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ISO/IATF16949 a Lean Manufacturing Framework or a Wasteful Process

Master's Thesis in

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ABSTRACT

The Quality Management Systems in automotive industry known as ISO/TS16949 which recently has been updated into ISO/IATF16949:2016 developed by western major car manufacturers as an alternative approach for Total Quality Management (TQM). As it is not tailor-made for each of the western OEM's, however by introducing customer specific requirements to the requirements made it more suitable for OEM's to monitor and manage the quality and reliability of the products and processes throughout the supply chain. On the other hand, the lean philosophy is a key for cost reduction and in simple words 'do more with less'. As by some, the processes and the significant costs of certification and maintaining the certification is being considered as wastes, without taking into account the benefits, this study is striving to clarify this picture. The scope of the study is a OEM which I was working in last 18 months and my intention is to demonstrate whether with a serious commitment to IATF QMS the well known lean wastes in manufacturing reduces or not. The two departments including Warranty Claims (For all models) and Maintenance (Assembly and Body-In-White) performance measures reviewed and analysed as they are their performance can indicate wastes and success of lean manufacturing. The results of this study denote a significant improvement in Warranty claims and a considerable improvement in efficiency and effectiveness in Maintenance teams after improvement in QMS.

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1 Introduction

1.1 What is the research about?

This master thesis is about answering to this question which is promoting and strengthening Quality Management Systems (QMS) particularly in the automotive industry helping Lean manufacturing. The scope of this research is a vehicle manufacturing plant in one of Western European countries which is ISO/IATF16949 QMS certified (later certified with transition to ISO/IATF16949:2016) and lean manufacturing philosophy is the main focus to cut the cost of advance planning and production activities.

1.2 Why it is important?

The reason for this question is as some may say quality management systems or at least most of it is not a value-added activity and consider it as a costly and wasteful activity and against the lean manufacturing. This is trying to reveal if the QMS deployment and practice is really effective, in which areas, and how it is possible to optimise it in order to boost the effectiveness of the QMS to create a better support for lean manufacturing. As an internal ISO/IATF Lead auditor always I was facing this challenging question that the auditing process is a wasteful process. Although, I can understand the audit frequency and non-conformance closure policy can be very time taking process especially for those who are trained with problem solving tools and also have minimum knowledge of ISO/TS16949 (or ISO/IATF16949), but what this process actually is improving in terms of creating value or preventing waste is quite significant in my experience.

1.3 What has been done previously

There are a number of conceptual models that connect quality and learning (Dutton and Thomas 1984, Fine 1986, Levy 1965) and also the impact of learning and innovation on productivity growth (Cole et al. 1986, Gordon 1990), and a few number of empirical studies which actually tested the direct impact of quality tools on productivity improvement.

Hendricks and Singhal (1997) demonstrate the implementation of an effective total quality management (TQM) programs potentially improves the operation performance of firms. Fynes and Voss (2001) propose and test the links connects the impact of quality practices on

the various dimensions of the quality performance, the manufacturing performance, and the business performance. Sousa and Voss (2002) made a review of the TQM research, summarising that as the quality has been shown to be linked to operational performance, actually there is no identified link to the business performance. They suggested in order to satisfying the need for a vigilant study of Quality Management Systems and their links to the firms, they should provide several examples of similar studies. Iyer, Sarangi, and Sephardi (2013) mainly focus on quality practices associated with adoption of quality management systems (QMS) and TQM and try to empirically identify the mechanisms by which quality practices give rise to productivity change in Indian automotive parts manufacturers. They believe the implementation of both QMS and TQM are resulted in rise in productivities of the firms, however they believe TQM has got higher rate of performance. Although they did not mention QMS certification was in automotive certification (ISO/TS16949) and they merely mention QMS and ISO9001 while tier 1 automotive suppliers to OEM's are required to be certified to ISO/TS 16949 (at the time and at the moment ISO 9001:2015 /IATF 16949:2016).

C.P. Katha (2004) discusses and compares relationships between, ISO9000:2000, QS9000, ISO/TS16949:2002 and criteria of Malcolm Baldrige National Quality Award which has been established in 1987 in the U.S. by the Congress to promote quality awareness and business excellence, and believes with added requirement to the ISO9000 requirements by QS9000 and ISO/TS16949 it will make them closer to TQM. Although C.P. Kartha refers to the previous researches regarding significant performance after implementation and certification of ISO9000, but it mostly compared the requirements and emphasises and reaches to this point that Baldridge Award and quality standard certifications are getting closer to each other.

Gruszka, J., Misztal, A. (2017) have done a detailed review of structure of ISO/IATF16949 and updates and scheduling of transition from ISO/TS169494:2008 to the ISO/IATF16949:2016, but not much information about the performance improvement discussion and tangible productivity enhancement.

1.4   Motivations and background of the author

Since I joined the company in April 2015 in the engine plant, whilst I have had one-year experience of working in automotive parts manufacturer and supplier in Iran, I realised the

QMS certifications was a great deal for this industry. After lean training and working a few months in the operations as an assembly operator or in organisation's term 'Integrated manufacturing specialist', joining the Quality Management System team as an Internal Auditor for ISO/TS16949:2008 gave me a very steep learning curve within one and half a year, and I have been promoted to a new position in the vehicle plant (in the same company) as ISO/IATF16949:2016 Lead Auditor with one-week training of ISO/IATF16949 Lead Auditor and Core Tools (APQP, PPAP, FMEA, MSA, SPC) training. My career continued in this position for another one and half a year and received an offer from a 3rd party Certification Body (CB) to start working as an Automotive Assessor (IATF 16949 auditor) or in other words certified 3rd party auditor in accredited certification body.

As an auditor I learnt a lot from my audits as I had to learn from the process and understand objectives and activities in each department, although, working as an auditor will not make you people's favourite person. The positive side of this role is a never-ending learning job and every day is a learning day which is fascinating.

What it should be emphasised is I have had training of Lean principals by the company and also experience of working on the line as a production operative, similarly as an ISO/TS16949 internal auditor and ISO/IATF16949 internal lead auditor, during the finalising this thesis I am a ISO/IATF16949 3rd party CB automotive auditor under training. I am assuming it would be a great advantage that I worked in production line as well as QMS department to have a wider view of understanding and interpreting the observations.

 As both lean philosophy and ISO/IATF16949 QMS are key factors for any automotive organisation to flourish. However, the ISO/IATF16949 quality management standards are mandatory for automotive tier 1 OEM suppliers, and as we all know, anything becomes mandatory it loses its appreciation, thus, it is beneficial to understand them both and identify the link between them, the this may help the organisations to embrace them both with more understanding of them.

With this study I would like to understand this mandatory ISO/IATF16949 certification requirement is improving lean manufacturing for their benefits or it is just an extra costs imposed by major OEM's to the suppliers.

2 Literature Review

2.1 Lean and Automotive Industry

Since Henry Ford, the American industrialist introduced the legendry Model T car mass production in early 20th century with the invention of moving assembly line to reduce the production costs, till Toyota comprehensive Lean manufacturing systems known as Toyota Production System (TPS) in the late 20th century which turned this company from a small/middle size company to one of the largest, most successful and pioneer in automotive industry, one factor almost played the most determining role in successful mass production manufacturing and it was and is how to reduce the manufacturing cost while increasing and maintaining the customer satisfaction.

Nevertheless, the lean manufacturing is in contrast with mass-production as primitive manufacturing started with craft production, where a craftsman made an entire single product. With development of technology in industrial production, mass manufacturing began. Lean is directly in contrast with the mass production system that emphasises on making large quantities of items in a batch-and-queue mode. For instance, the mass production way of thinking can be demonstrated by automotive painting processes. These factories would usually have large paint colour change-over times. For example, it is like painting black cars in the week one, red cars in the week after, white cars in another week, and so on. This meant the customer could obtain the specific colour of preference merely every month or two. Nowadays, some of manufacturers upgraded and right-sized (optimised) their painting facilities and equipment so that colour change-over durations are very quick, enabling rapid response to the customers need. This rapid response to the customer's need, enabling the customer to pull the product, are very good example of a lean system.

Lean production system which has been pioneered by Toyota after World War II demonstrated a better way of organising and managing customer relations, the supply chain, product development and production operation. This new way of manufacturing has been named lean production, simply because it does (or achieves) more and more with less and less.

Automotive industry without a doubt dwells in one of the increasingly most brutal and merciless competitive markets in the world with low profit high volume. Nowadays, the high-volume car manufacturers are absolutely aware which their existence and future of their companies are tied up with this matter that how successful they would be with robustness in implementation of the lean manufacturing. Behind all of their attractive and inspiring slogans manufacturers know crystal clear that they have to put all of their power and strength to implement lean principals robustly from head to toe in their organisations. Although Lean is imperative for a profitable and flourishing manufacturing, managing quality and reliability is vital for increasing and maintaining a high customer satisfaction which is one of the crucial element for the products demand in the market. However, quality usually considered as a massive cost for the manufacturers and sometimes mistakenly has been sacrificed for the sake of production costs. Meanwhile, many believe a robust quality management system is not only increasing the customer satisfactions that will even help the waste elimination/reduction and continual improvement in work efficiency which are also the main goal of the lean philosophy. Toyota as an example is using Total Quality Management (TQM) which is putting customer first and endeavours strategically to protect the customer and reduce the rework and warranty's costs. But TQM require massive effort and time to create and organise a system to cover throughout the supply chain which for small or and young companies can be quite unjustifiably expensive and time taking. Hence, a standardised quality management system offers not only highlighting boundaries but also works with Lean manufacturing philosophy to protect the customer with maintaining quality and reliability criteria which consequently prevents extra costs for poor quality throughout the design, concept products, product creation, product realisation launch, manufacturing, delivery and warranty period in shorter time with comparison to the TQM.

2.2   Lean Manufacturing

Muda is a Japanese word which means "waste", any human activities which absorbs resources but creates no value. Although the original Lean Principal defined by Taiichi Ohno (1988) who was the Toyota executive and perhaps he was the most brutal enemy of waste in human history, and his philosophy delves into recognition of seven elements of wastes; but as time passed, gradually more new elements of wastes were recognised (i.e. manufacturing products and or providing services which is not required by customer, quality more than

customer's need or requirements can potentially be considered as waste). Also, unused or misusing talents of employees and work forces in organisation has been identified as an element of waste and added to the list by some. Perhaps there are more elements waste and would be identified in the future. For instance, in Six-Sigma methodology waste of unused skills is known as waste with regards of unutilised capacities or delegating tasks with inadequate training and skills. Unnecessary space is also recognised as a waste (Stamatis 2011).

J. Bicheno & M. Holweg (2016) believe lean is all about reaching to the destination with uninterrupted flow in the sequence of operations that deliver perfect quality and this flow is not only physical products and services, but also includes the information and the design to run the production. They put the continuous improvements by the lean into three categories; first is Reduction of wastes, second Enhancing the Value, and the third involving and engaging people and emphasised without any of these three the lean is not possible, however, as the weight may shift through the time as the condition changes. The value which plays a key role in lean philosophy must be only defined by the customer and no one else.

Womack and Jones (2003) in their book Lean Thinking explain the lean is only possible through a lean enterprise and not only lean manufacturing. This means a lean mind-set is essential for all of the departments and functions of an enterprise (or an organisation) such as accounting, IT, HR, marketing, sales, purchasing, distribution, and certainly design & development and not only manufacturing, otherwise lean manufacturing on its own will not be either possible or sustainable. They succinctly identified five principles for lean enterprise which are value, value stream, flow, pull and perfection. They explain how this philosophy stands against the incautious Ford mass production philosophy with creating a platform of clear understanding of customer's need, and analysing the activities within enterprise to deliver more customer satisfaction with less effort and resources.

The main purpose of TPS (Toyota Production System) includes minimising overburden in system (Muri) and inconsistency, and lastly elimination of waste (muda). Simply by designing a system free of inconsistency the process would be capable of delivering smoothly, but also it is extremely important the system be flexible to avoid the stress and overburden as it will create wastes.

7 classic elements of Wastes in Manufacturing identified by Taiichi Ohno are:

- Waste of over-production
- Waste of waiting
- Waste of unnecessary movement
- Waste of transportation
- Waste of over-processing
- Waste of inventory
- Waste of scrap (including Rework, Repair and warranty cost)

In fact, it is not only crucially important to eliminate the wastes in the activities but also in order to prevent them, it is imperative to analyse and categorise the nature of elements of those activities to identify and separate necessary and value-added activities and also necessary but non-value-added activities from purely unnecessary and non-value-added activities. Figure 2.1 illustrated different categories of activities. The question mark is a reminder of impossible situation of 'unnecessary activity' to be value added. The goal is necessary activities to be value-add activities by first removing unnecessary and non value-add activities, and second by reducing necessary but non-value-add activities, and third maintain the improvements.

Figure 2.1 - Value-Added Activity Verses Non-Value-Added Activity
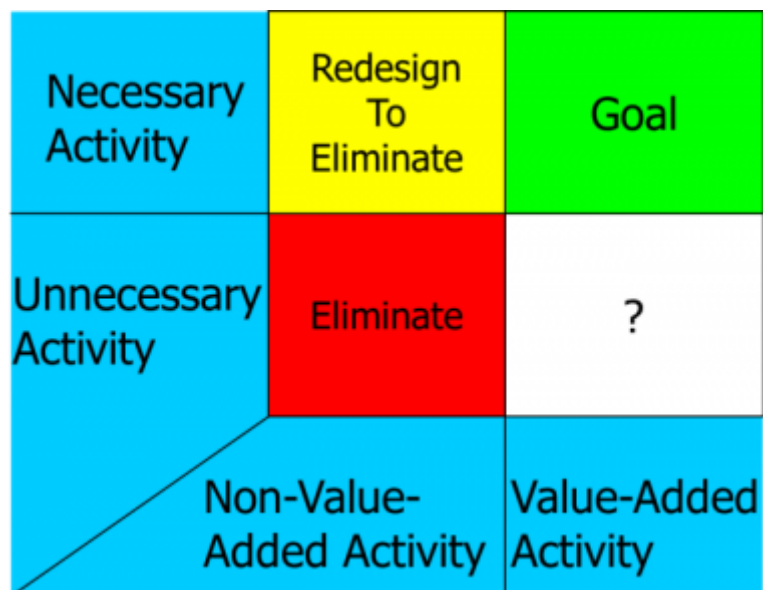
2.3 Lean Principals

Womack and Jones five lean principals are the with a renewed message in their book "The machine that changed the world" (with this warning message to automotive industry, simply 'Do or Die')

2.3.1 Value

Value is what has been specified and defined by the customer and that is the only way to strategically recognise and distinguish value added activities from non-value-added activities. Womack and Jones (2003) also explain about the target cost as the most important part of specifying value which basically by identifying all visible wastes (or muda) how much the target cost would be by squeezing out all the identified wastes. Once the final product target cost is ready and available to be broken down to bits to elements of cumulative work, then it can be the scope for every step-in value stream.

2.3.2 Value stream

The step by step sequence of activities throughout the supply chain activities from raw materials to the hand of final customer, or from concept to product launch is interpreted as value steam. The aim is to map and measure the performance of the value stream, and not functions and departments.

2.3.3 Flow

This ideology is literally opposite the traditional batch, hold and queue method by downsizing or optimising the batch sizes and also holding times as much as possible. As the batch and queue is a highly wasteful process by nature, as it has to wait until the batch is complete and then after inspection (which is not as accurate and sometimes possible comparing to small batches) release to the next process, and this is cumulative waiting waste, furthermore putting and holding more product and value on holding in inventory is in the nature of unnecessary large batches, plus more pressure on the transportations and consequently slowing it down. So, making the production flow by 'right sized' batches and using JIT by Kanban system is what Toyota production system (TPS) came up with to pioneer a smooth manufacturing.

2.3.4 Pull

Pull system is actually the situation which a need to be satisfied only when it is needed. An operator signals the warehouse whenever needed more parts (via Kanban system introduced by Toyota), so consequently material planning and logistics team receives the signal and delivers the right part with required number with the Just-In-Time (JIT) and MRP system.

2.3.5 Perfection

Perfection does not mean the product will be defect-less, instead it deliver what, when, the customer wants precisely at the fair price. The bench mark for this process is zero waste and not the best practices or competitors' performance, in other word 'continual improvement'.

2.4 Value Stream Mapping (VSM)

The key factor and starting point of lean analytical thinking is value and it can only be defined by the final customer. Value Stream Mapping is one of the best analytical tools to map a process and to identify value-added or non-value-added (both, necessary or unnecessary) activities. According to Mike Rother (2003) says a value stream is all the actions (both value added or non-value added) currently required to bring a product through the main flows essential to every product: (1) the production flow from raw material into the hands of customer, and (2) the design flow from concept to launch.

According to Deming (1982) any group should have as its aim (of) optimisation over time of the larger system that the group operates in. Anything less than optimisation of the whole system will bring eventual loss to every component in the system. Thus, the value stream mapping can be more meaningful in bigger picture to create an affective improvement in the system. Otherwise it can be visualised by improvement in one wing of an aeroplane will only unbalance it but also may ending up with disaster.

2.5 The Waste of Overproduction

Waste of overproduction is known as the worst or the costliest kind of waste among the seven elements of wastes. In automotive manufacturing industry there are three major problems:

1. The final product is the result of numerous activities and process and using numerous different parts and materials. Thus, the final product with no customer is costing the company highly.

2. There are different models and derivatives and demand in each model varies from the other one, so allocation of effort and investment in one model with lower demand will overburden on one production line and also overproduction and as they remodel after a few years then old model in inventory become obsolete.
3. The cost of inventory is considerably high as the investment is sleeping, also products may be damaged or contaminated and etc.

When they realised the cost of overproduction, Toyota introduced Just-In-Time (JIT) process. It is a customer focused and pulling system which means each operation has a customer which is next operation, and it should receive the order from that customer. This will reduce the overproduction as well as buffer lines in production processes. This will balance the demand and inventory and help in forecasting and optimises the balance on the production line and reduces surplus of unnecessary production.

2.6 The Waste of Waiting

Waiting for parts, materials on the production line can be as result of mis-scheduling, or overburdening on one operation, while other operations are waiting, before (lined up) or after (starving) that operation. This also can be seen in service industries as the activities are related to dependent on each other are not synchronised.

One of the most common situations for 'waste if waiting' which is when there is a shortage in some parts and line stops and everybody is waiting for parts to arrive. The 'Kanban System' introduced by Toyota first was very basic but highly effective to tackle this problem for Material Panning and Logistics. Kanban cards with red and green colours on each side could quickly send this message to the material planning and logistics team to act before the shortage. Nowadays this system becomes electronic and much faster but still we can see errors in these extremely modern systems which will cause trouble in smooth manufacturing. Today, there is variety of different software and tools to help industries for this problem such as 'Enterprise Recourse Planning' (ERP) and 'Systems Applications and Products' (SAP) is one of those to avoid such problem.

2.7 The Waste of Movement

Part of work study analysis is about eliminating unnecessary activities of operators which slow down the process or considerably exhausting him/her. These are recognised as

'bending', 'reaching' and 'lifting'. Work place should be designed to ease the worker's activities. 5S is one of the tools to keep the work environment comfortable, tidy and suitable for the worker to deliver his tasks and duties with less trouble and difficulties.

2.8   The Waste of Transportation

This is one of the areas which can be potentially very costly for an organisation. External and internal transportation needs to be analysed and optimised strategically. Material planning and logistic in factory layout, also in design of the tools should be considered very carefully with taking attention in detail. Any kind of ideas which can reduce or eliminate the transportation will help to reduce the energy and cost of final product. Waste of transportation can involve raw components, sub-assemblies, empty boxes or just about anything that is required for production. It will not only be found in the production area, but also the material delivery areas, throughout the supply chain and even in offices. Transporting material is a necessary activity but it does not add value to the final product. Eliminating or reducing this type of waste within your facility (or within your supply chain) may reduce overall lead time or cycle time. Within the production, waste of transportation is when product not stored close at hand at the point of use. If space allows (based on component sizes), best practice is to keep a small inventory store near the production area. This will avoid having to bring the product back and forth to a warehouse. When using the components, they should be at the station where they are being used. Any distance further than an arm's length away is considered a waste. Look for ways to store the components in use close to the worker whenever possible. When you do get them closer to the worker, continue looking for improvements by eliminating unnecessary motions (parts stored in the proper position on the correct side of the worker). Waste of transportation will be more evident in the material delivery areas than the production areas. Moving product further than necessary, storing product in a temporary location only to move it shortly thereafter and moving with empty delivery carts are all considered a very big waste. Application of standardized material handling routes will help reduce this waste. As part of the route, the delivery person will travel only with a full cart; component delivery one-way, empty totes the other way (assuming returnable containers are used). By doing this, the person transporting the parts will never travel with an empty cart which is considered a huge waste in lean manufacturing. The basic concept is as follows; for every full box of components delivered

(using a Kanban system) an empty box should be available to be returned to the supplier. With every box of finished goods picked up, an empty box will be required by production.

2.9 The Waste of Over-processing

This is the area which works study and work analysis can be extremely helpful. When a processes and stream value of that process is studied and analysed, then unnecessary activities and parts of process are recognised and processed can be redesigned more robustly. This also known as part of the 'continues improvement' which is another key element in lean manufacturing. Practical problem solving like Fishbone of Ishikawa or 5Why's depending on type of problem can massively help to understand the nature and source (or in other words 'root-cause) of the problem and come up with effective interim containments, corrective and preventive actions to smoothening the process.

2.10 The Waste of Inventory

Inventory (of either finished products or sub-assembly parts and materials) is basically a necessary but non-value-added activity, thus, it should be optimised and reduced to a assured level which is not going to affect the customer but also not generating extra cost cash flow for the enterprise. The other waste in Inventory is actually the risk of damage and aging the raw materials, parts and final products.

2.11 The Waste of Rework Repair and Scrap

Rework is an extra and non-value-added activity on a product to be acceptable for the customer. It can be considered as the cost of quality but in fact this is the cost of failure in the system which was not able to produce perfectly that product in first place. The concept of First-Time-Through (FTT) or Right-First-Time (RFT) are example of those tools and destinations which world class manufacturers nowadays are trying to set it as their target. The cost of scrap and salvaged products which have been through using raw materials and many expensive parts is massively damaging financially plus cost of warranty and customer loyalty which might be even more damaging the brand reputation.

2.12 The New Wastes

The new wastes may be added to the original 7 wastes identified by Ohno, suitability either in manufacturing or services is that is applicable.

2.12.1 The waste of untapped human potentials

Bicheno and Holweg mentioned that there is quote from Ohno which says main objective of Toyota was 'to create thinking people', thus, this waste is directly coming from Ohno.

It is also recognised as the eighth elements of waste by the training provider called Babcock International Group Plc which was providing the lean manufacturing training for the company the research has been conducted. They dubbed it waste of talent and basically what they were promoting was not to stop people from innovation and development, and not letting talents stagnate and perish in the storm of mass production noisy atmosphere.

2.12.2 The waste of making the wrong product efficiently

Although this is eighth waste recognised by Womack and Jones, but it actually is related to the over-production waste and can be categorised in the original 7 classic wastes.

2.12.3 Excessive information and communication

This is the danger of getting lost in the excessive information and Ohno himself emphasised 'excessive information must be suppressed'. Nowadays it is quite tangible to spend hours and hours on social media with massive amount of value-added, confusing, confusing or even misleading information. Of course, there are genuine information and news on the social networks, but they easily can be lost in the middle of noises.

2.12.4 Waste of time

Bicheno and Holweg say that everyone is suffering from this kind of waste. They suggest to categorising the activities, for instance, as urgent, non-urgent but important and non-urgent and with this categorisation respond to them accordingly which is quite fascinating even when review our daily activities based on this methodology, as if we respond urgently to a non-urgent issue is a waste of spending time which can be allocated to an urgent or important activity or vice versa, non-urgently responding to an urgent issue which can be disastrous or at least disruptive.

2.12.5 The waste of inappropriate systems

Inappropriate systems visualised by examples Bicheno and Holweg provided like the number of applications on our smart phones or computers which never been used and directly or indirectly we paid for them. They explain the lean way approach is to first remove the wastes

and then automating after, or a quote from Michael Hammer which says, "don't automate, obliterate!" The waste of inappropriate systems is not limited to automation and computers, but also things like record keeping, checking and reconciling are purely waste as well.

2.12.6 Waste of energy and water

Sources of energy or in other word the sources of power (like oil, gas, coil, etc.) are limited and perishable resources (except for the renewable energy resources like sun, wind, damn, etc), and we all are witnessing the impacts of unwise usage of non-renewable sources of energy on the globe. Although, the energy management systems significantly improved in factory, office and home, but at the end of the day, still it is human to behaviourally and culturally reduce the wastes by using the appropriate approaches.

2.12.7 Waste of natural resources

Basically, it is promoting the recycling as Howkins, Lovins and Lovins of the Rocky Mountain Institute estimated 99% of the materials used in manufacturing of products in the U.S. become waste (or garbage) within 6 weeks after sale. So, let's go paper less!

2.12.8 Waste of 'No follow through'

Waste reduction is not same as cost reduction, and further actions are necessary basically to reduce the cost and increase the sales. It is like micromanagement instead of looking at the bigger picture or in other words using helicopter (or satellite) view. You can use shortcuts or speed up with dangerous driving and save a few minutes, but if you do not use the saved time, you simply have not done any saving at all.

2.12.9 Waste of Knowledge

Bicheno and Holweg explain meaning of this waste is simply letting knowledge disappear, especially in design and innovation, but not limited to and can be applied to many fields. Basically, a knowledge, an experience or lesson-learnt that gained for example during new product designed, launched, manufactured, introduced and marketed is nor recorded to be used to avoid in the future projects and simply forgotten. Even if the knowledge or experience is recorded in the head of person there is always risk of losing it when the individual leaves the organisation or any incident or event prevent him/her to continue cooperation with the business.

2.12.10 The waste of empty labour

Bicheno and Holweg explained this is more about the empty labour which is a complex and apparently growing issue particularly for lean managers to deal with.

Personally, I feel uncomfortable to either agree or disagree with their point as it may sound Taylorism, however the standardised work, cycle time calculations and analysis, can give some clarity with the nature of the job to understand and justify the work. Kaizen and employment involvement is an important factor which can put the labour and manager on the same side (which traditionally they were on the opposite sides) to plan to remove and overcome the obstacles on the other side.

2.12.11 Trading off wastes against each other

After reading the explanation of Bicheno & Holweg, which basically says this is the situation when you slow down a process because there is a bottleneck on the process. For instance, if we have a cycle time of 2 minutes for chassis and under body, and on the other hand 3 minutes cycle time for upper body ultimately chassis and under body ought to wait one minute idle for each process.

Frankly I understood this is not much different from the waste of waiting and Line balancing is what managers usually do for smoothing the process, however when it comes to cross functional synchronisation it might be quite challenging. For example, when it material planning and logistics has to analyse and standardise the batches (for size, numbers and timing) for every single part which is being used in the production to prevent waiting situation by disrupting the production flow.

Designing out inconsistency (Line balancing) is when different parts of an organisation or system are not proportionate or do not work proportionately. For example, in one production line we have one operation A with 38 seconds cycle time (cycle of a repetitive job from start to the end is called cycle time) and next operation B which is working with 45 seconds cycle time it means these operations are not designed proportionately to work smoothly. In fact, operation B is slowing down the operation A for 7 seconds, and all the operations after operation B are going to be waiting for at least 45 seconds. As a result, cycle time of these two operations and all the production (assuming operation B has the longest cycle time) is 45

seconds per product. This will cause over burdening from operation B to the rest of production line which will lead to other extra costs and also generates waste of waiting time for operations. These numbers in mass production are really appalling.

Imagine if with redesigning these two operations and allocating activities proportionately to these two operations, taking 4 seconds of activities from operation B and putting on operation A activities then both would have 41 seconds cycle time and no waiting time and overburden for any of them. Practically, that is not always possible in reality but it is possible to move towards that zero waste goal which called 'Destination Zero'. This process of analysing, categorising and moving work elements between operations is called Line Balancing.

2.12.12 Finally: Can You Go Too Far on Waste Reduction

Lean way is simply a never-ending journey and there is no perfection, but a perfection destination and the lean journey is to that zero waste destination. New wastes may be identified in the future and removing those wastes the lean will evolve.

2.13 Continuous Improvement (Kaizen)

The cultural attitude towards work and life which everything can be improved through the process is one of the key elements the Japanese car manufacturer has flawlessly deployed in its organisation. Involvement every member and giving this opportunity to them to share their ideas and suggestion to make the process smoother, easier and faster is always welcome. In fact this is a win-win tool for both employees and also employer, because on one hand employees can share their problems and issues at work with employers to improve it, on the other hand, the organisation benefits from recognised problems and concerns and have this opportunity to rectify them far in advance.

2.14 What is ISO?

The International Organization for Standardization (ISO) is an independent, non-governmental, non-profit (which is selling standards to finance development of standards), international organisation with a membership of 161 national standards bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation and provide solutions to global challenges. It started in 1946 when representatives from 25 countries met in London

at the Institute of Civil Engineers and to create a new international organization 'to facilitate the international coordination and unification of industrial standards'. On 23 February 1947 the new organization, ISO, officially began operations. Since then, it published over 22070 International Standards regarding almost all aspects of technology and manufacturing.

The generic nature of the ISO allows it to be applicable to all of the manufacturing and services industries. EC (The European Community) adopted ISO 9000 and made ISO 9000 registration (and certification) compulsory condition for trade and business with other nations.

Structure of ISO9001:2015 which is the fifth and latest version of ISO9001 and superseded the ISO 9001:2008 (fourth edition) version. It is including ten chapters which actually chapters from four to ten are conveying the ISO9001 requirements. According to ISO 9001 introduction 'The adoption of a quality management system is a strategic decision for an organization that can help to improve its overall performance and provide a sound basis for sustainable development initiatives.' and philosophy of it is based on the process approach and the well-known Plan-Do-Check-Act (PDCA) cycle of Dr. Deming and risk-based thinking. It is fascinating as quality management principles are including some of quite specific elements of lean! Those quality management principles which specifically mentioned in ISO 9001:2015 are: customer focus, leadership, engagement of people, process approach, improvement, evidence-based decision making (decision based on data) and relationship management.

The figure 2.2 is a virtual picture of Plan-Do-Check-Act cycle is demonstrating the quality management system as a whole and how it can be applied to all processes and functions. It illustrates how clauses ISO9001:2015 4 to 10 can be categorically grouped in relation to the PDCA cycle.

Following of this chapter those requirements would be discussed and explained how potentially can help any enterprise to improve.

Figure 2.2 - Quality management systems and Plan-Do-Check-Act approach.
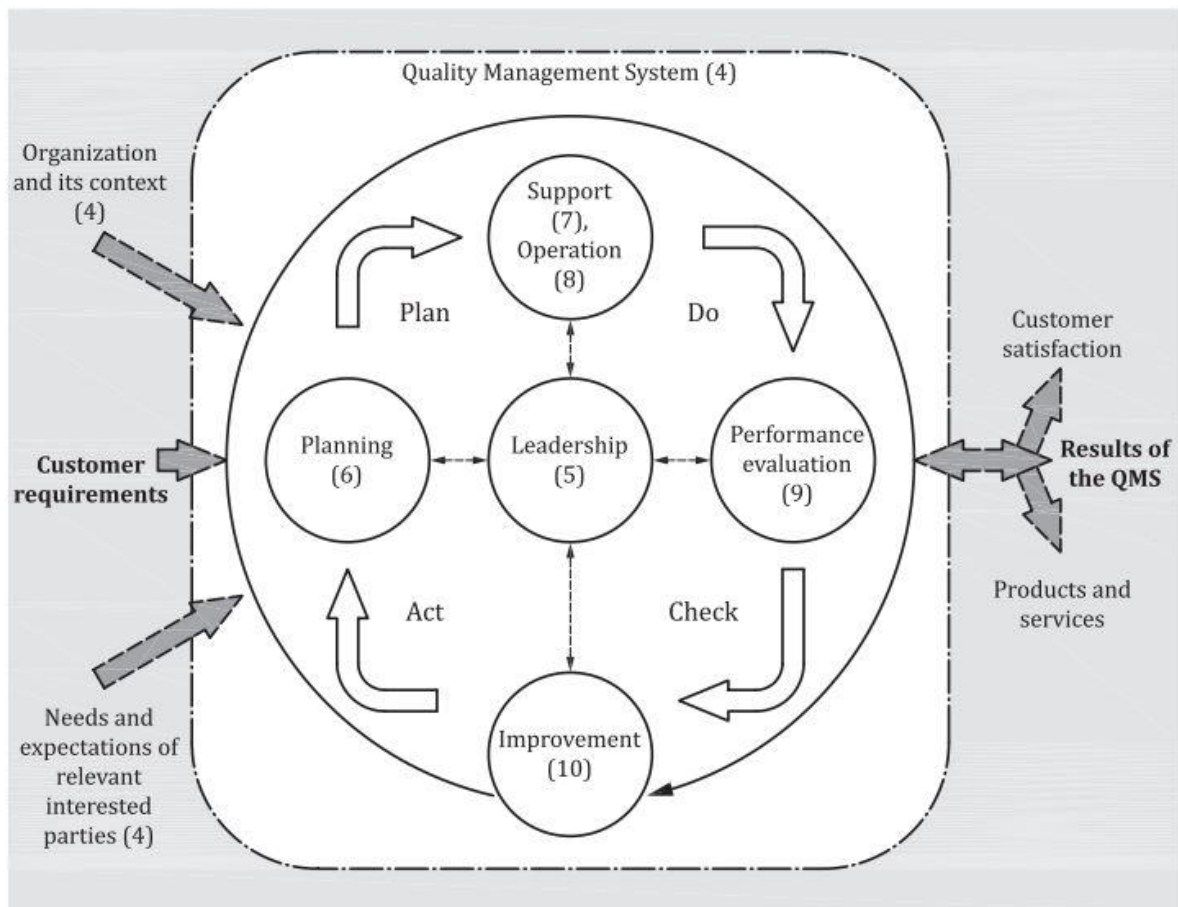
2.14.1 Context of the organization

The chapter 4 of ISO 9001:2015 which is the first and most fundamental part of it reminds me this Chinese idiom that says "If know yourself and know your enemy, then you will be invincible" (Chinese idiom, from Sunzi's "The Art of War"). It is all about the understanding the organisation and its framework and boundaries, analysing internal and external strength and weaknesses, threats and opportunities, and strategically plan for the organisation. This simply reminds me the SWOT (Strengths, Weaknesses, Opportunities and Threats) and also PESTLE (Political, Economic, Social, Technology, Legal, and Environmental) analysis, however there is no obligation to use only these risk analysis tools and organisation can chose any risk analysis to the organisation for this matter.

In this chapter ISO demands the organisation to establish an appropriate and process approach quality managements system with inputs and outputs, sequence and interactions of processes, recognised criteria and methods for an effective operation and process control including monitoring, measuring and performance evaluation (KPI's), resource management, organisation, roles and responsibilities, lively act on the results of risk analysis and the results of performance evaluations to assure continual improvement, so this shall not be forgotten to make these activities documented and retain it for analysis and improvement.

2.14.2 Leadership

The general requirements for leadership (in chapter 5) which is mostly inspiring the people, promoting and improving the QMS and basically making sure QMS system is working, however there are some specific requirements which are to be customer focused which literally understanding the customer statuary and regulatory requirements, risks which can threat the organisation commitment and customer satisfactions, and appropriately addressing them.

Establishing a documented **quality policy** and communicating it to the organisation, giving a clear direction, which provides a framework of quality objectives including the organisation commitments to satisfy the intended requirements and also continual improvement.

2.14.3 Planning

When an organisation planning to achieve the intended results, which have been aimed in creating and inspiring the organisation, it ought to give assurance that the design quality management system is able achieve its intended result, enhance the desirable effects and prevent, or reduce, undesired effects and achieve improvement. To achieve this is all about risks and opportunities and PDCL cycle to be reviewed and corrective and/or preventive actions to be put in place to make the planning robust and reliable and this is a never-ending process. Quality policies are the relevant, measurable, monitor-able documents with all of required information to control the plan and enhance the customer satisfactions.

Planning the change is what specifically ISO decided to be considered by looking into the changes and potential consequences of them, assuring integrity of QMS during or after the change, availability of required resources and updates in roles and responsibilities if required.

2.14.4 Support

Generally speaking chapter seven in ISO 9001:2015 is containing a significant number of requirements. Basically, it wants to assure the internal and external availability and capability of resources including people, infrastructure (i.e. building, equipment, transportation, IT etc.), suitable environment for the operation (i.e. social, psychological, physical etc.) to achieve intended results. Assuring the suitable measuring and monitoring equipment and system is in place, calibrated and traceable.

The organisational knowledge loss, poor or ineffective training, competency and awareness, are considered as highly likely damaging threats for an organisation. Communications internally and externally play a significantly vital role in success an organisation, thus, it shall be clearly defined both internally and externally.

Document control and updates, also record retentions are the areas which many may find it tedious, however without documented record of information how is it possible to maintain knowledge, or analyse the information and make decision based on data?! Although, this is one of the requirements people in manufacturing neglect very often, but this is the only angel recording their good deeds!

2.14.5 Operation

Chapter eight constitute the most populated part of ISO 9001:2015 with the most of its clauses and requirements. It includes operational planning and control in operations and services. In fact, the planning and QMS design and all of the supporting process resulted in conforming product or services. With this thought it emphasises on communication with customer related to provided product and services, complaints, contingency plan if the in case of risks to customer requirement etc. In this, generally speaking the main aim is to assure the actual product and service to be what necessarily needed to be. For this reviewing and reminding the requirements of products and services, changes to those requirements etc, are mentioned as an ISO requirement.

Design which is one of the most critical part of success or failure of a product or service and consequently prosperity of an organisation, thus, the design related requirements are included to this chapter as well. The defined nature, durations, and complexity of the design and

development activity process, review and progress, verification and validation by interested parties, define authorities and responsibilities, communications and harmony between the team members who are involved in design and development stages, define requirements for the product provisionally, the level of control to adhere to those intended requirements for the customer and interested parties are emphasised in this section with the inputs, control, outputs and changes of the design and development.

Control of outsourced (externally provided) processes for products and services which is another essential and key player in any operation or service to assure the intended result can be achieved. ISO 9001:2015 call for the organisation to assure to control and monitor their suppliers and outsourced process provider to that extent which will not affect the conformity of the product and services.

 Control of production and service provision is the where the core activity of a business is happening, thus, that is why it is at the main focus of the QMS. From documented information of the product and services with all of the required specification from the customer(s), how the sequence of activities is, how to measure and monitor the activities to maintain the intended result, and finally how to inspect the product to assure the quality of the product, implement actions to prevent human errors (error-proofing), and post-delivery activities.

Identification and traceability is one the critical elements of the QMS which in my experience is quite vital solution in control of manufacturing process and also control and containment of suspect and non-conforming products.

Preservation is another subject which has been considered by ISO quality management system to ensure the materials during and after the production is kept at the condition which would not breach integrity of maintaining the intended quality of the product. This can be using an expired adhesive or a raw material life time.

Post-delivery activities which seems out of cycle of manufacturing is actually quite important and necessary to assure the customer requirement are actually met and if not rectify it and use customer feedback to improve the process towards the direction which satisfies the customer.

Control of change or in other words, change management is the area which needs extra vigilance in planning, cross functional collaboration and communication to assure the change is not affecting the organisation's performance. Engineering change, organisational change, product change, and so on can potentially have an enormous impact on the performance of an organisation and to prevent any issue during the change advance planning and a strong project with help of a cross functional team consisting all of the stakeholders' representatives. Control of non-conforming outputs is the final area which ISO 9001:2015 is emphasising as a vital requirement to assure the customer is not at the risk of receiving non-conforming product.

Corrections, segregations, containments, return or suspension, product or services, also informing customer and obtaining customer authorisation for acceptance with customer's concession if possible, creating documented information regarding the product specifications and non-conformity are the areas which this sub-clause of operation explains and demand as a requirement.

2.14.6 Performance evaluation

Performance evaluation is the 9th chapter of the ISO 9001:2015 requirements. It is simply about monitoring, measuring, analysing and evaluating the activities throughout the organisation. Potentially this is the first step for any organisation which is committed to continual improvement as we do not measure we do not know whether we improved or worsen the process. This can be the minimum benchmark to compare analyse the performance against its own performance.

Customer satisfaction has been included in this section, although this is quite challenging for many organisations to evaluate the customer satisfactions but must not be omitted from the evaluation of the process. Because quality only will have meaning in the eye of the customer and that is where we can see actual results. Evaluation of conformity of product and services, degree of customer satisfactions, QMS performance and effectiveness, planning, risks and opportunities, outsourced processes providers performance, etc. all should be included in the analysis.

Internal audit is one of the critical factors which considered on evaluation and analysis of the QMS system to assure the QMS requirements are being adhered to or if there is any deviation put the corrective actions in place and bring it back to where it needs to be. Although this is one of the main subject that could be mistakenly looked as waste but this more or less reminds me the DMAIC or DMAICR in SIX SIGMA which are: Define, Measure, Analyse, Improve, Control, and Replicate. Internal audit in my view is more control, although analysis of the process for adherence and also improving it in case of nonconformity is also instituted in the process but assurance of maintaining the QMS system is the main purpose of the internal audit in QMS.

Audit scope and criteria should be defined. Auditor selection process must be along with objectivity, partiality to assure the effectiveness and integrity of the audit. Reporting to top management and immediate corrective actions to eliminate the nonconformity are other elements which required by the ISO 9001:2015.

Management review is the final elements of the performance and evaluations section. It is imperative to assure top management are aware of the effectiveness of the QMS system and also the performance of the organisation towards the strategic direction of the organisation.

2.14.7 Improvement

This is the tenth and last chapter of ISO 9001:2015. The general requirement for improvement seems more like a commanding mission for the organisation, to be determined and take any opportunity for improvement and enhance the customer satisfactions, by improving product and services, corrective and preventive actions for undesired results and effects and improving the performance.

Nonconformity and corrective actions is the next elements of this chapter which my experience as an auditor gave me this indication that it can be a chronic weakness which can create a lot of damage and loss for the business and dealing with problems by trained and experiences specialists with appropriate problem-solving methodologies potentially can be a game changer.

And final requirement of this chapter and also ISO9001:2015 again continual improvement. Organisation shall continually improve QMS for the suitability, adequacy, and effectiveness.

The organisation shall consider need of improvement from analysing and evaluating of management review output.

2.15 What is the ISO/TS16949?

In 1994 three American automotive manufacturers (Ford, General Motors & Chrysler) created an expanded version of ISO9001 with some mandatory automotive requirements and called it QS9000. Until that time each OEM manufacturer were imposing separate sets of requirements for their suppliers. By standardising and streamlining the big three separate requirements into one common set of standards called QS9000 virtually and theatrically eliminated the varying demands and the wastefulness of old practice and making it easier for the major OEM suppliers to satisfy the customer specific requirements dictated by automotive manufacturers. Probably the success in QS9000 was one of the most important reasons that prompt to establish IATF (International Automotive Task Force) committee in 1999 by five major car manufacturer countries (USA, Germany, France, Italy & UK) to internationally standardise and create a common set of technical specifications requirements (ISO/TS16949) to be dictated to OEM suppliers and assure adherence to them.

ISO/TS 16949 (1st edition) which is literally ISO 9001 requirements plus automotive adds-on of technical specifications necessary in this sector, which originally established in 1999 by the International Automotive Task Force (IATF) members from five major countries - International Automotive Oversight Bureau (IAOB/USA), Associazione Nazionale Filiera Industrie Automobilistiche (ANFIA/Italy), Fédération des Industries des Équipements pour Véhicules (FIEV/France), Society of Motor Manufacturers and Traders (SMMT/UK), Verband der Automobilindustrie - Qualitätsmanagement Center (VDA-QMC/Germany) - in automotive manufacturing industry with the aim of harmonising the different assessment and certification systems internationally throughout the supply chain for the automotive sector. Following revisions were created (2nd edition in 2002 and 3rd edition in 2009) as essential for automotive sector enhancements and/or ISO 9001 revisions. ISO/TS 16949 (along with supporting technical publications which are called 'core tools' developed by OEM's and the national automotive trade associations) introduced a common set of techniques and methods for common product and process development for automotive manufacturing worldwide.

2.16 IATF 16949:2016

In 2015 while the new version of ISO9001:2015 published, IATF decided to publish a completely separate handbook with the updated requirements a year after (in 2016) which was complementing the ISO9001:2015 by automotive quality management systems requirements and named it IATF16949:2016 and set the final date for transition to new standard to be in September 2018.

The IATF is an "ad hoc" group of automotive manufacturers and their respective trade associations, formed to provide improved quality products to automotive customers worldwide. IATF members include the following vehicle manufacturers: BMW Group, FCA US LLC, Daimler AG, FCA Italy Spa, Ford Motor Company, General Motors Company, PSA Group, Renault, Volkswagen AG and the vehicle manufacturers' respective trade associations − AIAG (U.S.), ANFIA (Italy), FIEV (France), SMMT (U.K.) and VDA QMC (Germany).

The IATF hand book claims the goal of the Automotive QMS standard is the development of a quality management system that provides for continual improvement, emphasising defect prevention and the reduction of variation and waste in the supply chain.

Structure of IATF 16949:2016 is basically in alignment with ISO9001:2015 requirements and constituting automotive quality management system with adding stricter sub-clauses requirements to ISO9001 clauses. Literally the same as ISO/TS16949:2008 with this difference now we have two separate books to refer for automotive QMS requirements. In section 3, the automotive terms and definitions has been added to clarify the acronyms and meaning of automotive terms. Almost in all sections IATF came up with tighter and stricter requirements.

2.16.1 What are the 'core tools'?

Core tools are those specific automotive frameworks which have been developed to standardise some of most complicated and confusing process throughout the design, supply chain, supplier liaison, manufacturing, problem solving, error proofing, learning lessons etc.
I am going to briefly explain about five major core tools in automotive industry.

2.16.1.1 Advanced product quality planning (APQP)

Product quality planning process that supports development of a product or service that will satisfy customer requirements; APQP serves as a guide in the development process and also a standard way to share results between organizations and their customers; APQP covers design robustness, design testing and specification compliance, production process design, quality inspection standards, process capability, production capacity, product packaging, product testing and operator training plan, among other items aftermarket.

2.16.1.2 Production Part Approval Process (PPAP)

PPAP is a tool developed by Automotive International Action Group (AIAG) for the Part Approval process, which are basically interactions between OEM and supplier to assure all aspects of requirements for productions (e.g. design, machinery, raw materials, capacity of production, logistics, packaging, etc) are being met. In different regions the Part Approval process might be different, for instance in German automotive standard, VDA 6.3, Volume 2 Production process and product approval (PPA) is more common, so this depends on customer specific requirements from each OEM.

2.16.1.3 Failure Mode and Effective Analysis (FMEA)

FMEA is another core tools which is being used vastly in automotive industry. FMEA is an analytical methodology to consider and control potential problems and risks throughout the product and process development such as APQP. It is a documented process of cross-functional teams' collective knowledge. It is usually starts from Design problems which lead to developing DFMEA's (Design Failure Mode and Effective Analysis) and also Process (or manufacturing) problems which lead to creating and developing PFMEA's (Process Failure Mode and Effective Analysis). Although there FMEA are being used in other issues such as maintenance and equipment failure which is called EFMEA (Equipment Failure Mode and Effective Analysis), but DFMEA and PFMEA are main use of the FMEA's in automotive industry. It is normally multiplication of three-digit numbers of Severity, Probability and Detection each vary from 1 to 10 and the result usually called RPN number which normally varies from 1 to 1000. Each FMEA should ensure that full attention considering higher priority to critical and safety related parts or processes has been given to every component for

product and assembly. One of the most important factors in the successful FMEA is to be "before-the event" action not "after-a-fact" exercise.

2.16.1.4 Measurement System Analysis (MSA)

MSA an analytical and statically study to understand the within process and in-between processes variables to understand quality and reliability of measurements' data generated from that specific method of measurement. This can help to improve the most appropriate and effective measurement system for measuring that specific (or similar) characteristic. The main subject of discussion is based on Gauge Repeatability and Reproducibility (GRR, or Gauge RR) to identify of indication of equipment true value, bias, stability. Repeatability is variation of measurements obtained from a measuring instrument when it used several times. It is commonly called Equipment Variation (E.V.). Reproducibility is variation in the average of the measurements generated by different appraisers using the same gauge when using to measure same characteristics on one component. Commonly it is referred to Appraiser Variation (A.V.). Gauge R & R is a combined estimate of measurement system repeatability and reproducibility. The main calculation of MSA study is on variation in measuring equipment (E.V.), variation of (or degree of disagreement between) appraisers, and variation of the component's characteristics.

2.16.1.5 Statistics Process Control (SPC)

SPC is a statistical tool in automotive which main purpose of it is claimed to be 'Continual Improvement' and focus on customers need internally and externally. The need for process control includes Detection (which Tolerates Waste) and Prevention (which avoids waste). The main strategy should be waste preventive actions which it is not always possible. A process control system is working like a feedback from the system or in other words voice of the process. SPC is more analysing and concern with common cause of variation in the system instead of special causes of variation. SPC emphasises on to act on its indicator more wisely. It categorised the actions to 'Local actions' (which are usually required to remove special cause of variation, can be done by operator and is typically correcting 15% of the process problems) and 'Actions on the system' (which are required to reduce the common cause of variation, and require management decision for system's improvement, and typically solves 85% of the process problems).

2.16.2 IATF Rules

This is the rules that IATF have imposed to be followed by IATF certification bodies for certifying OEM suppliers. The IATF16949 Rules 5th Edition is the reference book for certification bodies to adhere to in process of certification of 3rd party lead auditors and auditors, and also in certification of automotive OEM manufacturers. Very intense training course called IATF ADP (Auditor Development Plan) to train, assess and evaluate the knowledge of automotive (Knowledge exam minimum pass 80% on all elements) including Core Tools (FMEA, MSA, SPC), IATF16949 and Rules 5th edition, and also application assessment (Application exam minimum pass 50% on all elements) of those automotive 3rd party audit such as 'process approach', 'non-conformance management', 'Core Tools', 'IATF16949', 'Customer Specific Requirements (CSR's)' and again 'Rules 5th edition'. Still that is not the end of story for auditor development plan as frequently (usually every two years) auditors should have refresher training and exams for core tools and other critical knowledge of IATF. The training and examinations are all being conducted by IATF Oversights members such as ANFIA (Italy), AIAG (USA), FIEV (France), SMMT (UK), and VDA (Germany) and the records of training are being held at the IATF ADP data base.

2.16.3 Customer Specific Requirements (CSR's)

Customer Specific Requirements are the requirements which each OEM may require in addition to the ISO/IATF16949:2016 requirements. Thus, normally the structures of these CSR's are in alignments with ISO/IATF QMS Standard 1st Edition. For instance, Ford may require FMEA as a risk analysis tool but Fiat may require FTA (Failure Tree Analysis) as a risk analysis tool, or process capability. The latest OEM CSR's can be retrieved from IATF Oversight website (http://www.iatfglobaloversight.org/oem-requirements/customer-specific-requirements/).

3 Methodology

3.1   How the research is conducted?

According to Andersen (1994), there are three ways to collect data: (1) Document studies, (2) Observations and (3) Interviews. Which method that should be used should depend on the

purpose of the investigation, the case background, the length of the study and available resources?

All of the three ways of data collection have been used for documented studies (through KPI's), observations (through number of audits and personal observations) and interviews (through information gain via discussions and non standardised questions with process owners).

3.1.1 Document Study

The purpose of the document study is to use data that is already spoken, written or published (Andersen, 1994), e.g. literature, annual reports and articles.

The records of QMS audits in the last three years in this vehicle plant are being reviewed and analysed and the changes in auditing strategy and audit frequency have been compared with external accredited Certification Body audit results. This part demonstrates continual improvements effectiveness of QMS internal audit process on eliminating or diminishing potential wastes. The second part of this study looks at the result of some Scorecards and Key Performance Indicator's (KPI)'s mainly for activities (for example: Warranty Claims, Maintenance KPI's) that can indicate if the waste decreased during these three years.

3.1.2 Observations

Through observations, either participating observation or non-participating observation, the social behaviours can be seen directly (Andersen, 1994). The researcher is always in direct contact to the objects been observed and observations are preferably used in the beginning of the study to create a clearer view of the problem (Andersen, 1994).

In this master thesis some of the observations personally have been concluded valuable information and lessons learnt during the internal and external third-party audits. The damages that an automotive manufacturer may endure and could potentially be prevented by effective implementation of ISO/TS16949 (or ISO/IATF16949) requirements, is a factual evidence which can be used to understand improvements in waste eliminations or waste reductions by compliance to ISO.IATF16949 requirements.

3.1.3 Interviews

An interview can be performed either verbally or written through a survey (Andersen, 1994).

All interviews for this study are verbally conducted during some of internal audits questions as an auditor I have put forward for auditees which are answered and recorded.

To gather information Interviews can be divided into structured, semi-structured and unstructured (Björklund & Paulson, 2007).

As the questions were made during my discussions with auditees it was unstructured as the nature of activities in each area is significantly different as the ratio of applicability of requirements varies process to process.

3.1.4 Reliability and Validity

According to Bryman and Bell (2011) validity can be achieved through internal or external validity. The external validity is to what extent a study can be generalised (Bryan & Bell, 2011) and internal validity is depending on the methods to real measurement what intended to be measured (Gripenberg, 2006) and this is possible to achieve by triangulation (Bryman & Bell, 2011).

The audit results are the analysis of number of internal audits activities and external (3rd party) Audits results and the relations to warranty claim performance which is categorised into 30 days, 3 months, and 12 months in service warranty claims for each model of vehicle manufactured in the plant for last three years of the time of study. Thus the results are measured by external measurements.

Regarding reliability of a study, depends on if it is whether repeatable or not (Bryman & Bell, 2011).

The repeatability of the study as it tracks three years on internal QMS activities and 3rd party (external) results, and comparing these three periods, thus, the repeatability of the study is being considered.

4   Analysis

4.1   Internal Audits

The plant first gained certification in 1993 to ISO 9002. In 2016/2017 moved to ISO 9001:2015 / IATF 16949:2016, with the addition of MQOS - Manufacturing Quality Operating System applicable to manufacturing with various 'overlapping' elements with ISO 9001:2015 / IATF 16949:2016. Each internal audit is conducted against ISO 9001:2015 / IATF 16949:2016 and relevant MQOS (Manufacturing Quality Operations Systems) Procedures. Planning takes place in Nov / Dec of the Fiscal year in readiness for start of next fiscal year. Audit planning & frequency are based on - The previous audit performance & results / volume & shift patterns / areas of concern / results of other Internal Audits i.e. Company Audits, External Audit results / relevant JLR Procedures. The schedule is shared with Production at the beginning of the fiscal year and agreed by Senior Management and concurred by Company Quality. QMS Audits conducted to QMS Internal Quality Auditing Procedure with a process approach and recognising Local Procedures for the area where applicable, focusing on effectiveness and efficiency alongside with applicable company MQOS procedures to the processes or functions. Reports compiled for any NC's observed, using an NC Response Document (which is simplified 8D with Interim Containment actions, Root-cause Analysis including Ishikawa Fishbone and 5Whys, Corrective and Preventive actions) and communicated to area for action. Results entered onto the plant Audit database. All documentation is stored electronically on the Audit Share point Site and is retained in line with company document control requirements.

Level of compliance is categorised into:
- Major non-conformance
- Minor non-conformance
- Opportunity for improvement
- Good practice

Escalation of Internal Audits Non-conformances:
- All open NC's are tracked from the day that the audit report is issued, which is within 24 hours of the audit taking place.

- Daily – All Open concerns are tracked daily via the End of Shift Status Report and issued to all concerned from the Plant Director down.

- Weekly – A Plant Compliance Status is issued to the Plant Director and Senior Managers and NC Owners.

- The "Open" status is reviewed at the weekly in Senior Management Meetings which is attended by the Plant Director and Senior Managers.

- If any issues still open at 15 days, the owners attend an escalation meeting with the Plant Director.

Internal Audit 2016/17 Fiscal Year:
- Introduction of 2 Full Time Auditors (April, October)
- Previous to this – All Auditors were Part Time, consisting of both Staff & Hourly personnel

Internal Audit 2017/18 Fiscal Year:
- 1 Part time auditor (Lead Auditor) co-ordinating the Schedule
- 2 Full Time auditors (Staff level)
- 1 Internal Auditor / Audit Admin (Hourly)

Advantages / Benefits of Full Time Internal Auditors (identified by the business):
- Experienced / dedicated team
- IATF trained able to share the learning / able to coach others / Subject Matter Experts
- Consistent approach to auditing
- Develop close relationship with the Auditee's
- Less impact to the business compared to Part Time Auditors

Auditor Training/Competency Requirements:
- All Full time Lead Auditors are 'IATF 16949 Lead Auditor' certified, with an accredited body, which includes a 'Core Tools' training course (APQP, PPAP, FMEA, MSA and SPC).
- Any Internal auditors are 'IATF 16949 Internal Auditor' trained, with an accredited body.

- All Lead & Internal auditors will require refresher training in the event of any changes to ISO 9001/IATF 16949 standard.

- Auditors must conduct 2 audits per year as a minimum to be able to conduct audits unsupported.

- Audit Manager/Co-ordinator must review competency of each auditor annually (as a minimum) according to Company's Internal Auditor Competency Framework. Auditor competency improvement/development should be identified and tracked. Records must be kept.

In 2017/2018 Fiscal Year until November 2017 (figure 4.1), 184 NC's raised by internal audits consisting of 32 Major & 152 Minor NC's, which 174 are already closed at the time (on time).

Figure 4.1 - 2017/2018 Fiscal Year to Date
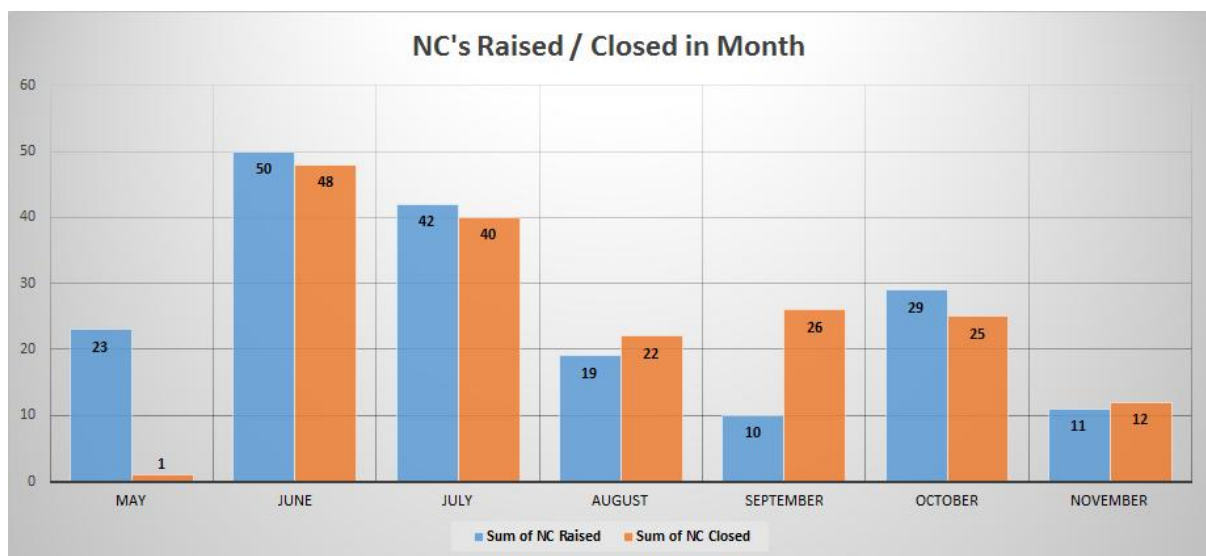
Internal audit also has introduced MQOS Procedural audits into its internal audits to overcome the weakness of plant's knowledge on company's procedures.

MQOS Procedure Audits (New for 2017 / 2018):

- 151 Procedure audits scheduled for the Fiscal year.

- Audits conducted by Area to the relevant MQOS Procedure.

- Any NC's raised will be dealt with as per any ISO / IATF NC's raised

- Results entered onto the CB Audit Database.

- All documentation is stored electronically on the Audit Share-point Site and is retained in line with company's document control and retention control requirements.
- Results tracked as per IATF Internal Audits.

Figures 4.2 and 4.3 are illustrating all of the non conformance analysis on the nature and the ISO9001:2015 and IATF16949:2016 clauses, and the categories of issues and recurrence of them. This helps the organisation to be able to investigate, identify the root-cause and put the appropriate corrective and preventive actions in place and make sure the improvements are being maintained.

As it is a manufacturing plant (and not involved with product design) you can see highest number of noncompliance is coming from production and service provisions, and corrective actions.

Figure 4.2 - Internal Audit NC's - IATF16949 Process Audit Repeat Concerns (2017-Current)
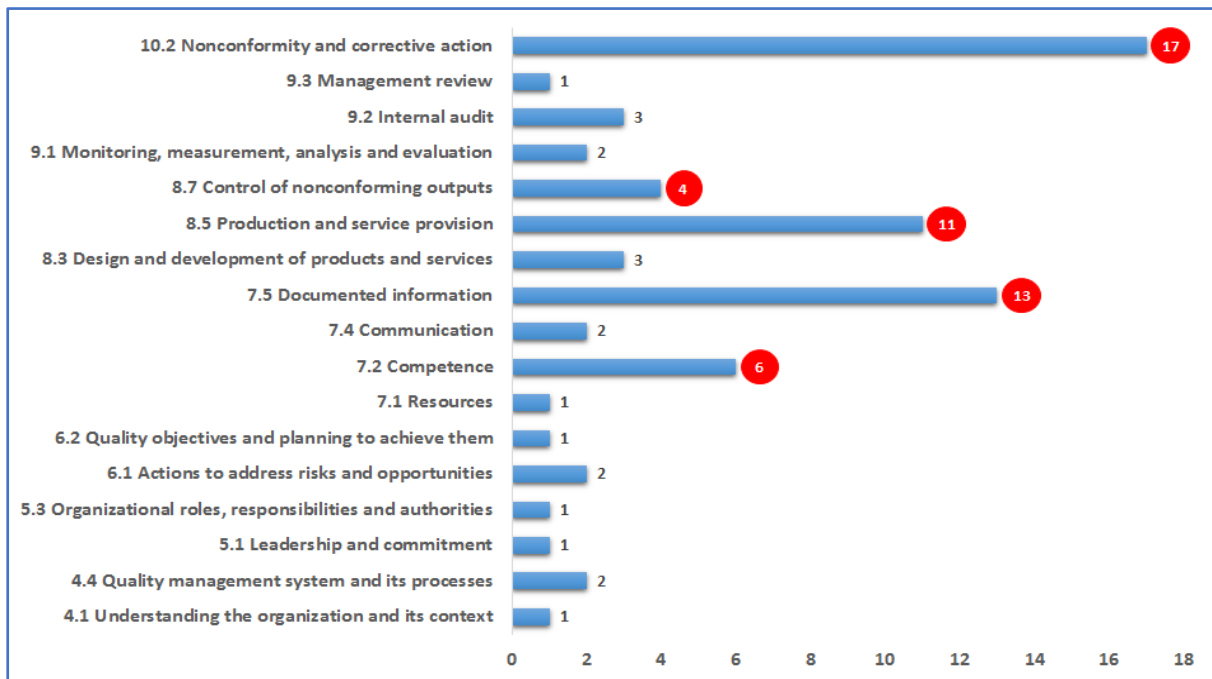
Table 1 demonstrates an example of top clauses from ISO/IATF16949 with most frequent non conformances the top clauses with most frequent non conformances.

As it is truly said a picture can speak more than thousands of words, Production and service provision and also Nonconformity and, corrective actions are those areas which ISO/IATF16949 audit results reflected. These are the areas which the organisation is bearing the highest brunt of wastes in lean manufacturing as well.

As the new versions of ISO9001 / IATF16949 emphasise on 'risk based thinking' with this method of analysis, the plant QMS team creates a good picture of most risky areas and can eco it to top management to act on them.

What is crucially important is effectiveness and efficiency in continual improvement which top management should be able to demonstrate to internal and external auditors.

Table 1 - Internal Audit NC's - Process Audit Repeat Concerns - Examples

8.5	8.5.1.1 Control plan
	8.5.1.2 Standardised work – operator instructions and visual standards
	8.5.1.5 Total productive maintenance
	8.5.2.1 Identification and traceability — supplemental
	8.5.4.1 Preservation - supplemental
	8.5.6.1 Control of changes - supplemental
7.5	7.5.2 Creating and updating
	7.5.3 Control of documented information Ref: 7.5.3.1 and 7.5.3.2
	7.5.3.2.2 Engineering specifications
7.2	7.2 Competence
	7.2.1 Competence – supplemental
	7.2.2 Competence – on-the-job training
7.1	7.1.4 Environment for the operation of processes
	7.1.4.1 Environment for the operation of processes – supplemental
	7.1.5.2 Measurement traceability
	7.1.5.2.1 Calibration/verification records
10.2	10.2 Nonconformity and corrective action
	10.2.1 and 10.2.2
	10.2.3 Problem solving
	10.2.4 Error-proofing

4.2   Internal Audits versus External Accredited Third-Party Audits

The history of ISO/TS16949 and ISO/IATF16949 third party audits results (including Recertification, Surveillance and Transition to IATF16949:2016) in the last three (fiscal) years (2015/16, 2016/17 & 2017/18) of the company which was the main scope of this master thesis, indicate a significant improvement in Quality Management System compliance. Of course, very strict regime of internal audit schedule and procedural rules has been dictated by corporation QMS team which is leading the QMS programme proactively.

In the 2015/16 fiscal year the plant was merely relying on part-time auditors from different departments and the number of audits in total was 45 in that year, this has slightly increased in 2016/17 to 49 with one full time auditor with no experience of audit and standards, and some use of part time auditors. In 2017/18 audit numbers reached to its pinnacle with 146 audits with two qualified lead auditors. Considering the transition from ISO/TS16949:2008 to ISO/IATF16949:2016 including training of internal lead auditors and auditors to new

ISO9001:2015 and IATF16949:2016 standards, gap analysis and identifying the new requirements from new standards which are not addressed in deferent departments in the plant and implementing new standards and initiating auditing the new standards.

The Table 4.2 demonstrate the history of Internal Audits Schedule frequency, types of audits and compares it with external 3rd party audits results which have been conducted by an accredited certification body. The results of improvement in plant quality management systems was quite significant and this is more fascinating which it was not only recertification audit but also transitional audit to new standards with mostly tighter requirements.

Table 4.2 - 3rd Party Audits Vs Internal Audit Activities

Year of 3rd Party Audit (Fiscal Year)	Type of the Audit	No. of Non conformances (NC's)	Number of Full-time Auditors	Annual Internal and MQOS Procedural Audits Number (Covering all Shifts for IATF Audits)
2015/16	ISO/TS16949 Surveillance	Seven (Minor's)	Zero	45 (ISO/TS16949 Audits)
2016/17	ISO/TS16949 Surveillance	Seven (Minor's)	One	49 (ISO/TS16949 Audits)
2017/18	ISO/IATF 16949 Cert. Renewal & Transition	Three (Minor's)	Two	146 (ISO/IATF16949 Audits) 151 (Procedural Audits)

The table 4.3 is illustrating the Plant internal procedure for non-conformance management and has compared it with company quality procedure. In my experience of one and half a year working in this plant as an Internal Lead Auditor, I must say the management commitment towards the non-conformance management in this plant is quite significant and can be considered as a key to the successful results. My observation of non-conformance escalation meeting in Senior Management Meeting which was taking place weekly on Thursdays at 11:00 am with Plant Operation Director or in his absence with his representative, gave a strong prompt to the process owners to work hard for closure of non-conformances and assurance of compliance.

Table 4.3 - NC Management Company Quality Procedure (CQ) Versus Internal Procedure

Procedure	NC's shall be closed within	1st Escalation Meeting	2nd Escalation Meeting	3rd Escalation Meeting
Company Quality	20 (Calendar) Days	Day 20+ with Quality Manager	Day 40+ with Operations Director	Day 60 with Company Quality Manager (CQM)
Internal NC Procedure	14 (Calendar) Days	Day 14+ with Operations Director	Day 21+ with Operations Director	Day 28 With Operations Director and CQ Manager

The results of this very intense and strict audit regime and NC management procedure have had a significant impact not only on the Third party Certification and Transitional audits' results but also considerably on functions key performance indicators (KPI's). I have decided to analyse the maintenance department in main Assembly Hall because any disruption in assembly hall would create a cumulatively massive waste of 'waiting' or 'Scrap, Repair & Rework' throughout the supply chain process. Interestingly the Maintenance departments were among those common audits finding in the last three years 3rd party audit by IATF16949 Oversight accredited certification body, thus, it was under heavier audit regime for robustness of implementation of corrective actions and also assurance of maintaining and consistency of it. I have to add that Maintenance following my discussion with Maintenance manager of Assembly halls for three main models, he confirmed the maintenance is under pressure from the top management for headcounts reduction to be more competitive to the companies' rivals. Although arguably there was no analysis of the technology's comparisons available between the company and its rivals to provide a clear picture for understanding of if the department performance is lower with same conditions such as machinery, equipment, complexity of process design etc, and make a decision on this matter accordingly.

4.3   Warranty Performance

The review of warranty performance indicators are covering four main current model year vehicles which were under production for the specified years of this thesis. The reason for warranty claim analysis is as the warranty is a good indicator of to what extent the customer's need have been met and also warranty claim is one of the biggest waste costs which automotive manufacturer (in particular) are facing with and as much as they can reduce the

warranty claims it would indicate more lean manufacturing. Although, arguably the warranty claims might be due to component failure, this also can be indicating how successfully an OEM could assist its own supplier(s) to improve and develop in quality and reliability. Supplier Technical Assistance (STA) department and ISO/IATF16494 2nd party auditors were responsible to champion that side of the quality management systems. As the IATF16949 goal is actually continual improvement, defect prevention and waste reduction throughout the automotive supply chain, and this included by supplier's management and also can be reflected through warranty performance results.

In fact, as it was discussed earlier the QS9000, ISO/TS16949 and ISO/IATF16949 all established by major western countries with mass production OEM vehicle manufacturers to expand and develop an agreed standardised quality management system (plus CSR's add on for each OEM specifically) to create some kind of stronger control and management beyond their manufacturing borders from the starting points to point of use through the automotive supply chain processes. The IATF Rules is a strict regime which is actually guardian of the ISO/IATF16949 standard's requirements application by Third Party Certification Bodies which are accredited IATF16949 Oversight. It paves a clear direction for certification bodies (CB's) to follow and also prevent any possible abuses from the CB's.

The warranty performance (in Figure 4.4, 4.5, 4.6 and 4.7) shows 0 (within 30 days), 3 (within 90 days) and 12 months in service warranty performance. As it is quite significant the trends for all 4 vehicle lines show a positive trend in the last three years.

The chart on the left-hand side (in the warranty performance figures) shows the model year performance over 2015, 16, 17 & 18.

For agreement of the research with the business I kept the name of models to maintain confidentiality of the research.

All of the four models are well established models as it passed the maturity phases of design and development and the learning curve of this model is not an effective matter with the research. However, the Small-Medium Saloon production line has been introduced last in 2016 and is the youngest using similar production line of Medium Saloon assembly line. The analysis of successful QMS system is more reflected from warranty claims within first 30

days as experience of the warranty manager says it 90% comes from the manufacturing issues. Warranty claims within 90 days root-causes are a mix of parts failure and manufacturing issues (normally fifty-fifty) and warranty performance within 12 months is indicating more of component failure or design issues.

The Medium Saloon model demonstrates a significant reduction of warranty claims within 30 and 90 days from August 2016 until August 2017 and that is exactly the time that the plant has employed two full-time IATF16949 auditors. Similarly, for the Small-Medium Saloon model we can see very good warranty performance especially within 30 days in service.

The Large Saloon and Coupe models are having longer history, but still the warranty performance in 30 and 90 days in service indicates very good performance or at least depicts improving trends.

It is confirmed the delivery performance of the production lines has not changed during the period of the research timeframe. Although, production of some models such as Large Saloon might be steadier in comparison with for example Small-Medium or Medium Saloon, but the production delivery target rate has not changed during this period. On the left-hand side of tables there is an average figure of MY (Model Year) YTD (Year to Date) figure which illustrating the average performance of each MY to the date. The trends of these figures also are indicating significant improvements, especially between 2017 and 2018 which the plant was in transitional period certified to ISO 9001:2015 / IATF16949:2016 by third party audit.

Moreover, the 12 month in service warranty performance also indicates in average all of four models are performing significantly better than 2015 and 2016 which the plant was relying on only part-time auditors and as the full-time auditors were gaining experience with learning more about the auditing ISO/IATF16949 and MQOS procedures audits and also coaching the areas with the requirements and also problem solving approach to the findings the Warranty of 12 month, 3 month and 30 days all were improving.

As an example an observation as an internal auditor was when the 88 engines were affected when the coordinate measuring machine (CMM) measurements indicated measurements are out of specification during the night shift but due to human error it was not picked up and non-conforming parts were sent to assembly hall and also sent to vehicle assembly. The root-

cause of the issue was the drill calliper was not checked part of PPM checks. Also, the other root-cause of the issue was human error and relying on a time consuming CMM measurement process and introducing measuring benches for checking parts more frequently. Although these are very effective corrective actions but also Machine FMEA also should be updated (or should be created if it has not one already). The waste of the scrapping 88 complete engines is not only a huge damage to a company but also is not possible to be calculated the damages to the brand, as legacy of bad quality remain on customers' minds for a long time. This is a simple example that how Warranty (as a measure of wasteful activities) can be prevented by robust and affective maintenance.

The Warranty audit is an illustrating a good picture of Plan-Do-Check-Act and after failure Re-plan, Re-do, Re-check and then Act again. However, the lesson which has been leant shall be recorded for the future use to prevent recurrences.

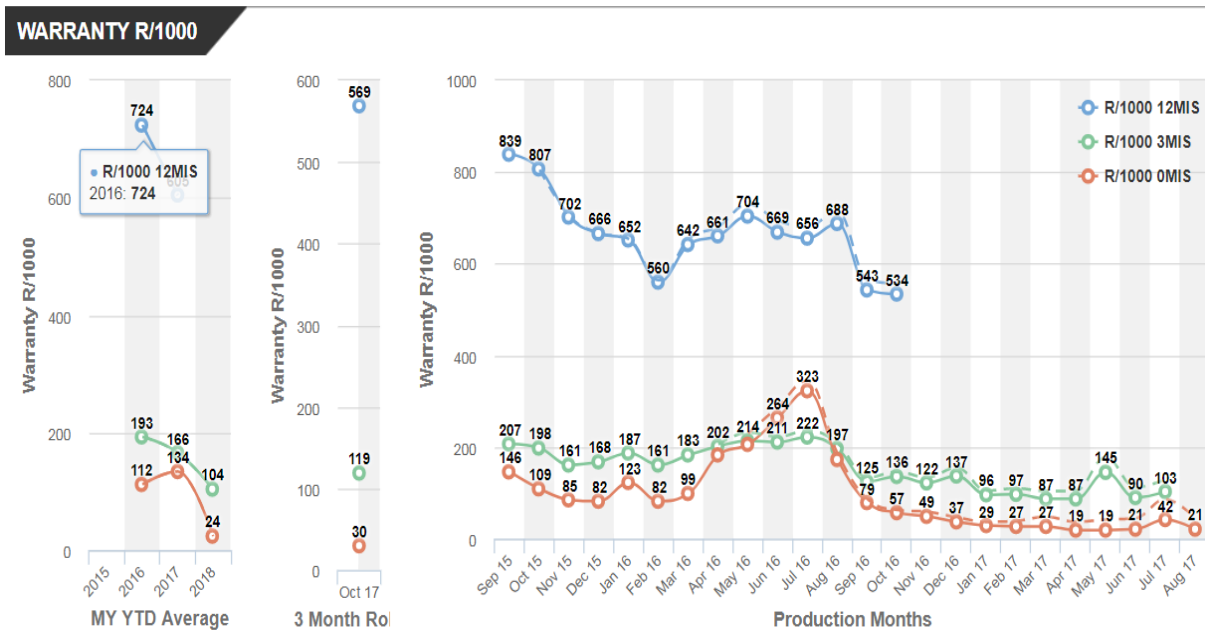Figure 4.4 - Medium Saloon MY, Warranty Performance

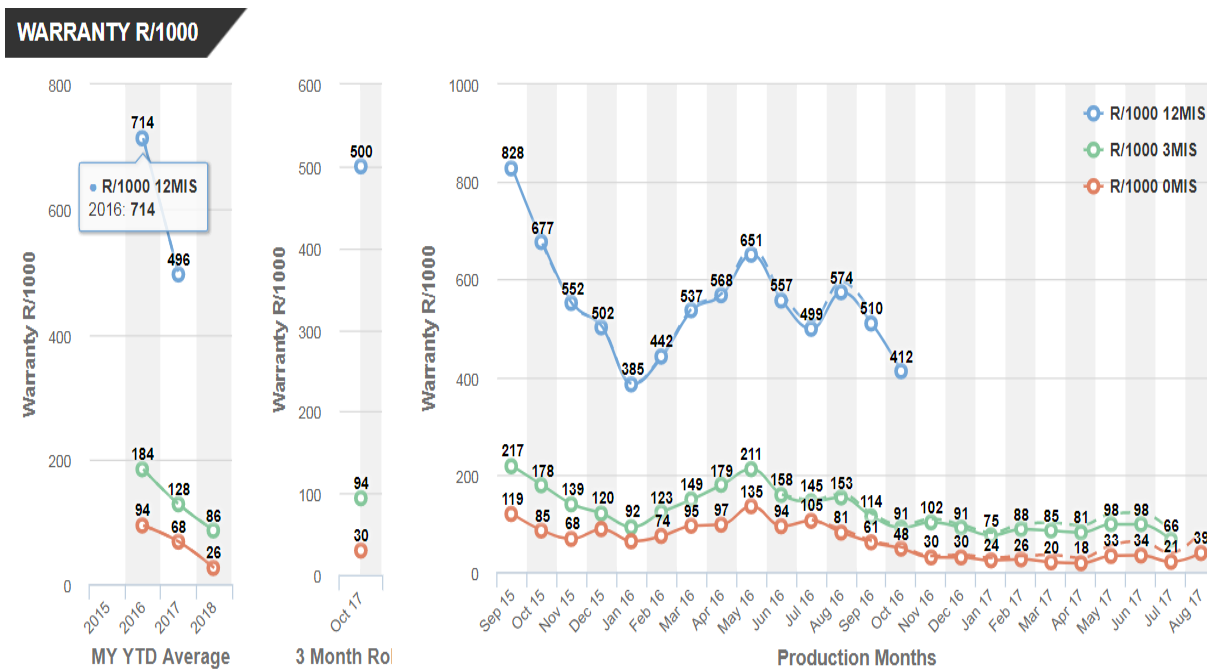Figure 4.5 - Small-Medium Saloon MY, Warranty Performance

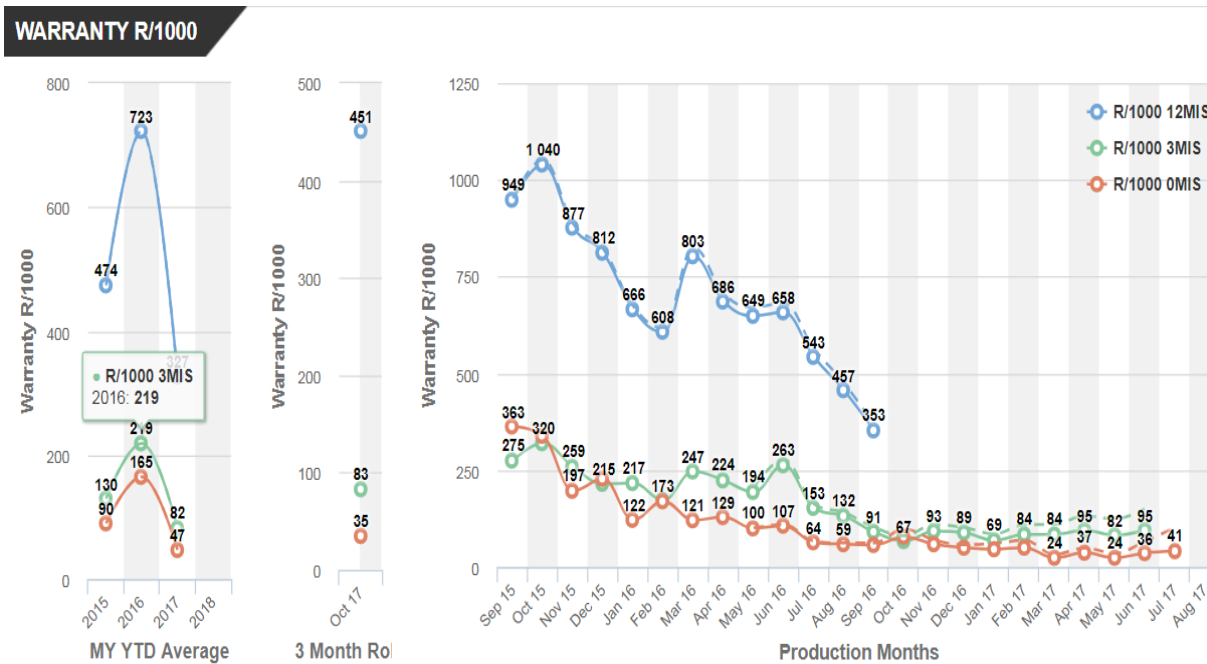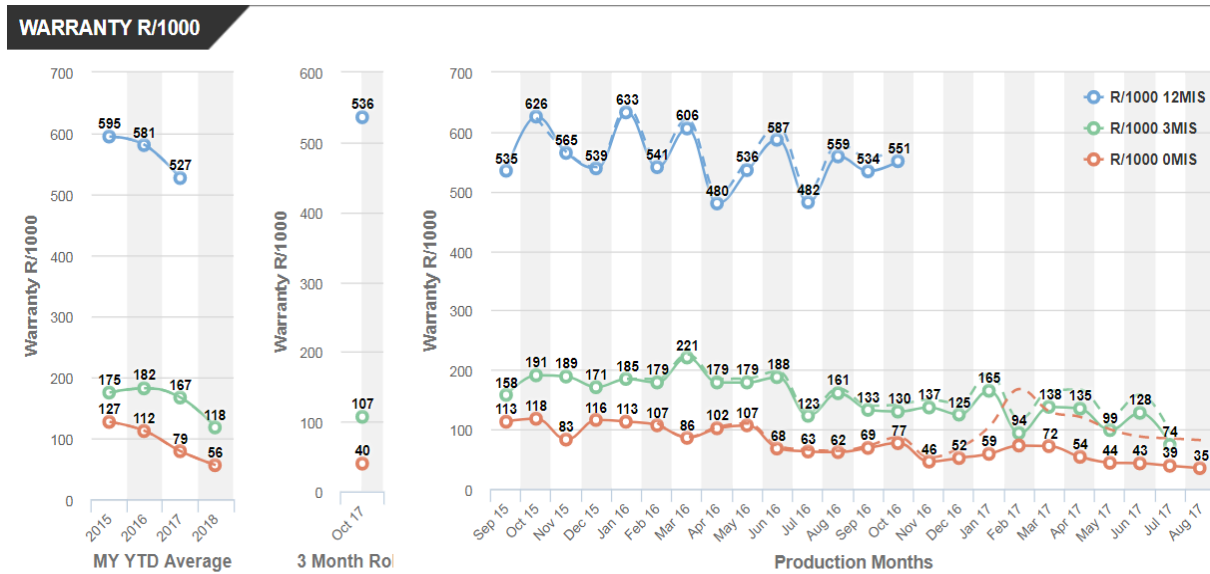Figure 4.6 - Large Saloon MY, Warranty Performance

Figure 4.7 - Coupe Warranty Performance

4.4   Maintenance Performance

Maintenance department is responsible to develop, implement and maintain a total productive maintenance system as it is a requirement by IATF16949 (clause 8.5.1.5). Maintenance department is chosen for this study as it is one of the most critical part of manufacturing which can potentially cause majority of manufacturing disruptions and the KPI's which are emphasised by IATF16949 which can be used such as Overall Equipment Effectiveness (OEE), Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), Preventive Maintenance (actual versus plan). This clause made use of preventive maintenance, periodic overhaul and predictive maintenance (if applicable) mandatory. The organisation uses the terminology of Predictive and Preventive Maintenance (PPM). The Maintenance departments in Assembly and also Body-In-White (BIW) both received one NC each in previous 3rd party audit in 2016 (for the period of 2015/16) and no issues found in these areas in 2017 (for the period of 2016/17). As the same certification body has been auditing the plant (at least) for last three years, the quality of certification body has not changed, however, the IATF Rules Edition5, requires changes in audit team after 3 years of certification period, thus, the audit team changed for audit in 2017. On the other hand, normally the new audit team are considered as fresh eyes and normally find new issues which might have been slipped the previous audits.

During my internal audit observations as an internal auditor, my focus was on PPM compliance, and also outstanding Corrective Maintenance (CM). The PPM's and CM's are categorised in three different categories including Safety Critical (rated with priority number 9) and shall be completed or corrected (or at least contained) within 24 hours, then process critical PPM's and CM's (with priority number of 6) and target for completions is 7 or 14 days base on criticality and experience of the Maintenance team, and the last category as cosmetic PPM's and CM's (with number 3 priority) and lead time of 14 to 30 days targets.

The Maintenance departments both are using Maximo software to manage their activities. The process of the PPM's is to conduct some checking on the equipments base on planning and if there is any need of actions required then the maintenance technician will raise a CM with the same priority number from PPM category. If there is breakdown on the production then they raise Emergency Maintenance (EM's) to conduct emergency corrective actions. In my observation I understood the nature of maintenance is very different from the other departments as the capacity of working hours is limited to the number of team, the knowledge and skill of the team, and also maintenance strive not to interfere the manufacturing and production with its activities which is making even the situation even more harder especially in the two or three shifts manufacturing processes. So, more pressure on the equipments which are being more in use, and also less time for maintenance team to conduct the PPM's to reduce the risks of breakdowns and interruptions in production.

4.4.1 Maintenance in Assembly Halls

Maintenance in assembly is consisting on four and half assembly halls i.e. B Block (Powertrain and Axles Assembly Hall for Coupe and Large Saloon models), D Block (Assembly Hall for Small-Medium and Medium Saloon models), F Block (large Saloon Assembly Hall) I Block (Powertrain and Axles Assembly Hall) plus half of C Block assembly hall for Doors Assembly (called Doors Off for Medium-Small and Medium Small doors assembly) with fairly similar technologies and machineries. D Block with two shifts and the same manager with responsibility of looking after the all four and half manufacturing areas' maintenance, however, the maintenance KPI's are not reflecting the same in these three halls. One of my observations as internal auditor was raising a non-conformance as the B Block did not have PPM, CM and EM KPI's and until that time even the manager did not

notice that. Although, it could be because the B block is having a fairly more relax environment as the coupe and large saloon models are not products with high volume demands and also maintenance performance in B block was fairly the best among the other halls. However, as the maintenance manager also confirmed the available man-hour could be better monitored and optimised with employing directing unused available man-hours to where there are more business needs and allocating them to other halls which were struggling to catch up with the maintenance activities.

As you can see in figure 4.8 the C Block is struggling with time availability and on the other hands for example F Block, I Block and B Block are having extra hours which can be allocated to C Block to catch up.

Figure 4.8 - The Assembly Hall Maintenance Time Availability (TA)
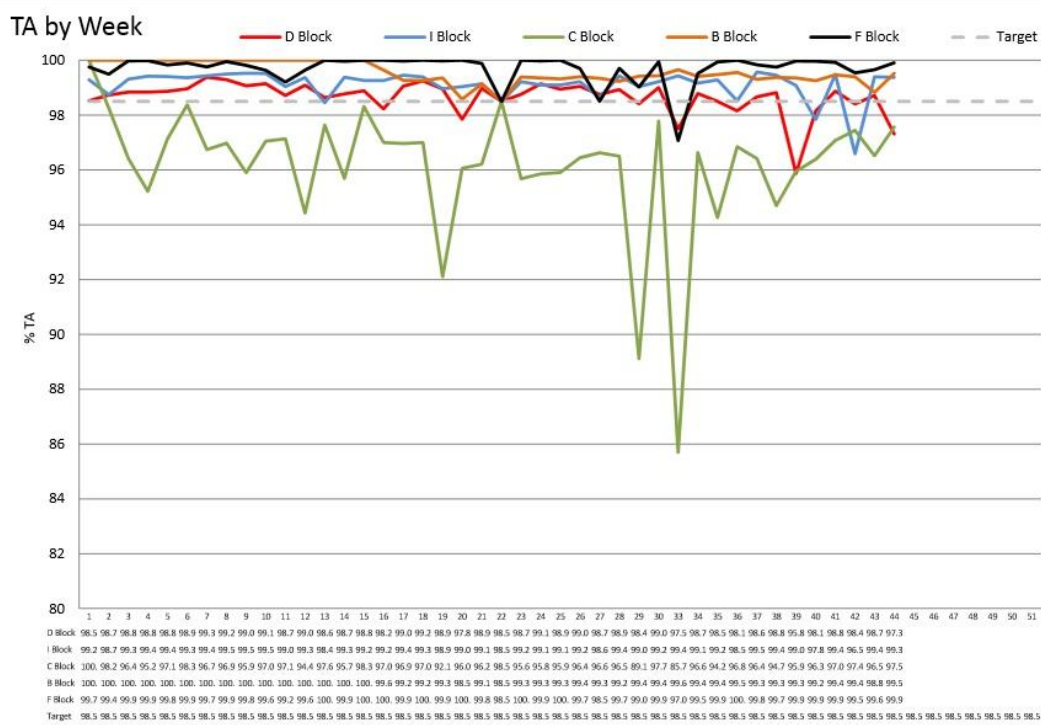
Maintenance performance KPI's is being reviewed by Senior Management Review meeting which is weekly. The Operating Percentage Rate (OPR) is one of the maintenance measures to illustrate the overall performance for Assembly Maintenance. As it is evident in figure 4.9

the Assembly Maintenance strictly monitors any type of disruption in production i.e. Production on Hold, Andon (an operator's assistance request system), E-Stop (Equipment Failure), Fault (in product), Blocked and Starved (lines). Obviously, this can help the cross-functional team to identify the critical processes, machineries, and activities. Then the team can trigger their Root-Cause analysis and problem-solving activities to eliminate the problems permanently.

Year To Day (YTD) Operation Percentage Rate (OPR) is one of the maintenance team KPI's which can be used for both for production and maintenance team. It is a weekly performance from the start of the year and monitoring Blue, Red and average of both shifts performances. It also monitors weekly performance of End of Line (EOL) performance.

Moreover, it categorises the type of the production disruptions such as Production Hold, Andon, Equipment Stop (E-Stop), Fault, (Line) Blocked, (Line) Starved.

Figure 4.9 - The Operating Percentage Rate in Assembly Lines

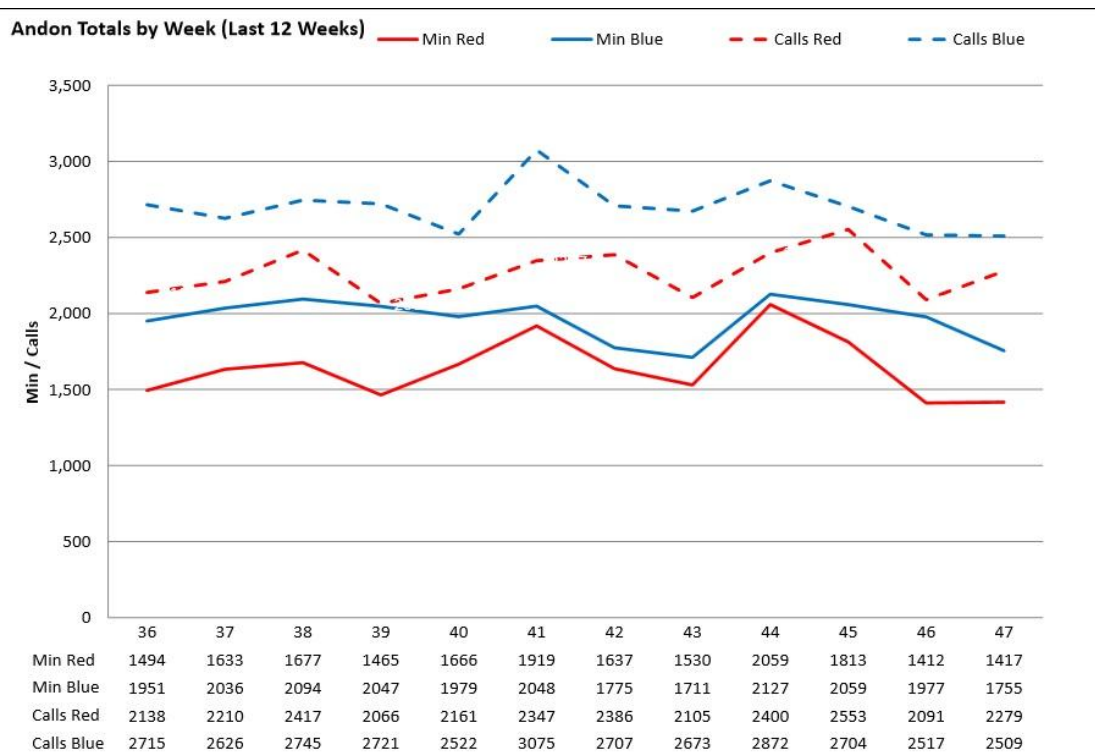It is quite fascinating that the Blue shift is not performing with the similar rate to the Red Shift. As you can see on the table above, the number of Andon calls and also extra minutes which were spent on Blue shift by maintenance is significantly higher than Red shift which is indicating probably a special cause of variation in cycle times. This may require a thorough investigation and root-cause-analysis (especially by a Six Sigma Back Belt specialist) to analyse and identify the issue and improve, maintain the improvements and probably (if applicable) replicate it to other areas.

As Andon calls attributes to the biggest waste in production, the business monitors this issue more closely and as we can observe in figure 4.10 the comparisons of number of calls from both shifts and minutes which have been taken by both shifts.

Figure 4.10 - Weekly Andon Calls

|	36	37	38	39	40	41	42	43	44	45	46	47
Min Red	1494	1633	1677	1465	1666	1919	1637	1530	2059	1813	1412	1417
Min Blue	1951	2036	2094	2047	1979	2048	1775	1711	2127	2059	1977	1755
Calls Red	2138	2210	2417	2066	2161	2347	2386	2105	2400	2553	2091	2279
Calls Blue	2715	2626	2745	2721	2522	3075	2707	2673	2872	2704	2517	2509

LiveViews OPR
24/11/2017

It is also important to take into account that the Assembly Maintenance is planning to reduce number of headcounts from 70 to 61 in 2017 and at the time of data collection the number of head counts are actually 64. Figure 4.11 is illustrating the number of (AOR

Available on Request) headcounts reduction in 2017 since January. The reduction of team members are via retirements and not redundancies.

It is significant even with headcounts reduction the PPM, CM and EM performance have improved through better optimasation and smarter allocation of work forces. The Maintenance manager explained that internal ISO/IATF audits made the team to review the activities such as PPM's and reoptimising them with analysing the criticality of the PPM, recurrance rate and probability of failure, and rerate the PPM's and consequently the CM's priortisations and fequency of checks. This also happened in Body-In-White Maintenance after of raising a number of on conformances by internal IATF team and number of escalations as the area was struggling with corrective actions.

Figure 4.11 - Assembly maintenance AOR (Available on Request)
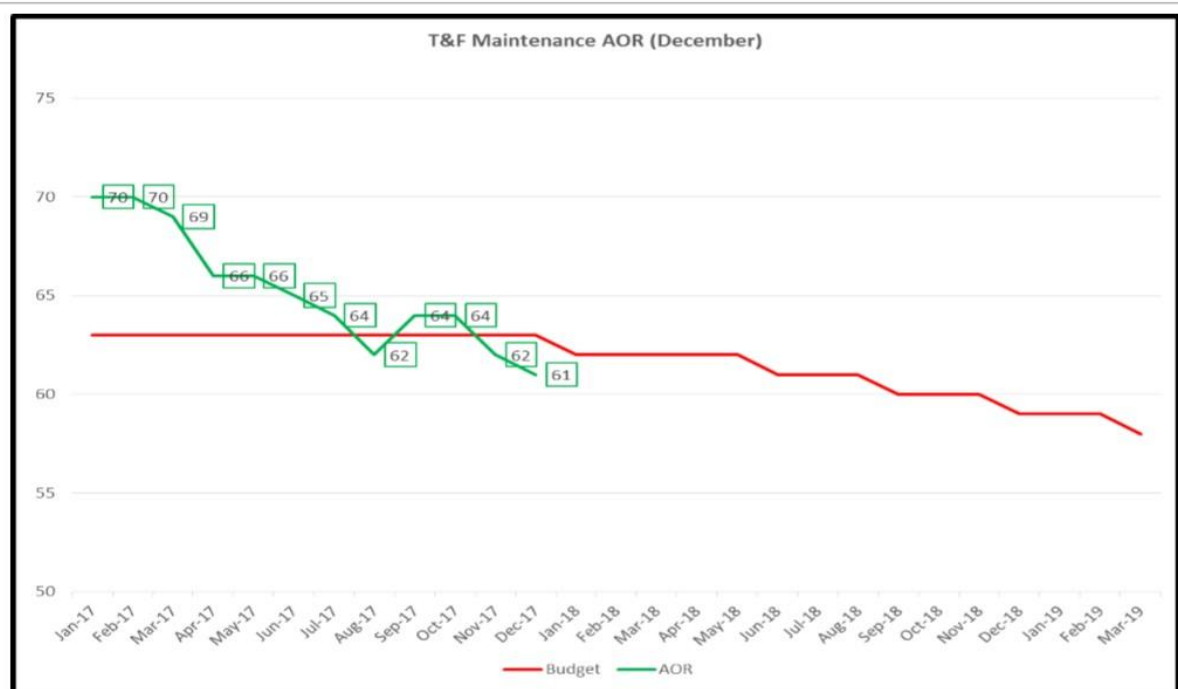
4.4.2 Body in White (BIW) Maintenance

Maintenance team KPI's responsible for BIW have been reviewed as they were struggling to catch up with their PPM programme and CM's and this matter was escalated by ISO / IATF16949 internal audits as following a third-party ISO/TS16949 audit one of the non-conformances raised against BIW Maintenance team in 2016/17. Internal audits were responsible not only to audit the processes but also verify and validate the corrective and

preventive actions from the IATF16949 third party audits non-conformances. This was to ensure to maintain the improvements. However, the after a number of audits still the KPI's were under the target dramatically and internal audit non-conformances from minor was escalated to major and from major the team came up with an thorough action plan to overcome the issue. This action plan was with the same approach as the maintenance did with the analysis of activities and optimises them to improve the effectiveness and efficiency. Interestingly measuring effectiveness and efficiency in the processes and also assurance of improving them is an important requirement in ISO/IATF16949. With this approach the BIW Maintenance KPI's improved significantly while the production also was not affected as it was planned to use the resources smarter. Tables 4.4 and 4.5 are listing top issues in terms of duration and recurrence. As you can see the same issue is the identified for the duration and recurrence and gives a clear picture to the business for problem solving and corrective actions to improve smoothness and reliability of the process.

Table 4.4 - Top faults by duration

CimPos Monitoring			Report Period:- Shift	Shift 26/11/201	Sh	WEEKEND			
Top 10 Faults Ranked by Duration									
Rank	Zone	Equipment	Fault Description	Fault Type	Duration	Occ	L3M Occ	Duration Pareto (Minute)	
1	Zone 22.2	Z222T 210R8	DWS 1 : Clamp open not on	GLUEING	12:00:00	1	6	720	
2	Zone 22.2	Z222F 260R26	SPRH 1 Tool 1 : Cube 1B bowl run	HENROB RIVETING	12:00:00	1	2	720	

Table 4.5 - Top Faults by Occurrence

Top 10 Faults Ranked by Occurrence								
Rank	Zone	Equipment	Fault Description	Fault Type	Duration	Occ	L3M Occ	Occurrence Pareto
1	Zone 22.2	Z222T 210R8	DWS 1 : Clamp open not on	GLUEING	12:00:00	1	6	1
2	Zone 22.2	Z222F 260R26	SPRH 1 Tool 1 : Cube 1B bowl run	HENROB RIVETING	12:00:00	1	2	1

In figure 4.12 we can see the BIW Maintenance KPI's are being monitored for MTBF (mean time between failures), MTTA (mean time to assist) and MTTR (mean time to repair).

As you can see the Scorecards do not reflect very considerable improvements, however, in some areas there were some improvements and some reverse effects. Although, the team is not fully fledged with the new strategy to update activities but it has been confirmed with the manager that the process of PPM's and CM's is working much better than previous programme.

The IATF process approach audit require to if the KPI's have not met the targets, start problem solving corrective and preventive actions and evidence of each and the outcome would be reviewed in internal and possibly 3rd party audits.

Figure 4.12 - BIW Maintenance KPI's

4.5   Problem Solving Approach

Was it only audits which have improved the process? I have to say no, not only that. The plant quality management system rigorously was striving to solve the problems and improve the process. My observation as a member of quality from experience of working with a cross-functional team and creating a quality procedure as the author of the procedure to control the (aluminium) panel split issue which was a serious and sneaky problem and had been picked up in different manufacturing technologies throughout the manufacturing chain, and the reaction to the problem in each technology was required to be different in terms of campaign for containments and investigation for non-conforming parts and affected vehicles. Although, the root-cause of the issue potentially goes back to Press-shop or Body-In-White (BIW) technologies, but if the issue be found sooner the waste would be less. (Please see Appendix: Exhibit 1, Exhibit 2, and Exhibit 3)

On the other hand, the audit findings were triggering investigation with root-cause analysis and corrective and preventive actions process which was standardised with The Eight Disciplines of Problem Solving (8D which originally developed by Ford) format, giving more push with the escalation procedure to the departments such as Production, Engineering, Maintenance and even Quality to actively work on the issues as soon as possible. This is actually the main goal of IATF16949 as an Automotive QMS standard to develop and a system for continual improvement, with insist on defect prevention, the reduction of variation and waste throughout the supply chain.

5   Conclusion

Conclusion of the ISO/IATF19646 effectiveness on continual improvement is really not the matter of simple calculation as the processes are mostly managed by humans and their knowledge and intentions towards the ISO/IATF 16949 requirements.

However, this study to some extent created an image of ISO/IATF16949 improvements and its effectiveness in lean manufacturing which was the result of strict audit regime, good knowledge of internal auditors for ISO/IATF16949 requirements, Core Tools, problem solving and top management commitment of serious corrective, preventive actions and escalation process.

Two key departments of Warranty and Maintenance in major part of manufacturing sampled for this study and their KPI's have been reviewed and the actions which took place to denote how the significant waste's elements are being monitored and improvement through the process via Plan-Do-Check-Act cycle are possible through ISO/IATF16949.

My observation through the three-year career gave me this understanding of Plan-Do-Check-Act is in fact Plan, Do (or test actions in small scale), Check (correct and prevent), and Act, and then like a pendulum (and not like a cycle) it swings back from Act to Re-Check (correct and prevent), Re-Do (testing new actions in a smaller scale) and if that is something to be replicated as a successful action to be Re-Planned for systematic improvements.

My understanding of ISO/IATF16949 certification can be quite effective for continual improvement through defect prevention and waste reduction if it has been implemented robustly and treated with a serious manner. It is important to make sure the auditors are well trained (and this is not happening in a short period of time), with IATF16949, core tools, problem solving methodologies, customer specific requirements.

Apparently, with strict implementation of IATF1649 and frequent auditing regime the warranty performance has significant improvements in last three years, which is massive waste reduction for the business. The average improvement is evident in less than one, three and twelve months warranty claims performance. The importance of the these different type of warranty claims as is mentioned before is, shorter warranty claims is more relevant to manufacturing issues, and longer warranty claims is more connected with parts failure and supplier issues. Although ISO9001, IATF16949 goal is continual improvements and waste reductions throughout the supplier chain in automotive manufacturing, but it is significant that warranty claims for less than thirty days performance curve is steeper than warranty claims performance rates for three and twelve months. This can be a fair indicator that manufacturing warranty claims performance significantly improved.

Although, it might be challenged by other changes in manufacturing process, while there have been no tangible changes to the processes, other than stricter audit regime, improvement and coaching of problem solving skills as it is a requirements of IATF16949, thus, still argument supports the effectiveness of IATF16949.

Maintenance activities such as preventive and predictive maintenance, corrective maintenance (or repair), emergency maintenance, overhaul, analysis of equipment effectiveness, etc, prevent manufacturing wastes such as production disruptions (which potentially creates chain of waiting waste, scraps/reworks, or over-processing), also prolong equipments life and reduce the costs.

Moreover Maintenance teams in BIW and Assembly Halls have massively improved their planned preventive and predictive maintenance, corrective maintenance lead time KPI's while maintaining the same number of resources which have been prompted by ISO/IATF16949 internal audits by qualified and competent personnel's and structured problem solving methodology. In other words they are doing more (or the same KPI score) with less (resources) which again is another explanation of lean philosophy and these again attribute to improvement in ISO/IATF16949 quality management system.

Although, the nature of BIW and Assembly production technologies is different, but this study identified they were both suffering from managing available resources, and the KPI's which are mentioned in IATF16949 clause 8.5.1.5 Total Productive Maintenance (which some of them are mandatory and some other if applicable), provide reliable indicators to identify weaknesses and act to improve weaknesses. Review of internal and external non conformances on maintenance departments in those technologies to some extent indicated similar weakness in PPM's and CM's activities and both teams with root-cause analysis and problem solving methodologies identified the issue and came up with action plans, and after implementing action plans the process significantly optimised and improved.

As it has been reminded earlier in this paper, the goal of ISO/IATF16949 has been described by the IATF16949 manual, is continual improvements, defects prevention and waste reduction this research demonstrated a strong link for between well organised IATF16949 QMS process with allocating more resources, and effectiveness and efficiency in manufacturing and processes. This study supported the claim that improvement in ISO/IATF16949 has direct link in waste reduction and improvement in performance of the key processes.

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Appendix

Exhibit 1- Sample of NC Reports:

Audit Ref:	PQ-9B-2017	Audit Title:	ISO/IATF16949 Internal Audit in SIPS Process				Date of Audit:	20/09/2017
Day Shift / Late Shift: (To Include Shift Handover)	Day/Late	Area Audited:	D & F Blocks				Report Issue Date:	21/09/2017
Auditors							Closure Date:	04/10/2017
Lead:	A. Kheradnejad	Audit Scope:	SIPS Processes on both shifts, handover report, escalations, work instructions, training records etc.				Previous Audit Ref:	PQ-9A-2017
Support:	N/A						Previous Audit Date:	28/06/2017
							Previous Audit NC's Validated OK/NOK:	03/07/2017
Area Personnel Contacted:		Simon Wilson, Lewis Messam, John Humphreys						
Circulation For Information:		A. Pepper, C. Williams, S. Carter, S. Brown, M. Hackett, A. Kheradnejad						

NC Number	Major, Minor OFI, Good Practice	ISO 9001 / IATF 16949	Owner	Details of Issue Observed	Follow-Up Date	Auditor Sign-Off (Name)	OK Date
1	Minor	9.1	A. Pepper	Ineffective measurement of performance as is required by ISO/IATF16949 clause 9.1. Evidence: GL's have LAM but not being filled and updated for months.	04/10/2017	A. Kheradnejad	04/10/2017

Exhibit 2 - Sample of NC Response Document (Simplified 8D)

Audit Ref	PQ-9B-2017	Audit Title / Area	ISO/IATF16949 Internal Audit in SIPS Process / D & F Blocks		Date of Audit	20/09/2017
Auditor(s)	A. Kheradnejad	Completed by	S. Wilson		Report Issue Date	21/09/2017

NC No.	Major or Minor	Details of Issue				
1	Minor	Ineffective measurement of performance as is required by ISO/IATF16949 clause 9.1. Evidence: GL's have LAM but not being filled and updated for months.				

Interim Containment

	Who	Actions	Target Date	Completed Date
1	SW	Stand G/L down and advise of expectation of job role	21/09/2017	21/09/2017
2				
3				

Conduct Sweep (to ensure any potential repeat issues are captured)

Who by	Date	Conducted / Results	Completed Date
		N/A	

Full Root Cause Analysis & Documentation is mandated in JLR-Q-003. Therefore as a minimum, you must complete a 5-Why & Cause & Effect Analysis.

Cause & Effect Analysis

5-Why Analysis

Why?	GL's have LAM but not being filled and updated for months.
Why?	GL'S failed to update fill in LAM
Why?	GL's did not know importance of the LAM
Why?	GL's have not been auditted
Why?	

NOTE: If additional space is required for root cause analysis, please attach the relevant documentation.

Root Cause Statement

GL's did not know importance of the LAM

GL's have not been auditted

Please state who has verified the root cause, how they did so and when:

S Wilson 21/09/17

Permanent Corrective Actions

	Who	Actions	Target Date	Completed Date
1	SW / RS	All GL's to be briefed by supervision of expectations not just SIPS GLs	28/09/2017	28/09/2017
2				
3				
4				
5				

Prevent Recurrence Actions

	Who	Actions	Target Date	Date Completed
1	SW/RS	Weekly audit added to Senior Quality Leaders cadance	29/09/2017	29/09/2017
2				
3				
4				
5				

Cascade (to ensure issues raised are cascaded to all area's / models / blocks for awareness)

Who by	Date	How (evidence to be provided)	Completed Date
SW / RS	29/09/2017	It has been cascaded to all GL's in SIPS.	29/09/2017

Exhibit 3 - ISO/IATF16949 Non-conformance Tracker:

ISO/IATF 16949 Internal Audits - Closure Status - 17.11.17

Issues Raised	Report Reference	IATF Auditor	Description	Owner	Audit Report Issue Date	Days open	24 Hour Response required for Major Nc's ONLY	Auditor 5 Day Follow Up With Area	NC Response Document Received within 10 Days	Auditor 10 Day Follow Up With Area	NC Response Document Received within 15 Days	NC Response Document Accepted	NC Response Document Validated	Accepted / Rejected by Internal Auditor Y / N	Escalation Mtg with Plant Director (LL6 level) (7 Days) FOR RE-OPENED Nc's	Stage 1 Escalation Mtg with Plant Director (LL6 level) (15 Days)	Stage 2 Escalation Mtg with Plant Director (LL5 level) (20 Days)	Comments
Major 1	D Block T&F 1B 2017	M. Hackett	D Block T&F Lines 1-4	S.Gray / T.Ryan	08.11.17	9	Y	Y										Voicemail left with T Ryan & S.Gray to remind of aged status of NC's - 16.11.2017
Minors x 3	D Block T&F 1B 2017	M. Hackett	D Block T&F Lines 1-4	S.Gray / T.Ryan	08.11.17	9	NA	Y										Voicemail left with T Ryan & S.Gray to remind of aged status of NC's - 16.11.2017
Minor 1	A1/A2 DHL 3A-2017	M. Hackett	A1/A2 DHL	P. Quinton / S.Hudson	09.11.17	8	NA	Y										Phone conversation with W.Whitehouse to enquire as to status of NC & ownership - 17.11.2017
Minor 2	A1/A2 DHL 3A-2017	M. Hackett	A1/A2 DHL	P. Quinton / L.Wright	09.11.17	8	NA	Y	Y									Phone conversation with W.Whitehouse to convey requirements for closure - 17.11.2017
Minor 3	A1/A2 DHL 3A-2017	M. Hackett	A1/A2 DHL	P. Quinton / L.Wright	09.11.17	8	NA	Y	Y	NR	Y	Y	Y	Y	NA	NR	NR	Closed - 17.11.2017
Minors x 2	PQ1B-2017	M. Hackett	Hydropulse / S&R	A.Pepper	14.11.17	3	NA											