which is how is the maintenance department performing in one of your previous answers, unless you'd like to add anything?

*OD – I think to a certain extent its very easy because it has to, the plant in **OEM has 100% OEE it literally cant stop**, out of the **other ones**…they **have excellent performance** but I think a combination **of skill, knowledge and damned hard work** maybe **hides** the*

underlying issue *of* ***not*** *doing enough* ***preventative****, but then the maintenance staff (and I do sympathise) will* ***argue*** *that we continually* ***cut the CapEx*** *to give them the monies* ***to invest*** *in* ***proper preventative maintenance****. It would be great if we could have a full suite of spares for an electric bender which meant you could have the same scenario as you have in OEM – you know where you have a plan B so it's* ***easy to do preventative maintenance*** *when you're in a maintenance department and you have it on a bench and you can* ***spend time*** *doing it, doing it when you have the coordinator and senior supervisor* ***on your back saying 'I just need it fixed!*** *I'm not bothered'* ***that's when it gets difficult****…****I think that's where we fail****. The modular approach, where we have something fail….take it off, put another one on and spend the next 8 hours refurbishing that one and doing some proper preventative maintenance. But don't just take it off when its broken, take it off after 3 months or whatever.* ***To be fair to maintenance they haven't got the CapEx to spend on plan B facilities****.*
5. Does maintenance have its own strategy? Is it developed, reviewed and moved forward? *OD – Because* ***maintenance comes under manufacturing*** *it would be up to the* ***manufacturing manager to review that*** *and I* ***cant honestly say how often that's done****.* ***Every week*** *there's an ops meeting chaired by the plant manager and there all the* ***review*** *all of the previous week's* ***KPI's*** *on an ongoing basis. So we review performance such as* ***quality performance, cost performance, OEE*** *and within that is machine downtime and we do* ***it by line not machine****. So every week we have a review of performance and where we are against plan and output. That's on a Monday, then on a Tuesday I have a review with the plant managers and they give me a scorecard with the KPI's that summarises that. But I cant honestly say that the detail behind the achievement of that number, how well that's reviewed. The* ***output we review every day****, every week but that really* ***is reviewing output as opposed to strategies and input*** *and I rely on the plant managers to review that and see where they're at.* DD – so the main measure for maintenance are the same as for manufacturing. OEE and machine downtime effectively.

*OD – **Yep…and also budget achievement**. Our **biggest spend in this plant is maintenance** – fact. Because we are pretty much an automated manufacturing plant. So Ian is measured every month on maintenance spend. I know its easy..what is it…we have 8 weeks before the end of the year now and I know for a fact that the easiest thing for us to do now to hit our operating profit would be to not spend anything. I find myself between a manufacturing point of view and an OPD position, where we might need something, but if I don't hit that operating profit I might not have a job!*

DD – How do you find that conflict? The engineer in you and your everyday responsibilities…

*OD – it is difficult. Next year for this plant CapEx, not new model, they wanted 3.2 million of CapEx which was like that end of the scale (mimicked a large arm spread) and that should have went down to a need of about 1.5 million. Cos I know where we're at I cut it down to about 400,000 as a minimum. What really, really annoyed me and I was very vociferous in the meeting..we sat and I went through all of them in the plant, and that was the problem we had. At the time we didn't have a plant manager so I was sitting in and we haven't got one at the moment. I've had a couple of plant managers The one we had at the beginning of the year went back to Gestamp after 6 months so I dropped into half doing the job – kind of cos I like doing it as well and now I've put person 1 over both sites. AT the time when the CapEx went in there was no plant manager so we went through the CapEx request and **asked what they really, really, wanted and needed (maintenance) so from what should have went in as 1.5 million started at 3.2 million and I got it down to 500,000 euros**. So I sat there in a telecom with all of us in the NE, and Llanelli and Romania etc. In **the North east here we will make about 15 million operating profit. In the past 5 years we have made 100 million profit. Llanelli has never made a profit in 10 years**. It's a loss making plant – its terrible. It probably should be closed. **This plant, this exhaust plant is going to make a 3 million profit** and I put in that next year our CapEx should be about 500,000 and I probably cut it too far. I probably did my job as an OPD as opposed to a plant manager. In the telecom it was '**OEM yeah we need a million** as*

*we need to improve our DS3, **Sunderland said 1.5 million** as they need to invest in mould machines and **I said 400, 000**. **Then Llanelli said 2 million**. And this was after the OPD cut it! They had things like fixing the toilets! I probably said too much but I thought fuck it. I'm sitting there and saying 'I'm letting this plant down' 'I'm sitting here with the head of maintenance and I've cut his down to 500,000 in a plant that's making 3 million profit and has ppm levels of 7 ppm which is exceptional and you want fucking toilets!' That is the **problem when you get the conflict across a European bid system**. Head was saying don't worry we'll have another cut on it…but I was saying I had already cut mine before it was entered. So the problem is what do you really, really need. Everyone can play the game and say 2 million etc. but what do you really need. You can't go up over, that's the problem with the group system.*
6. Who has responsibility for this? N/A
7. How is the current MS performing in your opinion? N/A
8. How do you measure its performance? N/A
9. How do you think it affects the performance of the business? N/A
10. Does it have the potential to damage the relationship with the supply chain (OEM)? *OD- **Absolutely**. The last **big problem** we had, which to be honest **cost the plant manager his job2 years ago**. We had **one single piece of kit**, a punch press which punches the apertures in the whole IP (instrument panel). There is **only one machine**, that's all there is. Because we **highlighted** this machine as a **risk**, there was a **level of safety stock** that we had, because from ultimately from a*

manufacturing point of view *and this is the conflict, you* ***want to have loads of stock in place finished goods and loads of spare stock****…so it's everywhere. But* ***there is a strategy*** *in the plant where there is* ***a single piece of machinery that has the ability to stop the plant****, you will hold a* ***certain amount of break glass stock****. Machine has gone down****, break the glass*** *– you* ***have a days' worth of stock****, you know. And this was one of those machines and the* ***plant manager*** *took the decision to take his* ***break glass stock*** *down to I think* ***3 hours…way below what the customer thought we had****. Bearing in mind this was always a problem plant and* ***OEM were always all over us and knew what our safety stock should be*** *etc. It was running quite well*

So this press broke, a hydraulic press which just locked, got stuck. There had ***been issues with it for the previous 2 weeks****, where it had tripped out and maintenance had fixed it and it had ran. Then it kept happening more regularly and* ***nobody had flagged it*** *as being a potential problem. The plant manager also ran the safety stock down to 2 or 3 hour,* ***bottom line is we stopped the line for 4 hours****.*

DD – as in used up the safety stock as well as another 4 hours?

OD – ***yes****. So they called us in, went in there, we've got maintenance crawling all over it…OK break glass should see us through for another shift so you know…if there's a risk to stopping the customer within the shift you've got to let them know. So, you've got to ring OEM and tell them and they're like 'Why? But you have X amount of safety stock?'*

*'****No. we only have 3 hours'*** *and then this goes to the* ***director of Production Control*** *in the plant. Its very difficult then, because my job then is to keep the noise down, the Director of Production control can't fix the machine but the* ***MD of OEM is saying, get your arse in there and find out what Plant 3 are doing****!* ***So he turns up with their maintenance tech's and as you know OEM Maintenance tech's are the best, and they're like pfft, we can't fix it****! So we stopped it for 4 or 5 hours, so* ***huge, huge problem. The consequence of that is for the next 9 months I had to report to the directors of OEM as to where we were in terms of plant recovery so that it would never happen again****.*

DD – in terms of that process or just in general

*OD – **that plant**! So all of a sudden that plant got the focus back again. Go back to my job, we make bits for cars, its not very impressive – that's what we do. **So my job really, is to have people in jobs, not to make bits for cars**, but to have people in jobs. I have a mentor in Japan who is really good and he said I have two jobs, one is to keep the noise down and the other is to gain acceptance. So for me to keep the noise down in the plant, what I had to do is go every month to OEM and say this is where we're at. **So does it affect the relationship – ABSOLUTELY!***

DD – do you think that focus (for 9 month) helped anyone.

*OD – What it did is give the production control director the power to say to his MD Plant 3 are shit, I've got them in every month now. Every month you might just report 'on track, on track' but it's **the green mile**. You know, it's the standing joke. You go into parts control and if you go upstairs and turn right, that means you're ok. Because the meeting rooms to the right hand side are just review meetings. If you're made to walk the length of the office to the **production control director's office, you're there for an arse kicking**. Every month **walking the green mile**, you know and that's what it is. I'm paid to get the arse kicking's and keep the noise down. **Does it have an effect – Absolutely massive.***

11. What outputs would you like to see from the maintenance department? Long term?

    N/A

12. The buffer stock that you mentioned, how does manufacturing calculate how big that is?

    *OD **– Just history, previous breakdowns, risk etc**. that's all and to be honest and apart from that example it very rarely catches you out. **OEM will say 'ah it's a bespoke piece of kit, you should keep a days' worth of stock no matter what'** but to be honest every single piece of kit out there is bespoke in some way shape or form.*

DD – how do you balance damaging the relationship with the OEM against holding X amount of safety stock?

OD – One of our KPI's for this year from the OEM is 100% delivery and that is the ticket – it absolutely has to be. But one of our ***key KPI's in the business is inventory reduction, as we have no money****.* ***In the NE we have cash, we're a cash rich element of CK Europe. But CK Europe in Llanelli, Spain and Romania has huge net debt and basically we run on a loan from CK in Japan****.*

Don't quote me, but if the legal entity of CKEU went to a bank now, we would not get funding as we're technically bankrupt. ***Because we run on a loan of 145million from Japan****. That means we have the ability to pay people. So, one of our KPI's over the next few years is net debt reduction, and that can only come from 3 streams:* ***Operating profit improvement, Inventory reduction****…but you can only sell the family jewels once, but that releases a load of cash and* ***CapEx reduction****. So a key measure is inventory reduction,* ***currently*** *in the* ***NE*** *in total we have about* ***30 million of inventory*** *and our intent by the end of the year is* ***to get down to 23 million****. That releases 7 million of cash which is huge. So you're balancing against the KPI's of the business of inventory reduction compared to the* ***plants need is for stock…manufacturing loves stock****. As soon as it comes through the door we pay for it. Some understand and some don't, all that material that you see out there in baskets and standing is all cash tied up. If you change any of those pallets into pound notes people would take care note of them, but they just think its stock. So a key KPI net debt reduction through inventory reduction and operating profit improvement so you have to kick plant managers and manufacturing managers to the absolute minimum…****then you have OEM saying you must have safety stock for every process****! For our* ***far east suppliers OEM say we should carry 15 days safety stock****,* ***we carry 10 and we're being targeted with carrying 5****!! And that's from the far east, by ship! But if it's your problem and you don't have the bits, then you have to charter the plane to get the bits. If its from Europe its 70k…*

13. If answer is buffer stock…how does this fit with lean principles (depending upon production system answer!) N/A
14. Is that cost analysed? Does the risk outweigh the cost? N/A
15. In your opinion, would the operators and skilled staff welcome a change that saw them carry out additional duties in line with strategic objectives (such as cost reduction or TPM)? *OD -Erm…**I think it's a huge risk.** Its somewhere to aim for, but again, from when I was manufacturing manager, **I have quite a firm view on this**. We pay our operators to do boring and repetitive jobs – sometimes 400 times a shift until 2am in the morning and we give them radio headsets, so they can listen to the radio. **So, I don't want them, I don't pay them to have that responsibility**. **I pay them to do the same thing 400 times, boring jobs but well paid**. The fact is we give them radio headset so they can listen to the radio and they just do the job and go home. We have around **800 operators in the North East** and that's what we pay them to do. **Out of them, 100/150 might welcome it**. If we went for it, **probably half of them would go 'I need more money' and probably 5% of them have the capability of doing it**…in my opinion. You've probably got..it depends what level but **we struggle to get them to clean down jigs at the end of a shift** and if you look at the making of an exhaust it's a dirty process. So cleaning spatter off a jig, you know…if I then went and gave them an Allan key and asked them to tighten a bolt on this…they'd be stripping them, hoiying them back. Maybe I'm being demeaning on this, but I think **we pay operators to operate**. If you look at what we've done in maintenance, what **we've got is two levels of maintenance staff. Multi skilled maintenance technicians, time served**, whatever and can fix everything. Then we **have maintenance technicians – not multi skilled***

technicians, but robot technician like we have here or process technicians*.* ***Those tend to be, good operators that move up and have a level of skill.*** *These are* ***a level above operators*** *but* ***below maintenance*** *and their job is to take some of the more* ***routine maintenance duties away from maintenance****. If the robot breaks down then that's maintenance but if the weld tips, or things like if the wire birds' nests in the wire feed unit, you don't want manufacturing staff then getting Allan keys out and digging it out. Cos it will just happen again and they might hurt themselves, but I would expect a robot tech to go right, its bird nesting in there…but why? Where an operator would just take it out and it would happen again…so I think that teaching them those skills…We have had good operators that can take it to the next level and allowed them to take it…*

DD – but its not one of the targets for you…?

OD – ***No! I'll be honest, I don't expect to see on a final assembly cell to see a spanner, an allan key a pair of pliers, a hammer cos they shouldn't have to use it…***

DD – I read an interesting article on TPM and how successful it was in Japan different…

OD – ***cos they'll do what they're told.***

DD – as they're accepting of that environment and that holistic approach.

*OD – If you look at the final assembly area in Japan its completely different. They'll put a sign on and a guard and the sign is always a cartoon of fingers chopped off with blood coming out and in Japanese it says 'Don't put your hand in here'…that's fine for them. We say 'do you not need a light guard on?' No – we've told people not to put their hand in….****so it's a different culture, a different culture****.* ***So, whereby we've had good operators and created a level to take away mundane and routine work away from maintenance staff, I think that's a better strategy than giving 800 people and teaching them how to use an Allan***

***key**. There will be some who can don't get me wrong, but the vast majority, and Allan key? They wouldn't know whether to turn it right or left you know. Grease that – there'd be grease everywhere…*

DD – Most plants now have a set amount of staff that are not employed by you also, they're employed by an agency as well?

OD – In the ideal world…yes, but in reality. I look back to when I was manufacturing manager we would get a part back from OEM and I'd have a constant argument with Engineering that the operator should have seen the problem. I'd argue that the operator is just pressing a button you know…400 times a shift. Is he really going to see it?

16. Can you talk me through the selection process for a Tier One supplier from an OEM please?

17. What are the key factors which determine the stability of the supply 'contract'?

OD – What do you mean?

DD – What are the key things or targets that you have to hit with the OEM so that contract is renewed every year?

*OD – We get a contact for the product not yearly…So we'll win the business for model car 2 for example. The requisites for that are **cost**…so within the cost model there are implications for an OEE expectation. So we'll give ourselves those, to then give ourselves a cost. Customer is not bothered…all they want from us is:*

***The price** – which has to meet what they want.*

*The **entry ticket** which is absolutely non-negotiable is **delivery at 100%.** They just want the bit…non-negotiable.*

PPM** which is within their target so they'll give us a PPM. Generally, less than **10 (PPM).

*A **cost reduction commitment**, which is normally **4% year on year cost reduction**. To be honest anything other that**, they're not bothered about our OEE**…*

DD – do you think that's standard, no matter who the OEE?

*OD – **Yes**, yep.*

DD – With the cost down as well? Do you think the percentage varies or its about that?

*OD – Erm – we've been **targeted with 6%** and we're going **to deliver 4%. 4% is about 14million cost reduction**. So basically if we had the same prices this year, as we had last year we would have had 14 million profit. So if you look at the balance, we're going to make about 14 million profit this year but if you look at next year we have to save that again. SO the **contractual items are price and cost reduction**. The **entry tickets are delivery performance at 100% and quality performance at a given PPM**. That's it really.*

DD – do you think there's any room within the supply chain for sharing some best practice to mitigate some of these risks we've been talking about?

*OD – It is being done a bit more – you know the Automotive Alliance (AA)? That's formalising it a bit, for example I know **all the 1st Tier** MD's and even though we all supply OEM and some supply similar products, **there generally is no competition between us**.*

DD – do you think it happens…do you think the OEM shares good practice and training?

OD – I think it's happening more, but ***I don't think it happens enough plus I don't think they're as good as they say they are!*** *Just look at today…they've got a 3,200 tonne press that went down last week, they got it away and its gone down again. When we've been in the shit and we've had maintenance people in from OEM to fix it, our maintenance people have been as equally skilled. I think it's a little bit of smoke and mirrors as well.*

DD – That concludes our interview….

Appendix 2.6 Transcript EM Plant 3

Interview with EM

- Executive manager for Plant 3 for manufacturing, maintenance and ME

1. How do you select your maintenance strategy as a plant? • Have a **preventative maintenance programme. Normally at weekend.** • **24 hrs/5 day a week. Extra work reduces access time for maintenance access**. • **If continues, won't be able to maintain processes**. • **Production not stopped for preventative maintenance**.
2. Who are the decision makers for the maintenance strategy? • I am mainly responsible but other guys such as ME and the next level down to make any changes. • **Now we monitor individual pieces of kit for downtime. ME reviews this for then generating an action plan. Also, worst 10 items for %availability is targeted for action. Certain areas performing well, others not well**. • **Not much preventative maintenance. Strategy based upon breakdown**. • **A lot of kit has no replacement frequency. Based on visual inspection only**. • Looking to implement some process control system utilised by OEM, to establish control systems for maintenance, process and production. • **Also, wishing to go forward having production take part in maintenance**.

3. What are the challenges for improving maintenance performance? • **Identifying what needs to be done by maintenance function and what can be done by production staff**? • Also, do the manufacturing team have the skills to pick up those skills? If they don't have them, who trains them? • **Great amount of preparation, training and resource needed to have PLM.** • **Ian gives the impression there is a distinct lack of understanding for what is required to implement PLM**. • **OEE minus right first time is 85%. So more maintenance focussed**. • **Previous barriers are beginning to be broken down between maintenance and production through initiatives such as 100% right first-time weld.** Global initiative bringing departments together develops understanding. • **Admitted documentation re: planning for projects and activities can lead to access issues and generates a lack of understanding between departments.** • **Other initiatives in existence whereby maintenance help with process improvement projects, leading to cost improvements. Improves morale and efficiencies**.
4. Are you involved in the setting of the maintenance budget? • Yes, including cost down.
5. How do you mitigate the risk of maintenance plan failing? • **8-12 hours of synchro stock**. • Also additional 12 hours of critical stock in a warehouse. • **There is not a contingency plan for all m/c and parts.**

• **Standardisation very important for cost reduction** at commissioning stage. I.e getting in the same manufacturers so spares can be minimised.
6. Do purchasing have an impact on the purchase of spares and standardisation? • In some instances, yes – but not across the board. • Wouldn't always have the budget allocation to fir supplier branded parts all the time. Sometimes have to think alternatively.
7. Do you share best practice with supply chain? • Yes on **press shop activity (OEM) and some production components (none on maintenance).**
8. How do you think culture plays a part in some of the direction you want the maintenance department to go in? • **A big part is ownership ' well, its not my problem'.** • **People raise points and ideas, but if people don't go and talk and listen and do something about it, then they will just stop and not do it anymore**. • There is a greater visibility now between departments now – because I'm in charge of them all now. It helps as I have a technical understanding of everything as well. • **Ownership and listening to people is really important. Listen to problems and involve them with the solution.** • **Raise and praise system introduced. Manage suggestions, record them and track them**. • People might come up with an idea such as a space saver, I let them do the job then reward them if its successful. • **I think it helps people feel part of things, if they've suggested something. It provides ownership**. • SM insists leadership and going forward together very important.

9. What are your 3 challenges to truly move maintenance forward further? • **Effective introduction of PLM** • **Effective assessment of data to monitor breakdown** • **Changing mindset of senior people within the business as to the importance of maintenance. Away from the traditional view of 'they don't do nowt them'.** • **Believes there is still a 'not broken, don't fix it' attitude at a senior level.** • **Possibly the OEE as a measurement KPI affects the attitude. If OEE is good – why spend more?**
10. Do you have an input?
11.
12. Does the maintenance department have any specific objectives?
13. Is there a process for developing the Maint. prograSMe?
14. Who has responsibility for this?
15. How is the current MS performing in your opinion?

16. How do you measure its performance?
17. How do you think it affects the performance of the business?
18. Does it have the potential to damage the relationship with the supply chain (OEM)?
19. What outputs would you like to see from the maintenance department? Long term?
20. How does the business mitigate risk of machine failure?
21. If answer is buffer stock…how does this fit with lean principles (depending upon production system answer!)
22. Is that cost analysed? Does the risk outweigh the cost?
23. In your opinion, would the operators and skilled staff welcome a change that saw them carry out additional duties in line with strategic objectives (such as cost reduction or TPM)?

Appendix 2.7a Transcript OD Plant 4

Interview with Operations Director (OD)

Meeting: Plant 4

Present: Derek Dixon, OD

DD - Can you talk me through what Plant 4 produces at this site please? OD – *So I'm* ***OD, Operations Director for Plant 4 in the North East****. Its a 9000m^2 Plant, it's a JIT production facility for car seats. So we effectively buy in components from various different tier2's. Metals, assemblies, foam, plastic trim, electrical components and other ancillary things and we assemble those items together on a linear single assembly line,* ***running at a rate of 1 job a minute****.* ***Seats are built synchronously, in line with our customer OEM****. So every car has different options of seats, some have got heating in them, some haven't, some have occupant sensors, some haven't, some have leather, some cloth. We are building exactly in line with the OEM build.*
DD - What sort of relationship do you have with your supply chain? OD – *Generally, its good. Ironically, we have third party suppliers as well as inter-company suppliers. The foam plant is classed as an inter-company supplier, even though its ran by the same management team. Like I say, Ironically, the inter-company supply is the most challenging, and I think that's true for a lot of OEM's as well. You seem to get, the relationship that you have with suppliers, as in third party – you tend to get a bit more respect that you are classed as cPlant 4ly the customer. When it comes to inter-company, it blurs the line and you're classed as Plant 4. What*

you tend to find is that with Inter-company, they tend to want to pull the joker out and you are as a customer trying to achieve your customer satisfaction scores from your suppliers, your inter-company suppliers can tend to mask that and say 'we're all one Plant 4' and we don't have to follow these steps that you would expect with third party suppliers. But generally, the relationship is good, its based upon trust and good communication, it's based on very good, robust contract that is set up from the outset and lots of information share from us as a company to let the suppliers know clearly what our expectations are from the outset.
DD - You mention that suppliers are selected through an audit process, and that includes maintenance capabilities? OD – *I haven't got the audit sheet in front of me but I've actually got a guy here who on behalf of Plant 4 does the site visits. Because the way the organisation is set up – obviously it's a global company, our central purchasing teams are responsible for setting up the contracts with suppliers, but part of that, one of their arm is SQA (supplier quality assurance), they will tap into the suppliers quality assurance team to tap into the suppliers which are about to be rewarded with business. This is to make sure they operate in line with our requirements***. Maintenance is a big part of that, as is resilience planning, processes and things like that. My guy does that and is is a UK fully trained auditor, he actually has done some of the audits for Plant 4*** *so he'd be a good guy for you to talk to.*
DD – That's a very positive thing that you audit the supplier for maintenance. OD – ***It won't necessarily be a 'deep dive' we confirm that maintenance procedures exist, that they are relevant and more than reasonable for their business and evidence of their maintenance regime is effective****.*

DD -Say an audit was carried out and you were happy with 90% of it, and the missing area of it was maintenance, is that something where you would help address that or would you…

OD – ***Definitely. It depends on the feedback we get from the auditor. I mean if the maintenance system didn't exist there would most likely be a recommendation to not pursue that supplier***. *If the maintenance procedure existed but was weak or needed some type of modification, that would fulfil our requirements then that would be notified to the supplier and the supplier would be expected to respond with an action plan to address this. Then there would be a follow up audit to find out if that plan had been followed through. We do this actually as part of our day to day activities. For example, if we get a supplier concern, quality or delivery or whatever, we would through our SQTS (supplier quality tracking system) we would launch that as an official complaint. Just as our customer would with us, our supplier then has the obligation of following through the full 8D (problem solving process developed by Ford) and in some cases our guys would then go to the site to review the 8D process and in some cases maintenance can crop up. For example, the tool was worn and the PM activity wasn't robust enough so the PM procedure is made more robust. Our guys would then go and make sure that was done and the effectiveness was validated. So its not just for new supplier selection it's for ongoing suppliers.*

DD – do you think its common practice what you're talking about there?

OD – I would say from my experience and I've been in automotive since I was 18 years old, all my experience in automotive has been of that. Probably strengthened more recently in the companies I've joined and I think Plant 4 is particularly good at it compared with one or two other employers. I did spend 3 years in the electronics industry – hated it and came back, but electronics did not have the same level of interaction with the suppliers. Relationships might have been alright, but they didn't have as much of a handle on supplier performance and KPI's and certainly wouldn't have been interested in whether the supplier had maintenance activity.

DD - What impact do you feel the maintenance department can have on the business?

OD – *All of our plant, as with most OEM's have a list of KPI's and those KPI's cover a lot of things such as productivity, efficiency our leanness and measurement of it.* ***Maintenance is an absolute key part of that process as we require equipment to be running constantly so if we don't maintain then we're not going to keep it running so we're going to end up with downtime and inefficiency so a good maintenance regime in here ensures that we're as productive as we possibly can be****. Without that, it's the complete opposite.*

DD - How is the current MS performing in your opinion?

OD – ***Generally pretty well. There's always room for improvement. You've got processes in place or risk assessments or reviews, FMEA (Failure Mode Effect Analysis) type activities which are constantly chipping away at things*** *which have not been addressed but need to be and then of course you have the other issues when if something happens and you have to react to it.* ***So, you have your proactive and reactive activities. I think in Plant 4 in my experience, pro-activeness has always been a weakness*** *and I'm talking about the 25 year history. Its something I've certainly become more aware of in my career maybe about 15 years into my career that there is a lot of reactive activities went into maintenance but not as much proactive. When I came to Plant 4 I tried to address that and that's when we actually started to use the FMEA process which is very, very – and this is because I'm from a quality background and I'm very familiar with it, and I was thinking that this was a very, very, good tool to use to employ in maintenance pro-activity. We actually* *starting using that in maintenance back in 2008, and it was after one or two issues we had in our **** system, which did give us some issues with the customer, where there was too many things happening that weren't predicted.* ***So we then launched an FMEA activity which looked at every step of the system and basically we tried to brainstorm everything that we thought could go wrong and identify what our reaction plan was against each of those things****. Then we adopted this and was an ongoing live document which we reviewed on an ongoing basis.*

DD – That sort of answers one of other questions, which is do you get involved in maintenance development?

OD – ***yeah, I was very heavily around 5/6 years ago. Not so much now****, I think the team is quite well empowered now and there are* ***like minded individuals running the teams now*** *so from a senior management point of view, I still get involved in maintenance, always interested in maintenance. I purposefully have left my name in the maintenance group email circulation, so that I keep looking at the emails to see if I need to get involved. I intervene less though, because I don't have to – not because I don't want to.*

DD - What outputs would you like to see from the maintenance department, Long term? Maybe that would have been the question before you implemented your changes, so going back to before that time maybe, what sort of cultural changes would have to be in place to facilitate those changes?

OD – I think it's a good question I think its something that from my experience, I've seen in different companies that I've been in where you've got your production departments, maintenance, materials, quality departments and they're all working in isolation. Production see maintenance as a pain when they come over and say I need some downtime to…Production see maintenance as a pain when something goes wrong and its maintenance's problem. ***I think the cultural changes is to***

integrate everything and maintenance is not just a little office over here and they pop their head out every now and then, but it's actually integrated with production and working with them and production see maintenance as their absolute ally, working hand in hand*. I think that…you always get the little things of ' look the maintenance lads away for a coffee again' you always get that – you get it with IT, but its much better than it was 6/7 years ago and now maintenance are an integrated part of the production process.*

DD – what you're describing there though still happens. So from your point of view, you mention the two departments working together in conjunction and having a common goal, how did that happen?

*OD – I think if we look at all the KPI's we have in the plant, one of the things we did, again about 8 years ago, we went down all of our KPI's and we went through our systematic review process -so we've got a matrix which shows you all of the different things we need to measure to establish our effectiveness and things like, productivity, efficiency were all on there and what we did was along the x axis, said '****who is the owner of the metric?' 'who is the contributor to the metric?' so it made it absolutely cPlant 4 how everybody fitted together****. Within TS16949 (Automotive standard) helped us to…things and getting more process orientated now instead of like the olden way where you had a standard to reach. What are your inputs, what are your outputs and what is going on in the middle? So you create turtle diagrams..*

DD – turtle diagrams?

OD – well, every department has turtle diagrams and in that diagram each department head has got to thoroughly critique what their role is in the business. So what are your inputs, what are your expected outputs and your outputs are productivity, efficiency all those KPI's and what are those things churning on in the middle, creating that. That's why it's called a turtle diagram, as you've got the pattern of a turtle from those inputs, middle and outputs. So you're looking at it from a man, method, machine, environment and materials point of view. So that also *helped contribute to that change in mindset. Fortunately, we've got enough* ***like-minded individuals here who've helped cascade that*** *and time has been spent from these like-minded individuals with the people who need to be coached or mentored up to be at that level. So there has been a lot of things gone on…*

DD – I bet. Everything you read suggests that it can take 5 to 10 year to change a culture…

OD – Fortunately we started off in 2005, ***my personal feeling is that if you get it right from the beginning it tends to be easier****. Its when you have to change it can be more difficult. Being mindful of the potential that things are changing away from what you want. You've got to be constantly trying to nip it back, nip it back. Know when to keep out of it and knowing when to intervene. If you intervene too much you can stifle people, sometimes you keep out of it too much and people end up going off in another direction so…its about knowing when to nip it in the bud when you need to.*

DD – quite a difficult skill! The matric thing I would certainly be interested in seeing that?

OD – Yep.

DD - How does the business mitigate risk of machine/maintenance failure?

OD – ***We have resilience plans, things like and we review these regularly****. We tend to look at our overall resilience on an annual basis. We discuss this at our management review – 'Is there anything else we need to consider?' The IATF standard which is replacing the TS standard is very much into things like that. Stretching from things like if the electricity goes off, what do we do? Well we've got a generator, we've got a back-up plan. What happens if our compressor goes down,? We've got a compressor company that we can call very quickly. Our key equipment, DC tools, if a DC tool breaks down, we've got spares and we've got enough critical spares to cover replacements. We've* *got a special contract set up with the repair companies where we can't do it internally, where they can fast track and do it in 2 days or something. If we've got a catastrophic situation where our DC tool is completely down we have a manual back-up that we can activate very quickly.* ***If the whole line goes down, we've got a manual back up mode that we can start very quickly. So these are all proceduralised that we can produce whenever we need to do it. There has been time when we've done it.***

DD – If you don't have some of those things in place then the fall back may be buffer stock.

OD – Overall, yes what we do is work on OEMs tac time. It works out as 1min 2s or something, we then put a factor into our own tac time, so we have an efficiency factor because we have our own OEE, we have we say if our customers tac time is 1min 2s then we're going to run at 58s. And then we put another 5% on there to take into account any outages we might get. Downtime if a motor goes down and it takes 10 mins to replace we put that in as well….so we manage a buffer, we do manage a buffer. ***We manage our buffer between 180 car sets and 210 car sets****. We could go higher but there's no point. If we think we're going too high, we'll just retune our tac time and bring it down. Just to keep that buffer in between 180 and 210. And obviously if something happens there's a series of escalation things that occur. For example, if the buffer goes below 180, the production managers informed, if its below 170 the site manager is informed. If it drops below 120 then I'm informed no matter what time, as its starting to get a little worried.*

Appendix 2.7b Notes OM Plant 4

Operations manager OM (Plant 4).

Notes in bullet form:

- Maintenance reports in to OM.
- Manufacture polyeurothene foam to automotive industry
- Supplies OEM1 and OEM2. 60% to OEM1.
- No **assistance from customer regarding maintenance or process**.
- Expansion programme and centre of excellence for the plant about to begin.
- Believes **maintenance can have a major impact on business**. Also, **the maintenance should be more proactive than reactive**, finding they're not doing that all of time.
- **Performing as a team 6/10**, but some individuals are performing at a higher level. Supervisors are higher, but people below not so well. **Newly qualified technicians, that were apprentices performing at a lower level. Low knowledge and skills let team down**.
- **84.3% OEE and 94.5% uptime. Within PLANT 4 group performing well for OEE, but OM believes the quality is holding this up, not machine uptime (maintenance**).
- Mixed performance from team. **Too reactive on one line yet willing to undertake predictive maintenance techniques in other areas (Vibration and Heat analysis).**
- Includes monitoring system for display of data.
- External recruitment not a particular challenge – no more than other positions. **Apprentices started due to difficulties in the past**. 3 months to fill a position with a decent candidate.
- For **maintenance to improve culture within maintenance individuals need to improve. They can be negative**. Maintenance staff should be proactive and reviewing work. Gave **example of walking past workshop and staff sitting around, as well as visiting job in 'pairs**.'
- Maintenance team given some **semi-skilled jobs such as tool changes which affects team performance and morale.** Rejected by Maintenance supervisor.
- Maintenance performance improvements by root cause analysis on each job a desire. To alleviate repeated work.
- KPI's OEE, plant performance, MTBF, MTTR, PM completion. More investigation of root cause required.
- Reason why it doesn't happen is **lack of ownership of job by maintenance staff**.

- Example given of how continuous improvement improve something like product flow. They would bring together materials dept. tooling, production and quality to bring about a solution. Never happens with maintenance. **Calls maintenance a closed shop, unwilling to consult with other departments on solutions**.
- **Feels maintenance are 'scared to share'**
- Engagement with maintenance development would occur through deployment of business objectives and how maintenance and Phil (maintenance manager) can have maintenance make that happen. **Cascade of objectives relatively new thing to business. Result of employing maintenance manager**…
- Relatively stable and progressive management structure within the business with long service.
- **Mentions progression available (with patience) for capable staff**.
- **Maintain 30 hours buffer stock**. They hold 6 and customer 24 due to space.
- Discusses Bronze, Silver, Gold Plant 4 standard TPM. Aiming for Silver level with eventual goal of Gold. Silver includes, full critical spare list. Easier in the JIT plant sue to assembly process. More difficult in Foam, due to manufacture and chemical processes involved.
- Believes the **promotion of these initiatives by leaders within the business is crucial to the success of similar initiatives**. Example provided is maintenance manager leading TPM standard project.
- Discusses staff renewal promotes cultural and mindset change to move department in the correct direction. Example provided of older members of staff passing on cultural beliefs to apprentices.

Appendix 2.8 Notes MC Plant 4

Questions for MC – Plant 4

Present: Derek Dixon, MC

Interview notes:

23. Can you describe your maintenance strategy pls?
    - MC is responsible for maintenance of FOAM plant and associated projects.
    - **Plan is being restructured, moving towards PLANT 4 levels of Bronze, Silver then GOLD level TPM award**.
    - Current strategy aim and target is 1**00% PM completion. MTBF 8hrs. MTTR 9mins. Uptime 95%. OEE 93%.**
    - Use FMEA to facilitate strategy for each process.
    - Wants to achieve Silver level by October
    - **Bronze level requires operators to complete cleaning checks as part of role**.
    - Describes **production staff undergoing a culture shock in having to do this**.

24. Who help develop it or drive it forward?
    - See above.

25. What are the key performance indicators you use?
    - Must report on; **Daily - Plant downtime, PM completion, Monthly - MTTR, MTBF and unplanned downtime (maintenance) & %PM completion**.
    - Prefers daily reporting and recording of MTTR and MTBF as feels they drive a maintenance department forward.

• **No CMMS system which is a negative** for recording data. Currently data input and recorded manually.
26. How is the current MS performing in your opinion? • Maintenance for 'line 2' has been poor. Only 17-month-old – a lot of commissioning issues. Manufactures helping with this. • 9 maintenance guys, 3 on each shift -follows OEM. 1 maintenance team leader who manages day to day technicians. **MC would like a team leader on each shift instead of just day shift so a responsible person was available at all times**. •
27. What are you basing your assessment on? • KPI data
28. How do you mitigate the risk of the Maintenance strategy failing? • 30 hours stock maintained as break glass. • Critical spares list.
29. If answer is buffer stock…how does this fit with lean principles (depending upon production system answer!) N/A
30. Do you have a direction you wish the Maintenance Department to go in? • TPM Project and CBM (previous answers) • Predictive maintenance. Temperature sensors, vibration and heat analysis.
31. What are the barriers to you achieving that?

• Cost – for example predictive maintenance technology. • **Cost must be fully justified by being able to demonstrate the impact** • **SM find technical justification and examples of impact difficult to comprehend and understand**. • **Discusses difficulties with decision makers agreeing to providing additional resource if plant is 'running ok'. Lack of visibility of results (a product) has an impact**. • **Friction with production. Access to m/c for maintenance – 'production is king'. 'Try and keep it running until weekend – at all cost' The do maintenance activities.'**
32. Is there internal and or external issues which might prevent you from achieving this? N/A
33. Do you think the appearance of the maintenance staff and the work area is important? • **Yes, try to make sure they are smart and presentable. Feels like otherwise they look like 'grease monkeys'** • **Work area, Yes. Appearance at the moment is not good, so is inconsistent**. • **Maintenance staff can lack ownership and can perform poorly with 5S in work area and on maintenance tasks**. • Employs a team leader to try and help improve motivation for things like this.
34. Where is the work area? • Noted from tour of shop floor. **Work area placed to one side of shop floor, not centrally. Relatively tidy, with some tools and jobs scattered around**.
35. Is training carried out for maintenance technicians? 36. How is the training identified?

• Training identified from a scoring system for each member of staff. Score indicating competency in a specific area. **Done through a Training needs analysis matrix. (TNA).** This is done in association withal tasks and kit they maybe expected to work on. **This has been created by MC so is not a company system or widespread with other managers**.
37. In your opinion, would the operators and skilled staff welcome a change that saw them carry out additional duties in line with strategic objectives (such as cost reduction or TPM)? • See above answers.
38. Do you think the culture of the plant/organisation, has an influence on how maintenance is developed, perceived or even accepted? Is culture important in your opinion? • See answer 9. • **Yes, important. 4 years ago employed apprentices (4 or 5) as couldn't tolerate existing, negative mindset of maintenance staff.** • All apprentices have full time role in Plant 4. **So, 5 of 9 maintenance team were apprentices. This was done as couldn't recruit the correct 'calibre' of personnel for maintenance. Both technical and character of candidates**. • **If maintenance staff do not project the correct character and personality, this can affect the perception of the department by all customers. So all good performance (KPI's) can be affected by negative projection**. • Believes part of staff 'happiness' can be improved through providing training and removing non-maintenance tasks from the staff. Not, tool changes…

39. Would you alter your MS IF it could be demonstrated an improvement in cost to the business?
40. What would make you change your maintenance strategy?
41. What sort of relationship do you have with your supply chain? • Spare parts- quite good.
42. Is best practice shared throughout your supply chain? With the OEM? • Some from global. None from external OEM.
43. Is that valuable?

Appendix 3 Propositions from Literature and Rich data

OP1 – Observation at Plant 1

IP2 – Interview at Plant 2.

TS – Testing Stage

Plant 1 – P1. Plant 2 – P2. Plant 3 – P3. Plant 4 – P4.

Proposition table:

No.	Proposition	Source	Comment
1	As stakeholders, leadership should be engaged in the development of the maintenance function.	**IP1; IP2; IP4** (Campbell and Reyes-Picknell, 2015) (Murthy, Atrens, and Eccleston, 2002) (Schein and Schein, 2017) (Wireman, 2014)	
2	The importance of the maintenance function is elevated through consistent discussion by leadership members with other stakeholders	**IP1;IP4 ;** (Campbell and Reyes-Picknell, 2015) (Lloyd, 2010) (Kelly, 2012) (Schein and Schein, 2017)	
3	Leadership should play an active role in identifying which	**TP1**	

	performance metrics are important for their information.	(Parida and Kumar, 2006; Kumar *et al.*, 2013; Parida *et al.*, 2015)	
4	Training is planned, implemented and documented regularly for the maintenance function	(Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
5	Training is identified and implemented as a matter of importance to ensure employee engagement in their responsibilities	**IP4** (Schein and Schein, 2017)	
6	Structured training improves performance and engagement with staff duties	**IP3** (Shanmugam and Paul Robert, 2015) (Schein and Schein, 2017)	
7	Training should be completed when scheduled to ensure staff morale and skills are maintained.	**IP1; IP3;**	
8	Staff skill discipline should be monitored and balanced in line with business needs.	**IP1** (Shanmugam and Paul Robert, 2015)	
9	Maintenance staffing is planned and staffing levels reflect workload.	**IP2;** (Wireman, 2014)	

10	An imbalance in maintenance skills can lead to work efficiency issues.	**IP1;IP3** (Campbell and Reyes-Picknell, 2015) (Tsang, 2002)	
11	Use of operators for some preventative maintenance tasks will release maintenance department resources.	**IP1;** (Campbell and Reyes-Picknell, 2015) (Lloyd, 2010) (Tsang, 2002)	
12	Operator training for low level maintenance tasks is crucial for engagement and effectiveness.	**IP1;** (Tsang, 2002) (Schein and Schein, 2017)	
13	The maintenance shift system can support production more effectively if it runs in parallel to production.	**IP1; IP2; TP1**	
14	Retaining maintenance technicians in employment can prove difficult within the automotive manufacturing environment	**IP1;** (Holweg, Davies and Podpolny, 2009) (Campbell and Reyes-Picknell, 2015)	
P15	Consulting maintenance technicians when developing maintenance plans will assist maintenance performance.	**IP3; TP1** (Smith, 2003) (Campbell and Reyes-Picknell, 2015) (Lloyd, 2010) (Tsang, 2002) (Shanmugam and Paul Robert, 2015) (Schein and Schein, 2017)	
P16	Clear progression opportunities will help staff retention and loyalty.	**IP4**	

		(Campbell and Reyes-Picknell, 2015)	
P17	An apprenticeship scheme can address skills shortages and technician recruitment issues.	**IP2; IP4;** (Wireman, 2014) (Campbell and Reyes-Picknell, 2015) (Holweg, Davies and Podpolny, 2009)	
P18	Traditional conflicts between production and maintenance will affect the ability of maintenance to perform its duties.	**IP1; OP1; IP3; IP2;IP4 ; TP1** (Lloyd, 2010) (Kelly, 2012) (Schein and Schein, 2017)	
P19	Production availability affects the perception of the maintenance department	**IP2;IP3; IP4; TP1**	
P20	Visibility of targets and performance influences the transparency and understanding of the maintenance department	**OP1; OP3;** (Schein and Schein, 2017)	
P21	The presentation of maintenance staff and work area affects the perception of the maintenance department.	**OP1;IP4 ; IP3;** (Campbell and Reyes-Picknell, 2015) (Shanmugam and Paul Robert, 2015)	
P22	Not all key stakeholders within the business perceive maintenance as adding value.	**IP1; IP3; IP2;** (Wireman, 2014) (Campbell and Reyes-Picknell, 2015) (Kelly, 2012)	

P23	Communicating maintenance priorities regularly improves understanding and cooperation	**OP1; IP1;**	
P24	Using operators for preventative maintenance will increase understanding and ownership of maintenance activities within production.	**OP1; IP1; IP4** (Campbell and Reyes-Picknell, 2015) (Lloyd, 2010) (Kelly, 2012) (Tsang, 2002)	
P25	The location and accessibility of the maintenance workshop affects engagement and transparency.	**OP1; OS4** (Campbell and Reyes-Picknell, 2015) (Tsang, 2002) (Shanmugam and Paul Robert, 2015) (Schein and Schein, 2017)	
P26	The level of workplace standards influences acceptance and integration with production.	**OP1; OP2; OS4; TP1** (Campbell and Reyes-Picknell, 2015) (Shanmugam and Paul Robert, 2015) (Schein and Schein, 2017)	

P27	Reporting on maintenance performance in regular communication to all staff, reduces cultural differences.	**OP1; OP2; OP3; OP4** (Schein and Schein, 2017)	
P28	Benchmarking the prioritising of work orders increases department efficiency.	(Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P29	Benchmarking the timely completion of work orders increases department efficiency.	(Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P30	Discussing work order priorities with stakeholders promotes understanding of all issues.	**TP1** (Campbell and Reyes-Picknell, 2015)	
P31	Trained work planning personnel complete maintenance work planning more efficiently.	**IP3; IP4** (Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P32	Effective work planning should include all necessary resources	(Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P33	All Completed maintenance should be inspected for suitability and quality of work.	(Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	

P34	A high percentage of urgent maintenance work orders indicates a reactive maintenance plan.	**IP1; IP3; IP2; IP4** (Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P35	All aspects of maintenance work should be tracked and recorded accurately.	**OP1; IP1; IP3; IP2; IP4** (Wireman, 2014)	
P36	A maintenance department must have an efficient and timely equipment and spares system.	**OP1; IP1;IP3; IP2; IP4** (Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P37	Effective budget management is critical for the effective performance of the maintenance department	**OP1; IP1; IP2;IP3**	
P38	All machine components identified as critical should have spare parts readily available.	**OP1; IP1; IP2; IP4** (Campbell and Reyes-Picknell, 2015)	
P39	All critical assets must have an identified secondary plan for production and maintenance activity	**IP1; IP4**	

P40	Tools of good quality and sufficient volume promote department morale and performance	**OP1; IP2** (Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P41	The annual maintenance budget should be sufficient to provide satisfactory resources for performance and development.	**OP1; IP1; IP3; IP2; IP4** (Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P42	All maintenance expenditure items are recorded accurately on an annual basis, and used for future budget planning.	**TP1** (Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P43	Maintenance budget performance is accurate and information is readily available.	**TP1** (Wireman, 2014)	
P44	The maintenance department measures performance in key strategic and operational areas.	**EN15341** (Campbell and Reyes-Picknell, 2015)	
P45	Information used for metric and indicators is recorded accurately.	**OP1; IP1; IP2; IP4** (Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	

P46	Performance data is used for strategic and operational decisions.	(Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P47	Performance information and key performance indicators are readily available to staff when required.	(Wireman, 2014) (Campbell and Reyes-Picknell, 2015)	
P48	Clearly displaying the targets and performance of maintenance promotes understanding and transparency of the department.	**OP1;** (Schein and Schein, 2017)	
P49	Safety stock is a regular feature within the automotive supply chain	**OP1;IP1;IP2;IP3;IP4**	
P50	A poorly performing maintenance department will lead to inflated levels of safety stock.	**OP1;IP1;IP2;IP3**	

Appendix 4 Model Feedback – Site 1Ltd.

Model feedback interview:

Site 1Ltd.

Present: Engineering Manager (EM), Derek Dixon

Leadership:

1. When planning maintenance progression/improvement do senior managers identify a key project manager to oversee its development? When is it reviewed?

   Driven from EM, but open to suggestions from team.

   Team effort.

   Technical review carried out by supervisor

   KPI by leadership

   Do you feel senior management engagement with maintenance development and performance is important?

   Yes all of them.

2. Is the reporting mechanism for maintenance performance established when planning maintenance?

   Evolves based on KPI's.

3. Who establishes the aims and goals of the department? Are they approved by senior managers?

   Yes approved by senior managers. KPi's defined by EM then agreed by exec team.

4. Have you experience of maintenance development being promoted as important to key staff and managers (outside of the department) by the leadership team?

   It is promoted through EM – very important.

Skills and Training:

1. How is training normally identified for maintenance technicians in your experience? Is it carried out externally or in house?
   Training completed relevant to equipment on site and statutory compliance. Not done through appraisal (there isn't one) done through a skills gap analysis.
2. Do you see it as being addressed sufficiently by the organisation to meet the needs of the department?
   Big thing is finding the time to release people in smaller teams. Also, being able to cross train (Mech/Elec).
3. Has training or a lack of skilled staff, been an issue affecting maintenance performance in your experience?
   Yes seems to be an issue everywhere

   What is your experience of an apprenticeship scheme being used to resolve staff recruitment issues?

   Yes, worth doing but important to make sure they complete jobs safely and to the correct standard. Don't learn bad habits from mentors and stay with the company.
   Very low staff turnover at Carbo.

staff resources:

1. Do you see staff communication and consultation as being important when looking to change or improve maintenance performance?
   a. How is this measured, i.e. Are operational staff asked for their opinion?

   Monthly meeting to facilitate discussion on this. Important to get their buy in as they'll have some good ideas. Looking to roll that out. Would not be interested in measuring it as it has nothing to do with the machines. Would fit more into HR survey and their objectives.

2. Do you think team morale or ownership of responsibilities is influenced by these engagement techniques?
   Met with positive feedback. Difficult to measure subsequent performance.
3. Is maintenance outsourced, if so what %
   a. Does this influence questions 2,3 & 4?

Production integration and perception:

1. Do you feel the integration of the maintenance function is still an issue within organisations?
   In any company, yes.

   EM and ops manager sit in same office, so no secrets. Ops have short interval meetings where maintenance attends, so communication absolutely key. Communication part of leadership, never helps maintenance explicitly. Asset availability most important.

2. Do you think perception of the department across the organisation, affects resources or the ability of the department to perform?

   Perception affected by communication. Where people with an expectancy aren't clear about their priority. So they put a job in but maintenance has no sight of what is most important. Provides customer service through interaction with different departments. Understanding 'big ticket' items.

   People interested in operations, availability, money. At senior level interested in 1. Safety. 2. Money. 3. Product.

   Perception – availability of kit most important. Unplanned downtime costs money.

3. If the department is not achieving the agreed KPIs, do you feel this may influence the perception of maintenance with other departments?
4. What causes these perceptions and can they be changed?
5. How important do you think the visible aspects of maintenance are? Uniform, work area.

Yes, perception is everything. Biggest impact is if bring an auditor in to see the maintenance area and it's a dump, that gives a poor perception. So it needs a correct procedure or an audit trail, such as a 5S audit so improvement can be demonstrated.

May not improve availability of kit but might improve waste.

Perception is a first stage but it won't change anything. It's about tangible facts.

6. What about the placement of the workshop? Do you think the visibility of the work area affects the integration of the department by the production staff?
7. Do you think organisational culture affects maintenance in any way?
    a. Why?
    b. Should it be addressed?
    c. Could it be addressed?

    Important to present data to show what is hurting and find a way out of that. That will change the perception and possibly culture.

Equipment and spares:

1. What factors do you consider during your resilience planning for maintenance?

    Critical spares list from manufacturer. Buy them unless your experience tells you different. Also FMECA for spares analysis, then score up your critical spares for priorities.

    Bad practice – driven by bad stock management more than having the incorrect spare. Not knowing if you have a part or not. Also, critical spares not being bought due to cash flow issues.

2. What influence do you feel resilience planning has on maintenance department performance?
3. Have you experience of poor maintenance planning having an impact on the organisation?
4. Have you any examples of good and bad practice?

Budget:

1. Can you describe how your budget for each year is set?
   Inherited it so far, based upon previous years spend. Should be based on breakdowns, cost of parts, frequency of breakdown and take it from there. As opposed to just taking it on the age of the asset and adding a % on from that.
   If focus on what is hitting the cost and availability of the machine and focus a strategy on that (for spares etc), it should inform on your budget as availability will go up and labour cost will go down.
2. Is your budget sufficient to achieve your objectives, or does it inhibit certain aspects of performance?
3. As a maintenance manager, what part do you play in this process?

Maintenance shift system:

1. In your opinion, does the shift pattern of the maintenance department affect performance?
   Run different shifts to production and it can cause communication issues with out a doubt. Handover problems for breakdowns and knowing what has been the issue on a previous shift. So communication to be improved through a review sheet covering previous weeks work.
   Shift runs differently to production as gives scope for PPM to be completed.
2. What KPI's (if any) have been affected as a result?
   Downtime and repeating already completed activities and mistakes.
3. If there is an impact, how do you feel this could be resolved?

KPI:

1. Do you find Senior managers are interested in maintenance performance? Or do they look at production measures only?

Everyone has a vested interest in satisfying audits which means having a competent strategy that is measured, so yes – they are interested.

Data is everything.

In your experience, which KPI's have the organisation or senior management team used to help improve maintenance performance?

Downtime. Define downtime. Need to worry less about travel time to job, just worry about the trend and change. Identify the biggest hitter and do a root cause on that so its gone!

Take the downtime that's related to machinery and try and attribute it to something such as training or poor use.

2. Do you feel KPI's affect the development or direction of the department? E.G. %preventative maintenance/total maintenance man hours.

   We collect lagging indicators. Very hard to collect leading indicators. Subjective. Use effective KPI's only – but what are you going to use it for. Is it helping getting rid of the downtime?
   Don't want too many KPI's with potentially numerous metrics under each one. KPI is what is trying to effect and change to improve that your performance is getting better.
   I would do cost efficiency, availability of kit….
   EM see's the preventative and proactive measures as being something that's not as useful. If you measure % reactive and its high, it probably means your preventative work is low quality or non existent.
   See the value of CBM as it is directly linked to savings on labour and kit.

3. Have you seen any examples of good practice with their use or application?

Interested in a handful of KPI's and being able to change them and show a trend. I.e not just measuring for the sake of it. What does it lead to? Does it affect availability? So, can you measure it. Change it? Show improvement – in cost or availability.

Overall feedback on model:

- ***Senior management and engagement very important. Driving down to their own teams importance of collecting data to help maintenance.***

- ***Training and skills very important, but making sure you identify what roles need what training.***
- ***Recruitment a big issue (maintenance).***
- ***Liked idea of staff engagement for planning and ideas.***
- ***Perception very important – gives good impression and instils belief.***
- ***M/C availability can improve perception, but also communicating with the customer (production)***
- ***Tangible items such as workplace items for perception, comes down to poor strategy not culture. (a bit confused) 0 maybe remove this ideal behaviour..***
- ***Equipment and spares remedied by a high level of stock and warehouse management.***
- ***Very interested in KPI's data everything. More keen on a few, selective and Key indicators. Discussed a number of metrics informing a KPI.***
- ***Only used lagging KPI – no leading.***
- ***Ensure any used are useful and lead back to an objective – or availability!***
- ***Autonomous maintenance for operators very important as it releases capacity for maintenance tech's.***
- ***Instead of buffer stock, look to MTBF and MTTR predict downtime and how many products that equates to hold that stock – not just a lump of buffer stock.***
- ***Nothing there that would discount. Big things to add; Availability and cost efficiency. Thats to get attention of senior managers.***
- ***Softer skills have a place but it's more management. Management can affect engineering, but by a good strategy.***
- ***Biggest restriction is SM team working together as they have their own agenda and if they don't play, maintenance will never get better.***

Additional notes:

Feedback was facilitated by a meeting with the Engineering manager (EM)for Site 1Ltd. EM attended a semi structured interview alongside his colleague. This was a Maintenance Coordinator.

The draft tool was amended to form a series of question which, when asked, would look to provide insight into their validity and application within a manufacturing environment. The objective nature of the respondents within their respective industry was anticipated to shed a fresh, alternative perspective on the findings. These findings would then evolve, allowing focussed and useful development.

At the outset, EM was direct, professional and business-like. Beginning with senior management engagement, EM acknowledged the importance of this aspect when aspiring to improve the maintenance function. This was linked with a need for clear data for decision making and the subsequent systems throughout the business which would supply this. Data and a specific link to important KPI's was a common theme throughout the conversation. EM was direct in his responses to KPI's, insisting their identification and use needed to be linked to business objectives as well being limited in their number. The conversation continued to the use of leading and lagging indicators as a means of driving maintenance performance, yet EM indicated only lagging indicators measuring cost and availability were essentially the only useful ones!

The issues experienced by the automotive industry in recruiting and retaining well qualified staff resonated with EM within the food industry. The suggestion of an apprenticeship scheme was met with approval as a means of addressing part of this issue. Although the discussion led to cautionary tales of managing such a system.

The research findings stated multiple issues of 'production integration' blocking the performance or development of the maintenance function. This was reflected within the interview with questions discussing the perception of the maintenance department by other aspects of the business – including manufacturing. This conversation gave rise to the first clear sign that the standpoint of EM on certain issues was both confused and contradictory. EM indicated that perception 'was everything' to a department and provided examples of how important it could be in an example situation of auditors. Conversely, he then went on to contradict himself, stating that it was of little importance as the only thing which mattered was 'cost and availability'. The feedback proving paradoxical continued with discussion centring on staff engagement for performance improvement on both a personal and department level. EM indicated this was in the process of being 'rolled out' across his areas of responsibility as he like the idea, though he then went on to state that it would be relatively useless to the performance of the department as how could it be measured for any possible improvements.

The nature and conflict of some of this feedback is enlightening. Although some answers reveal possibly one perspective of the person and manager of strategies for improvement – things he'd like to do. What emerges slightly later in the conversation is a revert to type stance of indicating that it is only cost and availability that is important – so anything else is immaterial. This conflict is a mirror image of some of the findings emerging from the automotive supply chain, where business targets such as OEE absolutely dominate the practice of the organisation, to the extent where they inhibit the development of individual areas….

Appendix 5 Interim revision (V5) of Gap Analysis Tool.

Category	Question	Score
Senior management engagement		
P1	Do Senior managers take part in the development of the maintenance department? a) Yes, they have an active role in maintenance development. b) Yes, but input is limited. c) Sometimes d) No, there is little input from senior managers	Option
P1	Do senior managers request information on the performance of the maintenance department? a) Yes, it is reported daily b) It is reported weekly c) It is reported monthly d) Performance is never reported	Option
P2	In what forum do Senior managers discuss the maintenance department? a) Through business wide communication, such as notices and in meetings b) Within production meetings c) Occasionally, when discussing individual department performance. d) Never.	Option

P1	Are the annual plans and targets of the maintenance department reviewed by Senior managers? a) Yes, plans are submitted and reviewed regularly. b) Yes, plans are submitted and reviewed each year. c) Plans are discussed informally. d) Plans are rarely reviewed; the department is judged on results.	Option
P3	Do senior managers approve which KPI's the maintenance department use? a) Yes, specific KPI's are consistently agreed, and must be linked to business objectives b) Yes, but the advice of the maintenance manager is required. c) Yes, they are submitted for approval but feedback is not normally provided d) Maintenance KPI's are not requested or reviewed by senior managers	Option

Skills and training (5)		
P4	Is there a training plan for the department? e) Yes, it is planned at the beginning of each financial year, reviewed regularly and documented for audit purposes	Option

	f) Yes, it is planned at the beginning of each year and reviewed at the end. g) It is planned each year, but rarely followed. h) Training tends to be requested on an ad-hoc basis	
P5	Are the training needs of the maintenance department identified? a) Yes, through the maintenance plan and regular meetings with staff. b) Yes, through staff requests. c) Yes, once a year in an appraisal. d) Never	Option
P6	Does staff training effect performance within the maintenance department? a) Yes, the impact measured through appraisal and personal performance. b) Yes, though there is little evidence to support this. c) The effect of training is rarely discussed. d) Unable to comment.	Option
P7	Are maintenance staff released when required for training? a) With the exception of a critical event, staff are normally released b) Yes, though staff capacity can sometimes be an issue c) Sometimes, though day to day jobs often take priority. d) Regularly, there are too few staff for extensive periods of training	Option

P8	Has the number of skilled staff in maintenance affected department performance? a) No, the ratio of mechanical/electrical/multi skilled staff is monitored and reviewed regularly b) No, we appear to have the correct balance though this is not discussed c) Yes, we are understaffed in certain skills which is affecting performance d) Yes, we are understaffed in general which affects our performance.	Option

Staff resources (9)		
P9	Are there enough maintenance technicians within the maintenance department for the current workload? a) The technician level is appropriate, all capacity is monitored and there is room for continuous improvement work. b) The staff level seems OK and some continuous improvement work is carried out, though there is no measure used.	Option

	c) There appears little capacity for any additional work except routine maintenance d) There are too few staff to complete the required maintenance tasks	
P10	Is there a mechanical/electrical technician imbalance within the department? a) No, all work orders can be planned and carried without delay due to manpower restrictions. b) No, all work orders can be planned and carried with few delays due to manpower restrictions c) Yes, a shortage in one area often leads to delays in work completion d) It is difficult to comment, delays are common in completing any work orders	Option
P11	Are operators used for general preventative maintenance tasks? a) Yes, they carry out specific, identified tasks and report the outcome regularly. b) Yes, they carry out general cleaning duties in their area. c) Some operators in specific areas take part, though not all. d) No.	Option
P12	Are operators sufficiently trained for these tasks?	Option

	a) Yes, all participants have been trained to carry out planned preventative maintenance tasks and document the outcome regularly b) Yes, most operators have been trained to carry out planned preventative maintenance tasks and document accurately c) Yes, but few staff have been trained and the quality of work requires improvement d) Not applicable	
P13	Is there sufficient maintenance staff to accommodate the production shift system? a) Yes, each maintenance shift is fully staffed and mirrors production. b) Yes, but staff resources mean this is difficult. c) No, a different shift system is required due to low staff numbers. d) No, overtime is required to cover production outside of the normal shift system.	Option
P14	Please comment on the ability of the business to retain maintenance department staff: a) Staff retention is good and operational staff have long service. b) Staff service is considered normal with some long service. c) Keeping staff is a concern though we're not worried yet.	Option

	d) Yes, staff retention is poor with high staff turnover.	
P15	Are maintenance staff asked their opinion on maintenance plans or equipment? a) Maintenance staff are regularly consulted for opinions on maintenance planning and direction. A suggestion and reward scheme is used. b) Maintenance staff are able to offer their opinion informally with some opinions taken on board. There is no suggestion and reward scheme. c) Maintenance staff can offer their opinion on equipment and plans, but the plans are not changed. d) No discussion occurs between maintenance senior staff and technicians about plans or equipment	Option
P16	Are promotion opportunities available to maintenance staff? a) Maintenance staff have a clear direction for training, development and promotion opportunities through appraisal. b) Promotion normally occurs internally, but career planning is not normally discussed. c) Maintenance staff may apply for internal opportunities though external recruitment is common.	Option

	d) There is little opportunity for promotion within the business.	
P17	Is there an apprenticeship scheme within the maintenance department? a) An apprenticeship scheme is in place and regularly reviewed for suitability. b) An apprenticeship scheme is in place, but the recruitment and and suitability are not normally reviewed. c) An apprenticeship scheme is in place, though it has not recruited for some time. d) No scheme is in place.	Option

Perception (6)		Likert?
P18	Do you feel the working partnership between the maintenance department and production can cause problems for both departments?	
P18	Do you think this may affect the performance of the maintenance department?	

P19	Do you think a high level of availability for production machinery improves how the maintenance department is thought of?	
P20	Are the targets and measures of the maintenance department displayed in a common, viewable area?	
P21	Is the appearance of the maintenance work area important for how people think of the maintenance department?	
P22	Do you feel the maintenance function is viewed as adding value to the business?	

Integration (5)		
P23	Is maintenance information and plans discussed in production/process scheduling meetings? a) At every meeting b) At most meetings c) Sometimes d) Never	Option
P24	Are Operators are involved in the maintenance of production assets? a) On all critically identified assets. b) On most critically identified assets	Option

	c) On some assets d) Never	
P25	Where is the Maintenance workshop located? a) Workshop is in an ideal and accessible area, for immediate contact. b) Workshop is in an area which requires improvement, for contact. c) Workshop requires major improvement for accessibility. d) Workshop is inaccessible and contact is difficult.	Option
P26	How would you describe the maintenance workshop? a) Work area is maintained to outstanding standards. Regular inspections are held for adherence to 5S standards. b) Work area maintained and inspected at the end of each shift. No standards for efficiency or inspection used. c) Work area can remain untidy throughout the working day, but is cleaned during quiet periods. d) Work area goes for long periods in an untidy state.	Option
P27	How would you describe the way in which the performance of maintenance is communicated?	Option

	a) Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are updated daily. b) Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are updated when possible. c) Primary goals and metrics are reported on and updated daily to relevant staff. d) Primary goals and metrics are reported to senior managers upon request.	

Planning and performance (9)		
P28	What percentage of work orders are prioritised? a) 100% b) 75% -99% c) 50% - 74% d) 0% - 49%	Option
P29	What percentage of planned work orders are completed in the allocated time? a) 100% b) 75% -99%	Option

	c) 50% - 74% d) 0% - 49%	
P30	Do Maintenance staff discuss work order priorities with departments who place the work order? a) In specific scheduled meetings. b) As regularly as possible. c) Informally, if the opportunity arises. d) Never.	Option
P31	Who/what is responsible for planning and scheduling of Work orders? a) A dedicated planning software system or specific trained member of staff b) Maintenance supervisor with no formal training c) Craft technician with no formal training. d) There is no set method for scheduling work orders.	Option
P32	How many of the following resources does the planning for work orders include: • Maintenance type	Option (Question format depends upon electronic

	• Tools • Material • Job instruction/procedure a) All 4 b) 3 from 4 c) 2 from 4 d) 1 from 4	questionnaire capability)
P33	What percentage of work orders, when completed, are inspected for quality and suitability? a) 75% -100% b) 50% - 74% c) 25% - 49% d) 0% - 24%	Option
P34	What percentage of work orders are identified as being emergency or urgent? a) 0- 15% b) 15 - 30% c) 30 - 50% d) 50%+	Option
P35	What percent of total jobs performed by maintenance are covered by work orders? a) 100% b) 65% -99% c) 35% - 64% d) 0% - 35%	Option

P35	Is downtime recorded accurately? a) Yes, for all assets with accuracy b) Yes, for some assets with accuracy c) Yes, with some inaccuracies. d) There is no accurate recording system.	

Equipment & Spares (7)		
P36	Does the maintenance department have an equipment and spares inventory system? a) Yes, the system is up to date and allows accurate monitoring of parts and materials usage. b) Yes, the system is in place but can be inaccurate. c) Yes, there is a system but it requires major improvements. d) There is no system.	Option

P36	What percentage of equipment and spares are readily available when required? a) 90% – 100% b) 85% – 94% c) 75% – 84% d) Less than 75%	Option
P36	What percentage of time has the inventory system negatively affected the completion of a maintenance task? a) Less than 5% b) 5% - 10% c) 10% - 20% d) 20%+	Option
P37	Does the maintenance budget prevent the purchase of equipment and spare parts? a) Never for critical spares, tools and equipment. b) Occasionally for tools and equipment. c) Occasionally for critical spares and tools and equipment. d) Regularly for all inventory items.	Option
P38	What percentage of critically identified equipment has	Option

	available spare parts when required? e) 97% -100% f) 90% – 97% g) 85% – 90% h) Less than 85%	
P39	What percentage of identified critical assets have an identified ‘insurance’ plan? a) 90% – 100% b) 85% – 94% c) 75% – 84% d) Less than 75%	Option
P40	How would you describe maintenance tools and equipment? a) They are of good quality and available when required. b) They are available as required but in need of updating. c) There are issues with their availability. d) Poor, a substantial review and investment is required.	Option

Budget (4)		

P41	How would you describe the maintenance budget in the following areas? • Tools and Equipment; • Spares and Materials; • Training; • Continuous Improvement. a) Sufficient in all four areas b) Sufficient in 3 from 4 areas c) Sufficient in 2 from 4 areas d) Sufficient in 1 from 4 areas	Option (Question format depends upon electronic questionnaire capability)
P42	Are inventory and manpower costs recorded within the maintenance department? a) For all assets and work orders b) For key assets only c) On an irregular basis d) Never.	Option
P42	How is previously recorded budget and cost information used in maintenance planning? a) To improve maintenance planning, inventory management and recording systems. b) To improve inventory management and cost reduction.	Option

	c) As a benchmark for establishing future budgets. d) Historical information is rarely used.	
P43	Is maintenance budget and cost information readily available? a) Available on demand. b) Available once the data is collated and calculated. c) Some information is readily available. d) Information is unreliable and difficult to gather.	Option

Key Performance Indicators (6)		
P44	Which of the following categories does the maintenance department measure? a) Manpower efficiency b) Machine Availability c) Planning efficiency d) None	Option (Question format depends upon electronic questionnaire capability)
P44	Which of the following categories does the maintenance department measure?	Option (Question format depends upon

	a) Cost b) Health and Safety c) Maintenance type d) None	electronic questionnaire capability)
P45	Are metrics recorded and calculated accurately? a) Yes, the recording of necessary data and calculation appears accurate. b) Yes, the calculation of data is accurate, though the recording of some metrics is doubtful. c) Both the recording and calculation of metrics can change depending upon who is doing it. d) Unable to comment.	Option
P46	How are performance information and KPI's used within the department? a) To improve future plans, including continuous improvement, machine availability and cost reduction. b) To improve specific assets for availability.	Option

	c) To provide analysis of current performance. d) There is little use of recorded performance information.	
P47	Maintenance performance reports are consistently available to specific staff when required: a) 95% of time b) 75% - 94% c) 60% - 74% d) Less than 60%	Option
P48	Are maintenance performance metrics displayed in or near the workshop area? a) Yes, clearly so all staff may note daily progress. b) Yes, though this is for maintenance personnel only. c) Yes, though any updates tend to be irregular. d) No, this information is held in a database/spreadsheet	Option

Buffer/Safety stock (4)		

P49	Does the business hold safety stock as part of its everyday operations? a) Yes b) No	Option
P50	Does poor maintenance performance affect the level of safety stock? a) Yes b) No	Option
P50	Are current levels excessively high? a) Yes b) No	Option
4 **??** **Take out?**	How are day to day levels of safety stock managed and calculated? a) Levels are closely monitored and managed effectively. Maintenance and production performance informs safety stock capacity. b) Levels are monitored and measured. This is informed by production availability and customer orders.	Option

	c) Levels are identified regularly, based on historic performance and customer requirements. d) There is little day to day management of stock levels.	

Appendix 6 Gap Test Tool Feedback.

Summary of testing interview with Senior Quality Engineer; Tier One supplier.

Purpose:

To discuss the format and content of the proposed audit tool.

Questioning was informal, open and guided by the following items:

- What do you think of the format as a useful audit tool?
- Wording of the questions?
- Options on each question: Should they be in a guidance document and a judgement is then placed on the question from that? Example P32, P41, 44 & 45
- Thoughts on the perception section. Irrelevant or not?
- Anything missing?

Feedback:

- V5 is an audit form presented in the form of survey. Providing options and allowing opinion.
- Purpose of an audit is for it to be independent.
- Questions are good questions, but the criteria provided should be hidden to the auditor.
- Auditor should decide what the score or answer is to the question based on the evidence provided.
- Scoring method required. Removes opinions and makes it a score. The can apply targets.
- In automotive everyone has a target and kpi, so this would mirror that.
- Each section should have a minimum required.
- Audits are poor if they hide what they are looking for. Audits are looking for evidence of conformance.
- Fine to provide an audit and say these are the criteria – this is what we are looking at This then provides a direct line to any score – as it is evidence based against set criteria.
- Can’t share the evidence that you’re looking for with the section being audited – as it then introduces the possibility of pre-fabrication of evidence.
- But sharing the criteria is fine – such as communication, planning etc.? (I think)
- Person carrying out audit is someone who not necessarily a quality person.

- Audit tends to be open ended, informal and based on discussions with several key members of staff. Questions asked are open ended. Results of discussion leads to the auditor completing the scoring for each question or category.
- V5 needs a crib sheet behind the categories stating evidence base for scores on each category.
- Audit as word is intimidating. Gap analysis tool possibly. A state of play – where are we at?
- Audit tool can be preloaded with higher scores i.e. ‘must have’s’ for the business could have higher scores….
- Gap analysis is more sellable as a useful tool. A state of the nation tool, which provides outputs.
- Number of questions for V5 is absolutely fine. Not about how many questions. Its about are all the questions relevant?
- Any audit questionnaire needs to small and concise but that depends what you need to know about.
- Reword questions with ‘what am I trying to find out’ in mind. What is the answer telling me?
- The content of V5 works in the main. Apply a scoring system. What V5 looks like is the crib sheet. The questions are the auditor questions, not the category questions…(1:00)
- Evidence for scoring is crucial.
- Also remove option for opinions on a question.
- Perception section (through) a survey may have a place to balance the audit score.

Appendix 7.1 Plant 3 Gap Analysis Test results.

Maintenance Engineering

Gap Analysis Tool

Category	Question	Criteria/Evidence	Judgement	Score	Notes	Characteristic
Senior management engagement	Who are the participants in the development of future maintenance plans?	Management action planning meetings. Communication lines. Staff engagement procedures.	a) SM have an active role in maintenance development. b) SM have an active role, but input is limited. c) SM engagement is inconsistent. d) No, there is little input from SM	a) – 4 b) – 3 c) – 2 d) – 1	Breakdown analysis. New plant information. Production and Engineering Manager. No documentation available.	Engagement in maintenance development.

Appendix 7.1 Plant 3 Gap Analysis Test results.

		Leadership engagement				
	Are maintenance performance reports regularly communicated to different levels of the business?	Reporting process flow charts Minutes of regular review meetings	a) Maintenance Performance reported daily to SM b) Maintenance Performance reported weekly to SM c) Maintenance Performance reported monthly to SM. d) Maintenance Performance is never reported to SM.	a) – 4 b) – 3 c) – 2 d) – 1	Weekly reports to ops meeting mins. Shift log – excel file to hold KPI detail.	Maintenance performance communication.
	In what areas of the business do senior managers discuss maintenance?	Action plans Minutes of meetings Business wide communication areas. Observation	a) Maintenance is discussed through business wide communication, such as notices and in meetings b) Maintenance is discussed within production meetings only. c) Maintenance is discussed occasionally, when reviewing individual department performance. d) SM never discuss maintenance performance.	a) – 4 b) – 3 c) – 2 d) – 1	Morning Ops meeting minutes.	Discussion forums for maintenance priorities.
	Does anyone approve the annual plans and targets of the	Maintenance planning meeting minutes E mail records	a) Maintenance Plans are submitted and reviewed regularly by SM.	a) – 4 b) – 3 c) – 2 d) – 1	Unable to answer. 0 recorded.	Engagement in maintenance development.

	maintenance department?	Maintenance review meeting minutes	b) Maintenance Plans are submitted and reviewed annually by SM. c) Maintenance Plans are discussed informally with SM. d) Maintenance Plans are rarely reviewed by SM; the department is judged on results.			
	What is the process for identifying and approving maintenance KPI's?	Maintenance planning meeting minutes E mail records Maintenance strategy review meeting minutes	a) Specific KPI's are consistently discussed and agreed between SM and maintenance. b) Suggested KPI's are reviewed by SM, but the advice of the maintenance manager is required. c) KPI's are submitted for approval to SM, but feedback is not normally provided d) Maintenance KPI's are not requested or reviewed by senior managers.	a) – 4 b) – 3 c) – 2 d) – 1	BDR, %PM's completed. Self records MTTR – not requested by SM. Passive interaction.	Engagement in maintenance KPI management.
				10	**2**	

Appendix 7.1 Plant 3 Gap Analysis Test results.

Skills and Training	Is there a training plan for the department?	Training records Maintenance skills gap analysis Training plan records	a) Yes, it is planned at the beginning of each financial year, reviewed regularly and documented for audit purposes b) Yes, it is planned at the beginning of each year and reviewed at the end with no follow up plan. c) It is planned each year, but rarely followed. d) Training tends to be requested on an ad-hoc basis	a) – 4 b) – 3 c) – 2 d) – 1	No plan in place. Little training previously taken place. Currently under review.	Training plan for staff development.
	How is a maintenance training requirement normally identified?	Staff appraisal Maintenance planning processes. Task breakdown reviews.	a) Systematically, through the maintenance plan and regular meetings with staff. b) By staff requests. c) Once a year in an appraisal. d) Never	a) – 4 b) – 3 c) – 2 d) – 1	Informally, but also in appraisal.	Training Needs Analysis utilised.
	Is the impact of training measured?	Appraisal Historical KPI data Maintenance schedule information. Training plan	a) Yes, the impact is measured through appraisal, department and personal performance. b) Yes, the impact is identified through a training plan review but production improvements are not identified. c) Yes, though there is little evidence to support this.	a) – 4 b) – 3 c) – 2 d) – 1	No training so little impact. Unable to respond with detail.	Training measured for impact.

			d) The effect of training is not measured.			
	Is the training plan always implemented as intended?	Training plan review documents	a) With the exception of a critical event, staff are normally released for training. b) Yes, though staff capacity can sometimes be an issue c) Sometimes, though day to day jobs often take priority. d) There are too few staff for extensive periods of training	a) – 4 b) – 3 c) – 2 d) – 1	HR facilitates attendance and logs completion.	Training delivery scheduled effectively.
	Is there a process for identifying the correct skill requirements of the department?	Maintenance task breakdown Recruitment strategy Training plan Appraisal	a) Yes, maintenance tasks are reviewed for skill requirements and the ratio of mechanical/electrical/multi skilled staff is monitored. b) Yes, though this is carried out inconsistently and affects performance. c) No, we use a historical mech/elec ratio for training and recruitment. d) No, we are understaffed in certain skills which is affecting performance	a) – 4 b) – 3 c) – 2 d) – 1	System in place, but infrequently reviewed. (ILU document)	Identification of workload skill requirements.

Appendix 7.1 Plant 3 Gap Analysis Test results.

				10	**2**	
Staff resources	Is the department adequately resourced?	Performance information Maintenance task breakdown analysis Maintenance recruitment activity Apprenticeship scheme?	a) The technician level is appropriate, all capacity is monitored and there is capacity for continuous improvement work. b) The staff level seems appropriate based upon maintenance performance measures. Some continuous improvement work is carried out. c) There appears little capacity for any additional work except routine maintenance d) There are too few staff to complete the required maintenance tasks	a) – 4 b) – 3 c) – 2 d) – 1	Maintenance technicians OK for staffing, maintenance tooling, under capacity.	Adequate department staffing.
	Is there a process for identifying the skills required for the maintenance workload?		a) Yes, all work orders can be planned and carried without delay due to manpower/skill restrictions. b) Yes, most work orders can be planned and carried out with few delays due to manpower restrictions	a) – 4 b) – 3 c) – 2 d) – 1	See above for skill identification.	Staffing requirements result from workload analysis.

			c) Yes but it is inconsistent, a shortage in one area often leads to delays in work completion d) It is difficult to comment, delays are common in completing any work orders			
	Are production operators allocated maintenance tasks?		a) Yes, they carry out specific, identified tasks and report the outcome regularly. b) Yes, they carry out general cleaning duties in their area. c) Some operators in specific areas take part, though not all. d) No.	a) – 4 b) – 3 c) – 2 d) – 1	No maintenance completed by operators. No low level maintenance.	Deployment of autonomous maintenance.
	Is the impact of any autonomous maintenance carried out by production measured for impact?	KPI information MTTR (trend) MTTB (trend)	a) Yes, maintenance planning identifies task breakdown with required resources. Additional capacity clearly planned and implemented. b) Yes, MTTR and MTTB analysed. c) Yes, the impact is noticeable though there is no specific metric used.	a) – 4 b) – 3 c) – 2 d) – 1	See above.	Deployment of autonomous maintenance.

			d) There is no evidence of any discussion or measurement of impact.			
	Are staff resources managed to reflect the requirements of production?	Maintenance task and planning records. Department skill profile.	a) Yes, each maintenance shift is fully staffed and mirrors production shift pattern. b) Yes, but this can cause resource issues on each maintenance shift. c) No, a different shift system is required due to low staff numbers. d) No, overtime is required to cover production outside of the normal shift system.	a) – 4 b) – 3 c) – 2 d) – 1		Effective shift pattern.
	Can the business retain skilled operational technicians?	HR records	a) Staff retention is good and operational staff have long service. b) Staff service is considered normal with some long service. c) Staff retention is good with older staff, poor with younger. d) Yes, staff retention is poor with high staff turnover.	a) – 4 b) – 3 c) – 2 d) – 1	Relatively good, but with older staff. Not many young staff.	Retention of skilled staff.

	Are maintenance staff consulted when planning and scheduling is carried out?	Suggestion and reward scheme Minutes of maintenance planning and scheduling meetings.	a) Maintenance staff are regularly consulted for opinions on maintenance planning and direction. A suggestion and reward scheme is used. b) Maintenance staff are able to offer their opinion informally with some opinions taken on board. There is no suggestion and reward scheme. c) Maintenance staff can offer their opinion on equipment and plans, but the plans are not changed. d) No discussion occurs between maintenance senior staff and technicians about plans or equipment	a) – 4 b) – 3 c) – 2 d) – 1	Little engagement and little plans for department. PM plans come from MP2 (CMMS) system. Little evidence of variation. Respondent only guy that alters things.. No suggestion and reward scheme	Consultation in maintenance planning.
	Is there structured career planning process for the maintenance department?		a) Maintenance staff have a clear direction for training, development and promotion opportunities through appraisal. b) Promotion normally occurs internally, but career	a) – 4 b) – 3 c) – 2 d) – 1	Evidence lies in PADR (appraisal),but little evidence of specific structure.	Progression opportunities.

			planning is not normally discussed. c) Maintenance staff may apply for internal opportunities though external recruitment is common. d) There is little opportunity for promotion within the business.			
	Does an apprenticeship scheme alleviate recruitment and skill issues?		a) An apprenticeship scheme is in place and regularly reviewed for suitability. b) An apprenticeship scheme is in place, but the recruitment and suitability are not normally reviewed. c) An apprenticeship scheme is in place, though it has not recruited for some time. d) No scheme is in place.	a) – 4 b) – 3 c) – 2 d) – 1	Strong apprenticeship scheme with 11 in 'cycle' at the moment. Placed where needed.	Effective staff renewal system.
				19	2.1	
Integration	How is the impact of the maintenance schedule discussed	Meeting minutes Email traffic	a) The schedule is communicated electronically and discussed at daily meetings.	a) – 4 b) – 3 c) – 2 d) – 1	Only plans discussed are PM's…discussed informally with	Consultation with maintenance stakeholders

	with other departments?	Process documents for schedule generation	b) The schedule and plans are discussed at most meetings c) The schedule and plans are discussed informally. d) No discussion takes place		production coordinator.	
	Is the location of the maintenance workshop suitable for access and contact?	Manufacturing floor plan	a) Workshop is in an ideal and accessible area, for immediate contact. b) Workshop is in an area poor for contact, requires improvement. c) Workshop requires major improvement for accessibility. d) Workshop is inaccessible and contact is difficult.	a) – 4 b) – 3 c) – 2 d) – 1	Located in between press shop and fab shop.	Maintenance workshop location.
	Does the workshop reflect the operational standards set by the surrounding work areas?	Standard operation procedures for workplace maintenance Conformity documentation	a) Work area is maintained to outstanding standards. Regular inspections are held and documented for adherence to 5S standards. b) Work area maintained and inspected at the end of each shift. No standards for efficiency or inspection used. c) Work area can remain untidy throughout the working day,	a) – 4 b) – 3 c) – 2 d) – 1	Verbally, says YES, but only weekly audit carried out.	Workshop housekeeping standards.

			but is cleaned during quiet periods. d) Work area goes for long periods in an untidy state.			
	How would you describe the way in which the performance of maintenance is communicated?	Visual inspection Communication records	a) Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are live. b) Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are updated regularly. c) Primary goals and metrics are displayed to relevant staff. d) Primary goals and metrics are reported to senior managers upon request.	a) – 4 b) – 3 c) – 2 d) – 1	Targets and metrics displayed in Respondents office only. Not outwardly produced or shown. No briefing of maintenance improvements to any staff. Action point!	Communication of maintenance performance.
				10	**2.25**	
Planning and Performance	Are all maintenance resources utilised in work completion	Staff feedback WO recording system	a) 100% of jobs performed by maintenance are fully recorded as WO.	a) – 4 b) – 3 c) – 2 d) – 1	Time only recorded, not full resources.	Management of resources.

	tracked and recorded accurately?	Staff deployment efficiency records.	b) 65% -99% of jobs performed by maintenance are fully recorded as WO. c) 35% - 64% of jobs performed by maintenance are fully recorded as WO. d) 0% - 35% of jobs performed by maintenance are fully recorded as WO.			
	How efficient is the planning of maintenance tasks?	CMMS feedback WO recording system Staff feedback	a) 100% of maintenance tasks are prioritised and recorded for time and resources. b) 75% -99% of maintenance tasks are prioritised and recorded for time and resources. c) 50% - 74% of maintenance tasks are prioritised and recorded for time and resources. d) 0% - 49% of maintenance tasks are prioritised and recorded for time and resources.	a) – 4 b) – 3 c) – 2 d) – 1	Time only evidenced. Recording of resources inconsistent. Recorded on excel spreadsheet.	Maintenance planning efficiency.

Appendix 7.1 Plant 3 Gap Analysis Test results.

	How effective is the maintenance planning schedule?	CMMS feedback WO recording system Staff feedback	a) 100% of WO are completed in the allocated time. b) 75% -99% of WO are completed in the allocated time. c) 50% - 74% of WO are completed in the allocated time. d) 0% - 49% of WO are completed in the allocated time.	a) – 4 b) – 3 c) – 2 d) – 1	Verbal feedback…little evidence to substantiate.	Maintenance planning efficiency.
	Are maintenance workorder priorities discussed with WO requesting departments?	Staff feedback Electronic communication Meeting minutes	a) In specific scheduled meetings. b) As regularly as possible, although it is inconsistent. c) Informally, if the opportunity arises. d) Never.	a) – 4 b) – 3 c) – 2 d) – 1	Verbal discussion only…	Consultation with maintenance stakeholders.
	How is the maintenance work schedule produced?	SOP's	a) In a systematic manner, with a dedicated planning software system or specific trained member of staff b) In a systematic manner, by a Maintenance supervisor with no formal training c) Craft technician with no formal training.	a) – 4 b) – 3 c) – 2 d) – 1	PM schedule is the only formal schedule produced. All else is informal.	Production of maintenance work schedule.

			d) There is no set method for scheduling work orders.			
	What maintenance resources are included within the planning process?	Planning records CMMS records Action plan review records	• Maintenance type • Tools • Material • Job instruction/procedure a) All 4 b) 3 from 4 c) 2 from 4 d) 1 from 4	a) – 4 b) – 3 c) – 2 d) – 1		Management of resources.
	What percentage of completed workorders require rework?	MTTR MTTB EN15341 data WO recorded feedback	a) 75% -100% b) 50% - 74% c) 25% - 49% d) 0% - 24%	a) – 1 b) – 2 c) – 3 d) – 4	Unable to answer with data. Action point for improvement.	Quality assurance of completed work orders.
	What percentage of work orders are identified as being emergency or urgent?	MTTR MTTB EN15341 data WO recorded feedback	a) 0- 15% b) 15 - 30% c) 30 - 50% d) 50%+	a) – 4 b) – 3 c) – 2 d) – 1	Stated 70%...but unable to produce evidence.	Work order tracking.

	How is downtime recorded?	CMMS Downtime recording system Downtime recording 'fields'.	a) Yes, for all assets with accuracy and to a high degree of detail. b) Yes, for some assets with accuracy and a high degree of detail. c) Yes, with some inaccuracies inaccuracy and detail. d) There is no accurate recording system.	a) – 4 b) – 3 c) – 2 d) – 1	Recorded on-shift log and against production uptime.	Recording of downtime.
				17	**1.9**	
Equipment and Spares	What is the maintenance department equipment and spares inventory system?	Equipment and Spares Process documents Equipment and spares records Maintenance completion documents/records	a) A comprehensive system is in place. It is up to date and allows accurate monitoring of parts and materials usage. b) A system is in place but can be inaccurate. c) There is a system but it requires major improvements. d) There is no system.	a) – 4 b) – 3 c) – 2 d) – 1	No storeman and no electronic recording or reordering system. Some critical spares not in place.	Equipment and spares inventory system.
	Is the Equipment and spares system effective?	Equipment and spares records Maintenance completion documents/records	a) 90% – 100% of equipment and spares is readily available when required.	a) – 4 b) – 3 c) – 2 d) – 1	System required major improvement. Not sure what is in place at any one time.	Availability of required equipment and spares.

			b) 85% – 94% of equipment and spares is readily available when required. c) 75% – 84% of equipment and spares is readily available when required. d) Less than 75% of equipment and spares is readily available when required.			
	How would you describe maintenance tools?	Tools and equipment records. Maintenance completion documents/records	a) They are of good quality and available when required. b) They are available as required but in need of updating. c) There are issues with their availability. d) Poor, a substantial review and investment is required.	a) – 4 b) – 3 c) – 2 d) – 1		Standard of maintenance tools.
	Does the maintenance budget accommodate all identified and required equipment and spare parts?	Equipment and spares records. Critical parts and inventory list Maintenance performance KPI	a) Yes, for all identified equipment and spares in maintenance planning schedule. b) No, only for critical equipment and parts. c) No, the budget is inconsistent and can result in poor inventory levels.	a) – 4 b) – 3 c) – 2 d) – 1	Capex can supplement budget. Unable to produce evidence. 0 recorded.	Budget for maintenance equipment and spare parts.

		WO completion records	d) No, the budget is regularly insufficient for supporting maintenance inventory levels			
	What is the procedure if a production asset breaks down and no spare part is available?	Critical part and process document.	a) 90% – 100% processes/parts have an identified 'insurance' plan b) 85% – 94% processes/parts have an identified 'insurance' plan c) 75% – 84% processes/parts have an identified 'insurance' plan d) Less than 75% processes/parts have an identified 'insurance' plan	a) – 4 b) – 3 c) – 2 d) – 1	Process is ongoing, being supplemented constantly.	Identification of critical processes and planning.
				14	**2.8**	
Budget	How would you describe the maintenance budget in relation to your requirements?	Meeting minutes (budget planning) Equipment & Materials inventory records Training delivery plan C.I. Project planning records	• Tools and Equipment; • Spares and Materials; • Training; • Continuous Improvement. a) Sufficient in all four areas b) Sufficient in 3 from 4 areas c) Sufficient in 2 from 4 areas d) Sufficient in 1 from 4 areas	a) – 4 b) – 3 c) – 2 d) – 1	Little evidence could be produced Unable to produce evidence.	Maintenance budget capacity.

Appendix 7.1 Plant 3 Gap Analysis Test results.

	What is the process for planning future maintenance budgets?	Meeting minutes (budget planning) S.O.P for maintenance planning and scheduling activities - ref (a) Inventory management records	a) Budget planning incorporates analysis to improve maintenance strategies on assets, inventory management and recording systems. b) Budget planning incorporates analysis to improve inventory management and cost reduction. c) Budget planning incorporates using previous information as a benchmark for establishing future budgets. d) Historical information is rarely used for future planning.	a) – 4 b) – 3 c) – 2 d) – 1	Includes reengineering of machines to improve maintenance type and reduce spare part requirement. Unable to produce evidence	Maintenance performance data informing budget planning.
				8	**4**	
Key Performance Indicators	In which areas is maintenance performance information recorded?	KPI historical information Maintenance performance reporting records	• Manpower efficiency • Machine Availability • Planning efficiency • Budget efficiency a) All top 4 options b) 3 from 4	a) – 4 b) – 3 c) – 2 d) – 1	Planning and budget efficiency. Manpower and machine availability only tracked through BDR. Production information	Range of maintenance performance measurement.

			c) 2 from 4 d) 1 from 4		for Machine availability held with prod. Dept.	
	In what areas does recorded information inform future maintenance planning?	Maintenance planning and scheduling meeting minutes E mail Planning records	• Cost • Health and Safety • Maintenance type • None a) All top 3 options b) 2 from 3 c) 1 from 3 d) None	a) – 4 b) – 3 c) – 2 d) – 1	Cost at the moment only. Maintenance type under development but not in place.	Analysis of recorded information.
	How are performance information and KPI's used within the department?	Maintenance planning and scheduling meeting minutes or records Staff feedback S.O.P	a) To improve future plans, including continuous improvement, machine availability and cost reduction. b) To improve specific assets for availability. c) To provide analysis of current performance. d) There is little use of recorded performance information.	a) – 4 b) – 3 c) – 2 d) – 1	Review of data appears to sit with PM schedule and completion only. BDR fed back to coordinators but discussion is difficult due to shift pattern. So superficial communication? A lot of responsibility with Simon for action.	Analysis of recorded information.

Appendix 7.1 Plant 3 Gap Analysis Test results.

	How is maintenance performance information normally reported?	Staff feedback Management meeting minutes Planning meeting minutes	Accurate maintenance performance information can be provided upon request: a) 95% of time b) 75% - 94% c) 60% - 74%. d) Less than 60%	a) – 4 b) – 3 c) – 2 d) – 1	Separate systems for recording, between production and maintenance. Feedback stated approx.. 90% accuracy when compare data.	Accurate recording of maintenance metrics.
	Where is maintenance performance information displayed?	Staff feedback Observation Record inspection Manufacturing performance display areas.	a) Maintenance performance information is clearly displayed so all staff may note progress with regular, accurate updates. b) Maintenance performance information is clearly displayed with regular, accurate updates, for maintenance personnel only. c) Maintenance performance information is clearly displayed to maintenance personnel, though updates are irregular. d) Maintenance performance information is not clearly displayed, this information is	a) – 4 b) – 3 c) – 2 d) – 1	Data held on a sheet only. Graphs/performance displayed in Respondents office. Not available for viewing by all (shop floor). Displays are out of date.	Display and communication of maintenance performance.

			held in a database/spreadsheet			
				9	**1.8**	
Buffer/Safety stock	Can maintenance performance influence the delivery schedule to the OEM?	Staff feedback KPI records Customer feedback Maintenance management meeting minutes Maintenance planning meeting minutes Critical asset definition plans Resilience planning documents	a) The effective use of safety stock and robust planning should minimise any impact. b) Yes, unexpected critical asset downtime may have a negative impact on customer deliveries. c) Yes, poor maintenance performance can result in sporadic customer delivery issues. d) Yes, consistent poor maintenance performance has resulted in customer sanctions.	a) – 4 b) – 3 c) – 2 d) – 1	DNA	
	How are the levels of safety stock managed?	Production records Stock level records	a) Levels are closely monitored and managed effectively. Daily maintenance and production performance, as well as customer orders informs safety stock capacity.	a) – 4 b) – 3 c) – 2 d) – 1	DNA	

		Production planning meeting minutes Staff feedback	b) Levels are monitored and measured but are mostly maintained at a static level. This is informed by production performance and customer orders. c) Safety stock levels are identified based on historic information on required stock levels. d) There is little day to day management of stock levels.			
	Does maintenance performance have a financial impact on the business?	Staff feedback KPI records Customer feedback Maintenance management meeting minutes Maintenance planning meeting minutes Critical asset definition plans	a) Yes, high levels of planning and performance improve production efficiency and maintenance impact. b) Yes, through close management of the maintenance budget and associated expenditure c) Yes, inconsistent performance can have a negative financial impact through poor budget control can increase safety stock levels.	a) – 4 b) – 3 c) – 2 d) – 1	DNA	

		Resilience planning documents	d) Yes, though this is not measured explicitly.			

Appendix 7.2 Plant 1 Gap Analysis Test results.

Maintenance Engineering

Gap Analysis Tool

Appendix 7.2 Plant 1 Gap Analysis Test results.

Category/Characteristic	Question	Criteria/Evidence	Judgement	Score	**Notes**
Senior management engagement ***Engagement in maintenance development***	Who are the participants in the development of future maintenance plans?	Management action planning meetings. Communication lines. Staff engagement procedures. Leadership engagement	a) SM have an active role in maintenance development. b) SM have an active role, but input is limited. c) SM engagement is inconsistent. d) No, there is little input from SM	a) – 4 b) – 3 c) – 2 d) – 1	**Ops manager and SM Engineer and section leader.** **Weekly and monthly meetings. 3 monthly meeting with SM.** **OSP meetings against objectives.**
Maintenance Performance Communication	Are maintenance performance reports regularly communicated to different levels of the business?	Reporting process flow charts Minutes of regular review meetings	a) Maintenance Performance reported daily to SM b) Maintenance Performance reported weekly to SM c) Maintenance Performance reported monthly to SM. d) Maintenance Performance is never reported to SM.	a) – 4 b) – 3 c) – 2 d) – 1	**Communicated to maintenance staff.** **Ops meeting reports WBR.** **Comms to SM as well as to EMC. Euro management committee.**

Appendix 7.2 Plant 1 Gap Analysis Test results.

Discussion forums for Maintenance priorities.	In what areas of the business do senior managers discuss maintenance?	Action plans Minutes of meetings Business wide communication areas. Observation	a) Maintenance is discussed through business wide communication, such as notices and in meetings b) Maintenance is discussed within production meetings only. c) Maintenance is discussed occasionally, when reviewing individual department performance. d) SM never discuss maintenance performance.	a) – 4 b) – 3 c) – 2 d) – 1	**Weekly meeting communicates projects by maintenance in briefing. Not all performance aspects discussed.**
Engagement in Maintenance KPI management	Does anyone approve the annual plans and targets of the maintenance department?	Maintenance planning meeting minutes E mail records Maintenance review meeting minutes	a) Maintenance Plans are submitted and reviewed regularly by SM. b) Maintenance Plans are submitted and reviewed annually by SM. c) Maintenance Plans are discussed informally with SM. d) Maintenance Plans are rarely reviewed by SM; the department is judged on results.	a) – 4 b) – 3 c) – 2 d) – 1	**Same as Q1.**
Engagement in Maintenance KPI management	What is the process for identifying and approving	Maintenance planning meeting minutes	a) Specific KPI's are consistently discussed and agreed between SM and maintenance.	a) – 4 b) – 3 c) – 2 d) – 1	**Targets come from Ops manager. KPI's come from Business plan objectives.**

	maintenance KPI's?	E mail records Maintenance strategy review meeting minutes	b) Suggested KPI's are reviewed by SM, but the advice of the maintenance manager is required. c) KPI's are submitted for approval to SM, but feedback is not normally provided d) Maintenance KPI's are not requested or reviewed by senior managers.		**Filters down in to Department action plan.**
				18	**3.6**
Skills and Training ***Training plan for staff***	Is there a training plan for the department?	Training records Maintenance skills gap analysis Training plan records	a) Yes, it is planned at the beginning of each financial year, reviewed regularly and documented for audit purposes b) Yes, it is planned at the beginning of each year and reviewed at the end with no follow up plan. c) It is planned each year, but rarely followed. d) Training tends to be requested on an ad-hoc basis	a) – 4 b) – 3 c) – 2 d) – 1	**Training plan documented. Staff audited for skills and maintenance training planned accordingly.**
Training needs analysis utilised	How is a maintenance training	Staff appraisal Maintenance planning processes.	a) Systematically, through the maintenance plan and regular meetings with staff. b) By staff requests.	a) – 4 b) – 3 c) – 2 d) – 1	**See above.** **From equipment within factory. I,L,U system for each staff member.**

	requirement normally identified?	Task breakdown reviews.	c) Once a year in an appraisal. d) Never		**Plan on excel sheet.**
Training measured for impact	Is the impact of training measured?	Appraisal Historical KPI data Maintenance schedule information. Training plan	a) Yes, the impact is measured through appraisal, department and personal performance. b) Yes, the impact is identified through a training plan review but production improvements are not identified. c) Yes, though there is little evidence to support this. d) The effect of training is not measured.	a) – 4 b) – 3 c) – 2 d) – 1	**Anecdotal evidence only. Like the idea of it. Beginning MTTR per person at other company plant for training requirements.**
Training delivery scheduled effectively	Is the training plan always implemented as intended?	Training plan review documents	a) With the exception of a critical event, staff are normally released for training. b) Yes, though staff capacity can sometimes be an issue c) Sometimes, though day to day jobs often take priority. d) There are too few staff for extensive periods of training	a) – 4 b) – 3 c) – 2 d) – 1	**Training plan implemented as staff resources are 'adequate'. Training plan excel sheet for evidence.**
Identification of workload skill requirements	Is there a process for identifying the correct skill requirements of the department?	Maintenance task breakdown Recruitment strategy Training plan	a) Yes, maintenance tasks are reviewed for skill requirements and the ratio of mechanical/electrical/multi skilled staff is monitored.	a) – 4 b) – 3 c) – 2 d) – 1	**I,L,U document used and reviewed with each member of staff for skill requirements and skill possession.**

		Appraisal	b) Yes, though this is carried out inconsistently and affects performance. c) No, we use a historical mech/elec ratio for training and recruitment. d) No, we are understaffed in certain skills which is affecting performance		**Also Major breakdown analysis helps identify skill gaps.**
				17	**3.4**
Staff resources ***Adequate department staffing***	Is the department adequately resourced?	Performance information Maintenance task breakdown analysis Maintenance recruitment activity Apprenticeship scheme?	a) The technician level is appropriate, all capacity is monitored and there is capacity for continuous improvement work. b) The staff level seems appropriate based upon maintenance performance measures. Some continuous improvement work is carried out. c) There appears little capacity for any additional work except routine maintenance	a) – 4 b) – 3 c) – 2 d) – 1	**Measure %completion against tasks set. Rarely less than 100%. Time for CI and Project work.**

			d) There are too few staff to complete the required maintenance tasks		
Staffing requirements result from workload analysis	Is there a process for identifying the skills required for the maintenance workload?		a) Yes, all work orders can be planned and carried without delay due to manpower/skill restrictions. b) Yes, most work orders can be planned and carried out with few delays due to manpower restrictions c) Yes but it is inconsistent, a shortage in one area often leads to delays in work completion d) It is difficult to comment, delays are common in completing any work orders	a) – 4 b) – 3 c) – 2 d) – 1	**See above answer for notes.**
Deployment of autonomous maintenance	Are production operators allocated maintenance tasks?		a) Yes, they carry out specific, identified tasks and report the outcome regularly. b) Yes, they carry out general cleaning duties in their area. c) Some operators in specific areas take part, though not all. d) No.	a) – 4 b) – 3 c) – 2 d) – 1	**PLM – plant led maintenance implemented. Low level maintenance tasks.** **Not all operators are trained and required to act. Man Tech staff in process**

					of being trained for PLM activity. **'Forced deterioration minutes' reduced from 2,500 per year as target. This emerges from operators accidently causing faults. PLM looking to remove this from improved operator knowledge.** **Manufacturing Technicians (semi skilled) to be trained to complete basic maintenance tasks.**
Deployment of autonomous maintenance	Is the impact of any autonomous maintenance carried out by production measured for impact?	KPI information MTTR (trend) MTTB (trend)	a) Yes, maintenance planning identifies task breakdown with required resources. Additional capacity clearly planned and implemented. b) Yes, MTTR and MTTB analysed. c) Yes, the impact is noticeable though there is no specific metric used.	a) – 4 b) – 3 c) – 2 d) – 1	**Forced deterioration minutes reduced by PLM plan.** **Not fully implemented yet though – so score of 3.**

			d) There is no evidence of any discussion or measurement of impact.		
Effective shift pattern	Are staff resources managed to reflect the requirements of production?	Maintenance task and planning records. Department skill profile.	a) Yes, each maintenance shift is fully staffed and mirrors production shift pattern. b) Yes, but this can cause resource issues on each maintenance shift. c) No, a different shift system is required due to low staff numbers. d) No, overtime is required to cover production outside of the normal shift system.	a) – 4 b) – 3 c) – 2 d) – 1	**3 Maintenance tech's one each shift - matches production.**
Retention of skilled staff	Can the business retain skilled operational technicians?	HR records	a) Staff retention is good and operational staff have long service. b) Staff service is considered normal with some long service. c) Staff retention is good with older staff, poor with younger. d) Yes, staff retention is poor with high staff turnover.	a) – 4 b) – 3 c) – 2 d) – 1	**No presentable evidence, but some long service. Age gap for staff a concern.**
Consultation in maintenance planning	Are maintenance staff consulted	Suggestion and reward scheme	a) Maintenance staff are regularly consulted for opinions on maintenance planning and	a) – 4 b) – 3 c) – 2	**Shift handovers, between maintenance staff. Daily**

	when planning and scheduling is carried out?	Minutes of maintenance planning and scheduling meetings.	direction. A suggestion and reward scheme is used. b) Maintenance staff are able to offer their opinion informally with some opinions taken on board. There is no suggestion and reward scheme. c) Maintenance staff can offer their opinion on equipment and plans, but the plans are not changed. d) No discussion occurs between maintenance senior staff and technicians about plans or equipment	d) – 1	**morning meetings with all other departments. Weekly maintenance meeting with all staff – discuss KPI performance. Not documented – only through 'master schedule'. Discussion occur but no evidence of engagement.**
Progression opportunities	Is there structured career planning process for the maintenance department?		a) Maintenance staff have a clear direction for training, development and promotion opportunities through appraisal. b) Promotion normally occurs internally, but career planning is not normally discussed. c) Maintenance staff may apply for internal opportunities though external recruitment is common. d) There is little opportunity for promotion within the business.	a) – 4 b) – 3 c) – 2 d) – 1	**Some sort of appraisal system is in place but acknowledged as not being effective. A new system is being developed for talent spotting. Informal process.**

Appendix 7.2 Plant 1 Gap Analysis Test results.

Effective staff renewal scheme	Does an apprenticeship scheme alleviate recruitment and skill issues?		a) An apprenticeship scheme is in place and regularly reviewed for suitability. b) An apprenticeship scheme is in place, but the recruitment and suitability are not normally reviewed. c) An apprenticeship scheme is in place, though it has not recruited for some time. d) No scheme is in place.	a) – 4 b) – 3 c) – 2 d) – 1	**Regularly recruit into apprenticeship scheme. 20 people in NE within maintenance that are 55+. Fill both skills gaps and resource/age gap.** **Training plan set for multi skilled Tech's with specialist knowledge in specific kit.**
				30	**3.33**
Integration ***Consultation with maintenance stakeholders***	How is the impact of the maintenance schedule discussed with other departments?	Meeting minutes Email traffic Process documents for schedule generation	a) The schedule is communicated electronically and discussed at daily meetings. b) The schedule and plans are discussed at most meetings c) The schedule and plans are discussed informally. d) No discussion takes place	a) – 4 b) – 3 c) – 2 d) – 1	**Discussed daily between shift coordinators. PM schedule displayed on Shop Floor.**
Maintenance workshop location	Is the location of the maintenance workshop suitable for access and contact?	Manufacturing floor plan	a) Workshop is in an ideal and accessible area, for immediate contact. b) Workshop is in an area poor for contact, requires improvement.	a) – 4 b) – 3 c) – 2 d) – 1	**W/Shop placed away from Production, 'in a corner'. Last on the list for space.**

			c) Workshop requires major improvement for accessibility. d) Workshop is inaccessible and contact is difficult.		
Maintenance workshop housekeeping standards	Does the workshop reflect the operational standards set by the surrounding work areas?	Standard operation procedures for workplace maintenance Conformity documentation	a) Work area is maintained to outstanding standards. Regular inspections are held and documented for adherence to 5S standards. b) Work area maintained and inspected at the end of each shift. No standards for efficiency or inspection used. c) Work area can remain untidy throughout the working day but is cleaned during quiet periods. d) Work area goes for long periods in an untidy state.	a) – 4 b) – 3 c) – 2 d) – 1	**Inconsistent adherence to workshop standards. Good for audit – not for general day to day activities. 5S Audits carried out internally, but not space is an issue.**
Communication of maintenance performance	How would you describe the way in which the performance of maintenance is communicated?	Visual inspection Communication records	a) Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are live. b) Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are updated regularly.	a) – 4 b) – 3 c) – 2 d) – 1	**Acknowledged as being a Gap within department. Internally and to shop floor. Good performance not acknowledged or reported on.** **No split of attributing factors into OEE. So if not**

			c) Primary goals and metrics are displayed to relevant staff. d) Primary goals and metrics are reported to senior managers upon request.		**contributing towards negative aspects of OEE – is it identified. Briefs provided to shop floor at same level as EMC – no breaking down of key information of audience.**
				9	**2.25**
Planning and Performance ***Management of resources***	Are all maintenance resources utilised in work completion tracked and recorded accurately?	Staff feedback WO recording system Staff deployment efficiency records.	a) 100% of jobs performed by maintenance are fully recorded as WO. b) 65% -99% of jobs performed by maintenance are fully recorded as WO. c) 35% - 64% of jobs performed by maintenance are fully recorded as WO. d) 0% - 35% of jobs performed by maintenance are fully recorded as WO.	a) – 4 b) – 3 c) – 2 d) – 1	**Time documented only as resources. Acknowledged as being a GAP.** **Recording of WO for reactive jobs inconsistent.**
Maintenance planning efficiency	How efficient is the planning of maintenance tasks?	CMMS feedback WO recording system Staff feedback	a) 100% of maintenance tasks are prioritised and recorded for time and resources. b) 75% -99% of maintenance tasks are prioritised and	a) – 4 b) – 3 c) – 2 d) – 1	**The execution of the plan is just under 100% but it incorporates time only – hence the lower score.**

			recorded for time and resources. c) 50% - 74% of maintenance tasks are prioritised and recorded for time and resources. d) 0% - 49% of maintenance tasks are prioritised and recorded for time and resources.		
Maintenance planning efficiency	How effective is the maintenance planning schedule?	CMMS feedback WO recording system Staff feedback	a) 100% of WO are completed in the allocated time. b) 75% -99% of WO are completed in the allocated time. c) 50% - 74% of WO are completed in the allocated time. d) 0% - 49% of WO are completed in the allocated time.	a) – 4 b) – 3 c) – 2 d) – 1	**1 month in FY17 was under 100% - though tracking of master schedule – hence score of 3.**
Consultation with maintenance stakeholders	Are maintenance workorder priorities discussed with WO requesting departments?	Staff feedback Electronic communication Meeting minutes	a) In specific scheduled meetings. b) As regularly as possible, although it is inconsistent. c) Informally, if the opportunity arises. d) Never.	a) – 4 b) – 3 c) – 2 d) – 1	**MP2 (CMMS) helps with importance and scheduling of specific maintenance tasks.**

Appendix 7.2 Plant 1 Gap Analysis Test results.

Production of maintenance schedule	How is the maintenance work schedule produced?	SOP's	a) In a systematic manner, with a dedicated planning software system or specific trained member of staff b) In a systematic manner, by a Maintenance supervisor with no formal training c) Craft technician with no formal training. d) There is no set method for scheduling work orders.	a) – 4 b) – 3 c) – 2 d) – 1	**See above**
Management of resources	What maintenance resources are included within the planning process?	Planning records CMMS records Action plan review records	• Maintenance type • Tools • Material • Job instruction/procedure a) All 4 b) 3 from 4 c) 2 from 4 d) 1 from 4	a) – 4 b) – 3 c) – 2 d) – 1S Score of 0	**No resources – time only.**
Quality assurance of completed work orders	What percentage of completed workorders require rework?	MTTR MTTB EN15341 data WO recorded feedback	a) 75% -100% b) 50% - 74% c) 25% - 49% d) 0% - 24%	a) – 4 b) – 3 c) – 2 d) – 1	**Unknown – score of 0. Not measured.**

Work order tracking	What percentage of work orders are identified as being emergency or urgent?	MTTR MTTB EN15341 data WO recorded feedback	a) 0- 15% b) 15 - 30% c) 30 - 50% d) 50%+	a) – 4 b) – 3 c) – 2 d) – 1	**Unknown – score of 0. Not measured. Although data possibly available through BDR data…**
Recording of downtime	How is downtime recorded?	CMMS Downtime recording system Downtime recording 'fields'.	a) Yes, for all assets with accuracy and to a high degree of detail. b) Yes, for some assets with accuracy and a high degree of detail. c) Yes, with some inaccuracies inaccuracy and detail. d) There is no accurate recording system.	a) – 4 b) – 3 c) – 2 d) – 1	**Maintenance record their version and production record their own. Acknowledge as being '80% accurate' of real downtime and stoppages. 2 versions are 'quite close.'**
				16	**1.77**
Equipment and Spares ***Equipment and spares inventory system***	What is the maintenance department equipment and spares inventory system?	Equipment and Spares Process documents Equipment and spares records	a) A comprehensive system is in place. It is up to date and allows accurate monitoring of parts and materials usage. b) A system is in place but can be inaccurate. c) There is a system but it requires major improvements. d) There is no system.	a) – 4 b) – 3 c) – 2 d) – 1	**Major BDR identifies spares used and required – although acknowledge some inaccuracies.**

		Maintenance completion documents/records			
Equipment and spares inventory system	Is the Equipment and spares system effective?	Equipment and spares records Maintenance completion documents/records	a) 90% – 100% of equipment and spares is readily available when required. b) 85% – 94% of equipment and spares is readily available when required. c) 75% – 84% of equipment and spares is readily available when required. d) Less than 75% of equipment and spares is readily available when required.	a) – 4 b) – 3 c) – 2 d) – 1	**Some inconsistencies with reordering and storing of spare parts. Stores person only works day shift and across 2 sites.**
Standard of maintenance tools and equipment.	How would you describe maintenance tools and equipment?	Equipment and spares records Maintenance completion documents/records	a) They are of good quality and available when required. b) They are available as required but in need of updating. c) There are issues with their availability. d) Poor, a substantial review and investment is required.	a) – 4 b) – 3 c) – 2 d) – 1	**Tools for maintenance deemed as being effective. No tool audit for quality and condition.**

N/a	Does the maintenance budget accommodate all identified and required equipment and spare parts?	Equipment and spares records. Critical parts and inventory list Maintenance performance KPI WO completion records	a) Yes, for all identified equipment and spares in maintenance planning schedule. b) No, only for critical equipment and parts. c) No, the budget is inconsistent and can result in poor inventory levels. d) No, the budget is regularly insufficient for supporting maintenance inventory levels	a) – 4 b) – 3 c) – 2 d) – 1	**Large cross section of process equipment. Budget of £1.1 million.**
Identification of critical processes and planning	What is the procedure if a production asset breaks down and no spare part is available?		a) 90% – 100% processes/parts have an identified 'insurance' plan b) 85% – 94% processes/parts have an identified 'insurance' plan c) 75% – 84% processes/parts have an identified 'insurance' plan d) Less than 75% processes/parts have an identified 'insurance' plan	a) – 4 b) – 3 c) – 2 d) – 1	**Critical processes identified as well as spare parts identification,**
				17	**3.4**

Appendix 7.2 Plant 1 Gap Analysis Test results.

Budget	How would you describe the maintenance budget in relation to your requirements?	Meeting minutes (budget planning) Equipment & Materials inventory records Training delivery plan C.I. Project planning records	• Tools and Equipment; • Spares and Materials; • Training; • Continuous Improvement. a) Sufficient in all four areas b) Sufficient in 3 from 4 areas c) Sufficient in 2 from 4 areas d) Sufficient in 1 from 4 areas	a) – 4 b) – 3 c) – 2 d) – 1	
	What is the process for planning future maintenance budgets?	Meeting minutes (budget planning) S.O.P for maintenance planning and scheduling activities - ref (a) Inventory management records	a) Budget planning incorporates analysis to improve maintenance strategies on assets, inventory management and recording systems. b) Budget planning incorporates analysis to improve inventory management and cost reduction. c) Budget planning incorporates using previous information as a benchmark for establishing future budgets. d) Historical information is rarely used for future planning.	a) – 4 b) – 3 c) – 2 d) – 1	**Budget planned from what spent in previous year as well as what are customer plans for purchase of parts (income). In addition, any CapEx on new kit.**
				6	**3**

Appendix 7.2 Plant 1 Gap Analysis Test results.

Key Performance Indicators ***Range of maintenance performance measurement***	In which areas is maintenance performance information recorded?	KPI historical information Maintenance performance reporting records	• Manpower efficiency • Machine Availability • Planning efficiency • Budget efficiency a) All top 4 options b) 3 from 4 c) 2 from 4 d) 1 from 4	a) – 4 b) – 3 c) – 2 d) – 1	**Reported for plant, but not for maintenance.** **Implementation of plan and availability tracked and reported.** **Manpower efficiency acknowledged as being desirable.**
Analysis and use of recorded information	In what areas does recorded information inform future maintenance planning?	Maintenance planning and scheduling meeting minutes E mail Planning records	• Cost • Health and Safety • Maintenance type • None a) All top 3 options b) 2 from 3 c) 1 from 3 d) None	a) – 4 b) – 3 c) – 2 d) – 1	**Cost and lost work time monitored and acted upon.** **No maintenance type recorded effectively.**
Analysis and use of recorded information	How are performance information and KPI's used within the department?	Maintenance planning and scheduling meeting minutes or records Staff feedback S.O.P	a) To improve future plans, including continuous improvement, machine availability and cost reduction. b) To improve specific assets for availability. c) To provide analysis of current performance.	a) – 4 b) – 3 c) – 2 d) – 1	**See answer above.** **Not great for answer.**

			d) There is little use of recorded performance information.		
	How is maintenance performance information normally reported?	Staff feedback Management meeting minutes Planning meeting minutes	Accurate maintenance performance information can be provided upon request: a) 95% of time b) 75% - 94% c) 60% - 74%. d) Less than 60%	a) – 4 b) – 3 c) – 2 d) – 1	**Not asked – due to previous answers. Pls see above.**
Display and communication of maintenance performance	Where is maintenance performance information displayed?	Staff feedback Observation Record inspection Manufacturing performance display areas.	a) Maintenance performance information is clearly displayed so all staff may note progress with regular, accurate updates. b) Maintenance performance information is clearly displayed with regular, accurate updates, for maintenance personnel only. c) Maintenance performance information is clearly displayed to maintenance personnel, though updates are irregular. d) Maintenance performance information is not clearly displayed, this information is held in a database/spreadsheet	a) – 4 b) – 3 c) – 2 d) – 1	**Maintenance KPI's not displayed. Only project work -as a case study shown in maintenance workshop.** **May be on a noticeboard for customer viewing – not shop floor.** **No shop floor viewing of maintenance performance improvements/impact.**

				9	**2.25**
Buffer/Safety stock	Can maintenance performance influence the delivery schedule to the OEM?	Staff feedback KPI records Customer feedback Maintenance management meeting minutes Maintenance planning meeting minutes Critical asset definition plans Resilience planning documents	a) The effective use of safety stock and robust planning should minimise any impact. b) Yes, unexpected critical asset downtime may have a negative impact on customer deliveries. c) Yes, poor maintenance performance can result in sporadic customer delivery issues. d) Yes, consistent poor maintenance performance has resulted in customer sanctions.	a) – 4 b) – 3 c) – 2 d) – 1	
	How are the levels of safety stock managed?	Production records Stock level records Production planning meeting minutes Staff feedback	a) Levels are closely monitored and managed effectively. Daily maintenance and production performance, as well as customer orders informs safety stock capacity. b) Levels are monitored and measured but are mostly maintained at a static	a) – 4 b) – 3 c) – 2 d) – 1	**Set on longest breakdown, current stock levels, customer orders. Monitored daily.**

			level. This is informed by production performance and customer orders. c) Safety stock levels are identified based on historic information on required stock levels. d) There is little day to day management of stock levels.		
	Does maintenance performance have a financial impact on the business?	Staff feedback KPI records Customer feedback Maintenance management meeting minutes Maintenance planning meeting minutes Critical asset definition plans Resilience planning documents	a) Yes, high levels of planning and performance improve production efficiency and maintenance impact. b) Yes, through close management of the maintenance budget and associated expenditure c) Yes, inconsistent performance can have a negative financial impact through poor budget control can increase safety stock levels. d) Yes, though this is not measured explicitly.	a) – 4 b) – 3 c) – 2 d) – 1	**Only seen as a cost to the business. No positive impact can be demonstrated.**
				10	**3.33**

Appendix 7.3 Plant 4 Gap Analysis Test results.

Category	Question	Criteria/Evidence	Judgement	Score	Notes	Characteristic
Senior management engagement	Who are the participants in the development of future maintenance plans?	Weekly meetings with Global. Audits for TPM achievement.	a) SM have an active role in maintenance development. b) SM have an active role, but input is limited. c) SM engagement is inconsistent. d) No, there is little input from SM	a) – 4 b) – 3 c) – 2 d) – 1	Maintenance Supervisor Team Leader Head of Global (Plant 4). Plan involves working towards Gold level TPM. Bi-weekly meeting, involving OM. More direction and auditing of TPM from corporate.	Engagement in maintenance development.
	Are maintenance performance reports regularly	Minutes of daily review meetings (ops meeting)	a) Maintenance Performance reported daily to SM b) Maintenance Performance reported weekly to SM	a) – 4 b) – 3 c) – 2 d) – 1	Weekly Reporting to corporate –	Maintenance performance communication.

	communicated to different levels of the business?	& Weekly availability meeting. Corporate reporting.	c) Maintenance Performance reported monthly to SM. d) Maintenance Performance is never reported to SM.		maintenance director. Report Weekly availability (98%), MTTR MTBF reported weekly and monthly to global. Data input into central learnet system.	
	In what areas of the business do senior managers discuss maintenance?	Action plans Minutes of meetings regular review meetings.	a) Maintenance is discussed through business wide communication, such as notices and in meetings b) Maintenance is discussed within production meetings only. c) Maintenance is discussed occasionally, when reviewing individual department performance. d) SM never discuss maintenance performance.	a) – 4 b) – 3 c) – 2 d) – 1	Set meetings for downtime and uptime. Weekly and Monthly review meetings. Discussed for commissioning and quality work. Discussed at a technical level – not business wide.	Discussion forums for maintenance priorities.

	Does anyone approve the annual plans and targets of the maintenance department?	Maintenance planning meeting minutes. Local & International. E mail records	a) Maintenance Plans are submitted and reviewed regularly by SM. b) Maintenance Plans are submitted and reviewed annually by SM. c) Maintenance Plans are discussed informally with SM. d) Maintenance Plans are rarely reviewed by SM; the department is judged on results.	a) – 4 b) – 3 c) – 2 d) – 1	Plans set around downtime and uptime targets – how to achieve. Targets set by OM.	Engagement in maintenance development.
	What is the process for identifying and approving maintenance KPI's?	TPM Gold standards (corporate) identify required KPI's.	a) Specific KPI's are consistently discussed and agreed between SM and maintenance. b) Suggested KPI's are reviewed by SM, but the advice of the maintenance manager is required. c) KPI's are submitted for approval to SM, but feedback is not normally provided d) Maintenance KPI's are not requested or reviewed by senior managers.	a) – 4 b) – 3 c) – 2 d) – 1	KPI's initially agreed by sister plant (JIT). MTBF 8 hours and 9 minutes MTTR. Gold level TPM standard is 200hrs/qtr MTBF and 5 mins MTTR. Data recorded in a manual manner at each machine. Team leader creates data.	Engagement in maintenance KPI management.

Appendix 7.3 Plant 4 Gap Analysis Test results.

					Multiple KPI's recorded on a local level by MC for personal comparison. He uses this in meetings as well.	
			Total and average score	**18**	**3.6**	
Skills and Training	Is there a training plan for the department?	Training plan document. 3 monthly review meetings on personal performance.	a) Yes, it is planned at the beginning of each financial year, reviewed regularly and documented for audit purposes b) Yes, it is planned at the beginning of each year and reviewed at the end with no follow up plan. c) It is planned each year, but rarely followed. d) Training tends to be requested on an ad-hoc basis	a) – 4 b) – 3 c) – 2 d) – 1	Yes – 12 months in advance. Difficult to release people for training. 3 month reviews on all aspects of performance – not just training.	Training plan for staff development.
	How is a maintenance training requirement normally identified?	TNA for each employee.	a) Systematically, through the maintenance plan and regular meetings with staff. b) By staff requests. c) Once a year in an appraisal. d) Never	a) – 4 b) – 3 c) – 2 d) – 1	TNA scored 1 -4.	Training Needs Analysis utilised.

Appendix 7.3 Plant 4 Gap Analysis Test results.

	Is the impact of training measured?	None at the moment.	a) Yes, the impact is measured through appraisal, department and personal performance. b) Yes, the impact is identified through a training plan review but production improvements are not identified. c) Yes, though there is little evidence to support this. d) The effect of training is not measured.	a) – 4 b) – 3 c) – 2 d) – 1	Training not measured specifically, but small projects beginning to be provided to maintain skills provided by training. MTTR and MTBF noted as being able to be influenced, but no examples available.	Training measured for impact.
	Is the training plan always implemented as intended?	Budget detail. Training plan.	a) With the exception of a critical event, staff are normally released for training. b) Yes, though staff capacity can sometimes be an issue c) Sometimes, though day to day jobs often take priority. d) There are too few staff for extensive periods of training	a) – 4 b) – 3 c) – 2 d) – 1	Training prioritised through Budget primarily. Some training gets dropped.	Training delivery scheduled effectively.

	Is there a process for identifying the correct skill requirements of the department?	Little evidence available, although skill requirements are known.	a) Yes, maintenance tasks are reviewed for skill requirements and the ratio of mechanical/electrical/multi skilled staff is monitored. b) Yes, though this is carried out inconsistently and affects performance. c) No, we use a historical mech/elec ratio for training and recruitment. d) No, we are understaffed in certain skills which is affecting performance	a) – 4 b) – 3 c) – 2 d) – 1	Maintenance skill requirements not particularly reviewed, more based upon mentality towards the role. Little evidence available. Highlighted answer is based on discussion feedback. Changes made to shift pattern to amend.	Identification of workload skill requirements.
				12	**2.4**	
Staff resources	Is the department adequately resourced?	Technician and manager feedback. Manual data recorded detail.	a) The technician level is appropriate, all capacity is monitored and there is capacity for continuous improvement work. b) The staff level seems appropriate based upon maintenance performance	a) – 4 b) – 3 c) – 2 d) – 1	Purely for maintenance - yes. Additional tasks such as tool changes, installation, CI cause resource issues.	Adequate department staffing.

			measures. Some continuous improvement work is carried out. c) There appears little capacity for any additional work except routine maintenance d) There are too few staff to complete the required maintenance tasks		Plan is 30% PM 20% corrective actions from PM's 50% project work. These are deployment requirements from corporate. All recording of data is manual.	
	Is there a process for identifying the skills required for the maintenance workload?	SWI for jobs.	a) Yes, all work orders can be planned and carried without delay due to manpower/skill restrictions. b) Yes, most work orders can be planned and carried out with few delays due to manpower restrictions c) Yes but it is inconsistent, a shortage in one area often leads to delays in work completion d) It is difficult to comment, delays are common in completing any work orders	a) – 4 b) – 3 c) – 2 d) – 1	Not answered completely, but creation of SWI (Safe working instruction) for each type of job. This identifies training and skill requirements. This is incomplete though.	Staffing requirements result from workload analysis.

Appendix 7.3 Plant 4 Gap Analysis Test results.

	Are production operators allocated maintenance tasks?	PM activity sheets and records. 1 Semi skilled staff support activities. TPM boards	a) Yes, they carry out specific, identified tasks and report the outcome regularly. b) Yes, they carry out general cleaning duties in their area. c) Some operators in specific areas take part, though not all. d) No.	a) – 4 b) – 3 c) – 2 d) – 1	1 Semi skilled staff completing 5S tasks and PM work to support maintenance. Operators not carrying out PM work.	Deployment of autonomous maintenance.
	Is the impact of any autonomous maintenance carried out by production measured for impact?	Anecdotal only.	a) Yes, maintenance planning identifies task breakdown with required resources. Additional capacity clearly planned and implemented. b) Yes, MTTR and MTTB analysed. c) Yes, the impact is noticeable though there is no specific metric used. d) There is no evidence of any discussion or measurement of impact.	a) – 4 b) – 3 c) – 2 d) – 1	Anecdotal evidence only.	Deployment of autonomous maintenance.
	Are staff resources managed to reflect the requirements of production?	HR and staffing shift records.	a) Yes, each maintenance shift is fully staffed and mirrors production shift pattern.	a) – 4 b) – 3 c) – 2 d) – 1	Shifts exactly the same. Each maintenance shift has 3 people plus	Effective shift pattern.

			b) Yes, but this can cause resource issues on each maintenance shift. c) No, a different shift system is required due to low staff numbers. d) No, overtime is required to cover production outside of the normal shift system.		a daytime supervisor.	
	Can the business retain skilled operational technicians?	HR records	a) Staff retention is good and operational staff have long service. b) Staff service is considered normal with some long service. c) Staff retention is good with older staff, poor with younger. d) Yes, staff retention is poor with high staff turnover.	a) – 4 b) – 3 c) – 2 d) – 1	Stable at moment, but poor 4 years ago. (7/10) for service (MC's score). Apprenticeship scheme implemented to alleviate issue.	Retention of skilled staff.
	Are maintenance staff consulted when planning and scheduling is carried out?	Little evidence available but meetings (not recorded) take place.	a) Maintenance staff are regularly consulted for opinions on maintenance planning and direction. A suggestion and reward scheme is used.	a) – 4 b) – 3 c) – 2 d) – 1	Consulted with project work and repair work. Not 12-month plan or PM schedule.	Consultation in maintenance planning.

			b) Maintenance staff are able to offer their opinion informally with some opinions taken on board. There is no suggestion and reward scheme. c) Maintenance staff can offer their opinion on equipment and plans, but the plans are not changed. d) No discussion occurs between maintenance senior staff and technicians about plans or equipment			
	Is there structured career planning process for the maintenance department?	None	a) Maintenance staff have a clear direction for training, development and promotion opportunities through appraisal. b) Promotion normally occurs internally, but career planning is not normally discussed. c) Maintenance staff may apply for internal opportunities though external recruitment is common. d) There is little opportunity for promotion within the business.	a) – 4 b) – 3 c) – 2 d) – 1	No career plan. Reviews are based around performance only.	Progression opportunities.

Appendix 7.3 Plant 4 Gap Analysis Test results.

	Does an apprenticeship scheme alleviate recruitment and skill issues?	Little evidence base available.	a) An apprenticeship scheme is in place and regularly reviewed for suitability. b) An apprenticeship scheme is in place, but the recruitment and suitability are not normally reviewed. c) An apprenticeship scheme is in place, though it has not recruited for some time. d) No scheme is in place.	a) – 4 b) – 3 c) – 2 d) – 1	1 set of apprentices recruited 3 years ago, but too early to establish their contribution to the business. All are qualified but need experience.	Effective staff renewal system.
				18	**2**	
Integration	How is the impact of the maintenance schedule discussed with other departments?	Morning/Shift Meeting minutes	a) The schedule is communicated electronically and discussed at daily meetings. b) The schedule and plans are discussed at most meetings c) The schedule and plans are discussed informally. d) No discussion takes place	a) – 4 b) – 3 c) – 2 d) – 1		Consultation with maintenance stakeholders
	Is the location of the maintenance workshop suitable for access and contact?	Manufacturing floor plan.	a) Workshop is in an ideal and accessible area, for immediate contact.	a) – 4 b) – 3 c) – 2 d) – 1	Workshop area at one end of plant.	Maintenance workshop location.

			b) Workshop is in an area poor for contact, requires improvement. c) Workshop requires major improvement for accessibility. d) Workshop is inaccessible and contact is difficult.		MC would prefer workshop more visible.	
	Does the workshop reflect the operational standards set by the surrounding work areas?	Standard operation procedures for workplace maintenance 5S standards and rota.	a) Work area is maintained to outstanding standards. Regular inspections are held and documented for adherence to 5S standards. b) Work area maintained and inspected at the end of each shift. No standards for efficiency or inspection used. c) Work area can remain untidy throughout the working day but is cleaned during quiet periods. d) Work area goes for long periods in an untidy state.	a) – 4 b) – 3 c) – 2 d) – 1	State of workshop depends upon business of department. 5S picture displayed for workshop and rota available .	Workshop housekeeping standards.
	How would you describe the way in which the performance of	KPI performance report and action plan.	a) Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are live.	a) – 4 b) – 3 c) – 2 d) – 1	Share metrics with all other plants.	Communication of maintenance performance.

	maintenance is communicated?		b) Primary goals and metrics are reported on and displayed in a visible area to all staff. Results and achievements are updated regularly. c) Primary goals and metrics are displayed to relevant staff. d) Primary goals and metrics are reported to senior managers upon request.		Monthly review meeting with all other departments on all metrics. If KPI all green, then no actions (and vice-versa) Nothing communicated solely for plant 4. Scrap, right first time and OEE performance displayed live on monitors on shop floor and to managers. No thank you communicated to maintenance staff.	
				9	**2.25**	
Planning and Performance	Are all maintenance resources utilised in	Staff feedback WO recording system	a) 100% of jobs performed by maintenance are fully recorded as WO.	a) – 4 b) – 3 c) – 2	Not at the moment. CMMS	Management of resources.

	work completion tracked and recorded accurately?	Staff deployment efficiency records.	b) 65% -99% of jobs performed by maintenance are fully recorded as WO. c) 35% - 64% of jobs performed by maintenance are fully recorded as WO. 0% - 35% of jobs performed by maintenance are fully recorded as WO.	d) – 1	system not implemented. Recording system not efficient. Some jobs to be completed are not recorded. All recorded on an excel spreadsheet.	
	How efficient is the planning of maintenance tasks?	CMMS feedback WO recording system Staff feedback	a) 100% of maintenance tasks are prioritised and recorded for time and resources. b) 75% -99% of maintenance tasks are prioritised and recorded for time and resources. c) 50% - 74% of maintenance tasks are prioritised and recorded for time and resources. d) 0% - 49% of maintenance tasks are prioritised and recorded for time and resources.	a) – 4 b) – 3 c) – 2 d) – 1	Maintenance staff carry out die change work. 45 hours per week. So some resource is removed. Difficult to provide evidence – hence score. See below for time sheets for man hours recording and time sheets.	Maintenance planning efficiency.

Appendix 7.3 Plant 4 Gap Analysis Test results.

	How effective is the maintenance planning schedule?	CMMS feedback WO recording system Staff feedback	a) 100% of WO are completed in the allocated time. b) 75% -99% of WO are completed in the allocated time. c) 50% - 74% of WO are completed in the allocated time. d) 0% - 49% of WO are completed in the allocated time.	a) – 4 b) – 3 c) – 2 d) – 1	Verbal answer from MC. Difficult to prove due to recording system and job requests. Also, no seniority on shift away from day shift – so staff taken off job by senior production people. Also, scheduling system is created manually and recorded with time sheets. So inaccurate! Excel spreadsheet.	Maintenance planning efficiency.
	Are maintenance workorder priorities discussed with WO requesting departments?	Staff feedback Electronic communication Meeting minutes	a) In specific scheduled meetings. b) As regularly as possible, although it is inconsistent. c) Informally, if the opportunity arises.	a) – 4 b) – 3 c) – 2	Discussed in morning scheduled meetings.	Consultation with maintenance stakeholders.

			d) Never.	d) – 1		
	How is the maintenance work schedule produced?	SOP's	a) In a systematic manner, with a dedicated planning software system or specific trained member of staff b) In a systematic manner, by a Maintenance supervisor with no formal training c) Craft technician with no formal training. d) There is no set method for scheduling work orders.	a) – 4 b) – 3 c) – 2 d) – 1	Plan is a weekly worklist with PM's for week. Not scheduled in for jobs for a specific day. Job requests sent by email which add to this. So work schedule very fluid and influenced by several sources. *Note: CMS requires 1 person to manage system – hence persistent failures of system. MC never seen a successful CMS system.*	Production of maintenance work schedule.

Appendix 7.3 Plant 4 Gap Analysis Test results.

	What maintenance resources are included within the planning process?	Planning records CMMS records Action plan review records	• Maintenance type • Tools • Material • Job instruction/procedure a) All 4 b) 3 from 4 c) 2 from 4 d) 1 from 4	a) – 4 b) – 3 c) – 2 d) – 1	Planned jobs are predominantly PM's. So this is restricted and does not include other work. Plan does not include tools/material or instruction.	Management of resources.
	What percentage of completed workorders require rework?	MTTR MTTB EN15341 data WO recorded feedback	a) 0% - 24% b) 25% - 49% c) 50% - 74% d) 75% -100%	a) – 4 b) – 3 c) – 2 d) – 1	25% of all critical work orders should be supervised. So checked by team leader. This does not occur, as most critical work occurs at weekend. Unable to answer with a %	Quality assurance of completed work orders.
	What percentage of work orders are identified as being emergency or urgent?	MTTR MTTB	a) 0- 15% b) 15 - 30% c) 30 - 50% d) 50%+	a) – 4 b) – 3 c) – 2 d) – 1	Reactive work specifically not measured. Availability	Work order tracking.

		EN15341 data WO recorded feedback			benchmark is 96%.	
	How is downtime recorded?	CMMS Downtime recording system Downtime recording 'fields'.	a) Yes, for all assets with accuracy and to a high degree of detail. b) Yes, for some assets with accuracy and a high degree of detail. c) Yes, with some inaccuracies inaccuracy and detail. d) There is no accurate recording system.	a) – 4 b) – 3 c) – 2 d) – 1	Maintenance and production record separately and manually. With differences.	Recording of downtime.
				23	**2.55**	
Equipment and Spares	What is the maintenance department equipment and spares inventory system?	Equipment and Spares Process documents Equipment and spares records Maintenance completion documents/records	a) A comprehensive system is in place. It is up to date and allows accurate monitoring of parts and materials usage. b) A system is in place but can be inaccurate. c) There is a system but it requires major improvements. d) There is no system.	a) – 4 b) – 3 c) – 2 d) – 1	WASP scanning system used. Barcoded with re-order levels. Kan ban labels used on critical parts. Weekly audits carried out, but sometimes parts not booked out	Equipment and spares inventory system.

					through WASP system.	
	Is the Equipment and spares system effective?	Equipment and spares records Maintenance completion documents/records	a) 90% – 100% of equipment and spares is readily available when required. b) 85% – 94% of equipment and spares is readily available when required. c) 75% – 84% of equipment and spares is readily available when required. d) Less than 75% of equipment and spares is readily available when required.	a) – 4 b) – 3 c) – 2 d) – 1	Pls see above. Inaccuracies exist but 90%+ of parts available.	Availability of required equipment and spares.
	How would you describe maintenance tools and equipment?	Equipment and spares records Maintenance completion documents/records	a) They are of good quality and available when required. b) They are available as required but in need of updating. c) There are issues with their availability. d) Poor, a substantial review and investment is required.	a) – 4 b) – 3 c) – 2 d) – 1		Standard of maintenance tools.
	Does the maintenance budget accommodate all identified and	Equipment and spares records.	a) Yes, for all identified equipment and spares in maintenance planning schedule.	a) – 4 b) – 3 c) – 2 d) – 1	Budget completed 12 months in advance. So	Budget for maintenance equipment and spare parts.

	required equipment and spare parts?	Critical parts and inventory list Maintenance performance KPI WO completion records	b) No, only for critical equipment and parts. c) No, the budget is inconsistent and can result in poor inventory levels. d) No, the budget is regularly insufficient for supporting maintenance inventory levels		unplanned failures can disrupt this.	
	What is the procedure if a production asset breaks down and no spare part is available?		a) 90% – 100% processes/parts have an identified 'insurance' plan b) 85% – 94% processes/parts have an identified 'insurance' plan c) 75% – 84% processes/parts have an identified 'insurance' plan d) Less than 75% processes/parts have an identified 'insurance' plan	a) – 4 b) – 3 c) – 2 d) – 1	All reasonable critical spares are in place. Contingency plan for the plant. FMEA on each asset also, for all components within the asset.	Identification of critical processes and planning.
				19	**3.8**	
Budget	How would you describe the maintenance budget	Meeting minutes (budget planning)	• Tools and Equipment; • Spares and Materials; • Training; • Continuous Improvement.	a) – 4 b) – 3 c) – 2 d) – 1	Sufficient in 3 from 4 areas. But no budget for CI,	Maintenance budget capacity.

Appendix 7.3 Plant 4 Gap Analysis Test results.

	in relation to your requirements?	Equipment & Materials inventory records Training delivery plan C.I. Project planning records	a) Sufficient in all four areas b) Sufficient in 3 from 4 areas c) Sufficient in 2 from 4 areas d) Sufficient in 1 from 4 areas		even though maintenance are required to complete it. Training is from HR budget.	
	What is the process for planning future maintenance budgets?	5-year plans with monthly budget reviews. As well as end of year reviews with forward planning.	a) Budget planning incorporates analysis to improve maintenance strategies on assets, inventory management and recording systems. b) Budget planning incorporates analysis to improve inventory management and cost reduction. c) Budget planning incorporates using previous information as a benchmark for establishing future budgets. d) Historical information is rarely used for future planning.	a) – 4 b) – 3 c) – 2 d) – 1	2019 budget completed. Budget based upon previous 12/24 month budget data. CMS a capex purchase.	Maintenance performance data informing budget planning.
				7	**3.5**	
Key Performance Indicators	In which areas is maintenance	KPI historical information	• Manpower efficiency • Machine Availability • Planning efficiency	a) – 4 b) – 3 c) – 2	Manpower efficiency and	Range of maintenance

	performance information recorded?	Maintenance performance reporting records	• Budget efficiency a) All top 4 options b) 3 from 4 c) 2 from 4 d) 1 from 4	d) – 1	planning efficiency not recorded. Seen as valuable though…	performance measurement.
	In what areas does recorded information inform future maintenance planning?	Maintenance planning and scheduling meeting minutes E mail Planning records	• Cost • Health and Safety • Maintenance type • None a) All top 3 options b) 2 from 3 c) 1 from 3 d) None	a) – 4 b) – 3 c) – 2 d) – 1		Analysis of recorded information.
	How are performance information and KPI's used within the department?	Maintenance planning and scheduling meeting minutes or records Staff feedback S.O.P	a) To improve future plans, including continuous improvement, machine availability and cost reduction. b) To improve specific assets for availability. c) To provide analysis of current performance. d) There is little use of recorded performance information.	a) – 4 b) – 3 c) – 2 d) – 1	A briefing sent out to the department. Unsure as to whether they are read or understood. Used to drive planning for department.	Analysis of recorded information.

	How is maintenance performance information normally reported?	Staff feedback Management meeting minutes Planning meeting minutes	Accurate maintenance performance information can be provided upon request: a) 95% of time b) 75% - 94% c) 60% - 74%. d) Less than 60%	a) – 4 b) – 3 c) – 2 d) – 1	Recording can be inaccurate, due to lack of automation and manual nature.	Accurate recording of maintenance metrics.
	Where is maintenance performance information displayed?	Staff feedback Observation Record inspection Manufacturing performance display areas.	a) Maintenance performance information is clearly displayed so all staff may note progress with regular, accurate updates. b) Maintenance performance information is clearly displayed with regular, accurate updates, for maintenance personnel only. c) Maintenance performance information is clearly displayed to maintenance personnel, though updates are irregular. d) Maintenance performance information is not clearly displayed, this information is	a) – 4 b) – 3 c) – 2 d) – 1	Maintenance KPI displayed on team focus board outside workshop, in shop floor and within different zones around shop floor. Labour intensive so irregular. Not really useful to staff. No staff wide briefings to discuss the	Display and communication of maintenance performance.

			held in a database/spreadsheet		impact of good kpi performance.	
				15	**3**	
Buffer/Safety stock	Can maintenance performance influence the delivery schedule to the OEM?	KPI records Customer feedback Maintenance management meeting minutes Resilience planning documents	a) The effective use of safety stock and robust planning should minimise any impact. b) Yes, unexpected critical asset downtime may have a negative impact on customer deliveries. c) Yes, poor maintenance performance can result in sporadic customer delivery issues. d) Yes, consistent poor maintenance performance has resulted in customer sanctions.	a) – 4 b) – 3 c) – 2 d) – 1	Now at 30 hours based upon consistency of maintenance department. Influenced by planning and production also.	
	How are the levels of safety stock managed?	Production records Stock level records Production planning meeting minutes	a) Levels are closely monitored and managed effectively. Daily maintenance and production performance, as well as customer orders informs safety stock capacity.	a) – 4 b) – 3 c) – 2 d) – 1	As above	

Appendix 7.3 Plant 4 Gap Analysis Test results.

		Staff feedback	b) Levels are monitored and measured but are mostly maintained at a static level. This is informed by production performance and customer orders. c) Safety stock levels are identified based on historic information on required stock levels. d) There is little day to day management of stock levels.			
	Does maintenance performance have a financial impact on the business?	Staff feedback KPI records Customer feedback Maintenance management meeting minutes Maintenance planning meeting minutes Critical asset definition plans Resilience planning documents	a) Yes, high levels of planning and performance improve production efficiency and maintenance impact. b) Yes, through close management of the maintenance budget and associated expenditure c) Yes, inconsistent performance can have a negative financial impact through poor budget control can increase safety stock levels. d) Yes, though this is not measured explicitly.	a) – 4 b) – 3 c) – 2 d) – 1	Good performance at the moment but unable to quantify this. Measured for the purpose of a negative financial impact, positive impact not measured.	

Appendix 7.3 Plant 4 Gap Analysis Test results.

				9	**3**	

Appendix 7.3 Plant 4 Gap Analysis Test results.

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