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IMPROVING LOST PRODUCTION TIME DUE TO POOR INVENTORY CONTROL AT BRIDGEND ENGINE PLANT

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Declaration

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

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Date: 27th April 2018

Signature: _____

Abstract

Bridgend Engine Plant produces engines for Ford and Jaguar Landrover. The poor inventory control at the plant was a major contributor to lost production time on AJ assembly. A project team was created to carry out root cause analysis and find solutions to the problem. Using a DMAIC approach and utilising a variety of Six Sigma methods, the team discovered there were a variety of inventory control issues contributing to the stock shortages. When the data was measured and analysed, the largest issue was the priority in which trailers of material were off-loaded. With further investigations, the reason for this unorganised situation was caused by the lack of a recognised and agreed shortage process across all shifts in the warehouse.

Using process improvement tools, the team developed and implemented an advanced process, and on the first month of full implementation there was a significant cost saving. Unfortunately, the assembly line performance did not improve due to an increase in unscheduled maintenance and supplier concerns.

With improvements in place, the team introduced a control plan utilising process confirmation as the main driver behind monitoring the process. Due to the continuous improvement mindset, the project has also revealed opportunities to further enhance productivity and potentially further reduce cost.

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List of Equations

$EOQ = \frac{2CoD}{Cc}$	Equation 1	26
$\frac{CcQ}{2} + \frac{CoD}{Q}$	Equation 2	26
$\frac{dTc}{dQ} = \frac{Cc}{2} - \frac{CoD}{Q^2}$	Equation 3	26
$\frac{DCo}{Q^2} = \frac{Cc}{2}$	Equation 4	26
$Q^2 = \frac{2DCo}{Cc}$	Equation 5	26

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Chapter 1: Project Introduction & Problem Definition

1.1 Ford Motor Company

Ford Motor Company is a global automotive and mobility company based in Dearborn, Michigan, USA and was founded by Henry Ford in 1903. Ford had spent nearly all of the \$28,000 cash invested by the original 12 investors before it sold the first Model A on July 23, 1903. But thankfully, by October that year the company turned a profit of \$37,000. In 1908 Ford introduced the model T seen in Figure 1.1 and sold over 15 million before production stopped in May 1927 (Ford Motor Company, 2017)

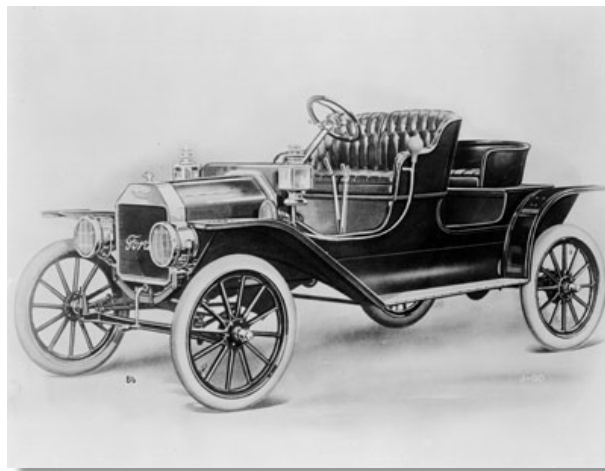


Figure 1.1 – 1908 Ford Model T (Ford Motor Company, 2017)

Figure 1.2 shows the integrated moving assembly line that was introduced in 1913, an innovation by Ford that reduced the Model T's chassis assembly from 12.5 to 1.5 hours (Ford Motor Company, 2017)



Figure 1.2 – 1913 Assembly Line of FMC (Ford Motor Company, 2017)

Ford continued to grow and branched out into boat and airplanes before focussing on automobiles and becoming a leading, global organisation, and a worldwide leader in automotive manufacturing (Ford Motor Company, 2017).

With about 166,000 employees and over 50 plants worldwide covering six continents, the company's core business includes designing, manufacturing, marketing, financing and servicing a full line of Ford cars, trucks, SUVs and electrified vehicles. At the same time, Ford is aggressively pursuing emerging opportunities through Ford Smart Mobility, the company's plan to be a leader in connectivity, mobility, autonomous vehicles, the customer experience and data and analytics. The company provides financial services through Ford Motor Credit Company (Ford Motor Company, 2017)

According to data collected by Jato Dynamics shown in Figure 1.3, Ford was the sixth largest global automaker in June 2017, by registration (Schmitt, 2017).

Top 10 Global Automakers				
	June 2017	YOY Jun	Jan-Jun	YOY YTD
 Volkswagen	907,553	5.9%	5,092,247	1.3%
 RENAULT NISSAN	855,043	5.0%	4,650,954	8.0%
 TOYOTA	811,850	5.2%	4,647,521	5.8%
 General Motors	644,499	-1.1%	3,878,426	0.2%
 Ford	547,601	-0.1%	3,092,299	-0.7%
 HYUNDAI KIA MOTORS	530,875	-18.1%	3,114,652	-11.5%
 HONDA	434,935	5.9%	2,509,365	7.6%
 FCA FIAT CHRYSLER AUTOMOBILES	431,666	3.2%	2,415,485	2.0%
 PSA PEUGEOT CITROËN	354,530	-4.8%	1,957,180	-5.7%
 DAIMLER	242,125	9.0%	1,340,537	13.7%

Data by JATO

Figure 1.3 - World's largest automakers June 2017, by registration (Schmitt, 2017)

Ford has a mission statement of "One Ford: One Team, One Plan, One Goal". Ford explain the meaning behind this statement as *"Accelerating the development of new products that customers want and value is a key component of the One Ford plan. From fun-to-drive, fuel-efficient cars to versatile, capable utility vehicles and tough, durable trucks that work harder and last longer, Ford offers a full line of high-quality products with global appeal"* (Ford Motor Company, 2017).

Ford also has a global brand promise "Go Further – we go further so you can" as seen in the logo in Figure 1.4. Ford believe this plays a main part in their business strategy and is about "people serving people" (Ford Motor Company, 2017).



Figure 1.4 - Ford Go Further Logo (Ford Motor Company, 2017)

Along with a vision statement of *"People working together as a lean, global enterprise to make people's lives better through automotive and mobility leadership"* (Ford Motor Company, 2017).

1.2 Ford of Britain

Ford of Britain was established in 1909. Ford Motor Company has four major manufacturing sites in the UK at Dagenham, Bridgend, Halewood, and a technical centre in Dunton.

Dagenham engine plant opened in 1959 and covers 44 acres. It currently employs 1,830 people and produces around 1.4 million diesel engines a year, ranging from four cylinder 1.4L TDCI to a 3.0L TDV6. The plant in Bridgend, Wales, opened in 1980 and is the centre of petrol engine production, ranging from four cylinder 1.25L to 1.6L Turbocharged Ford engines along with 3.0L S/C 5.0L N/A and S/C V8 engines for Jaguar Land Rover. The Plant at Halewood, Liverpool originally opened in 1959 and is run jointly with transmission specialists Getrag, on the same site where Jaguar Land Rover vehicles are assembled. This specialist gearbox plant supplies Ford cars and commercial vehicles. Dunton Technical Centre opened in October 1967 and is the research and development centre for the organisation (Ford Motor Company, 2017).

1.3 Bridgend Engine Plant

Bridgend Engine plant (BEP) is located on a 60-acre site in Mid Glamorgan, South Wales. See an aerial photograph in Figure 1.5. The plant was built in 1978 as part of the power train operations to manufacture the CVH engine which powered the Ford Fiesta, Escort and Orion vehicles. The first engine was bought-off the production line in 1979 and over a twenty year period, a total of six million CVH engines were produced at the plant.

BEP became a world class supplier of petrol engines due to its ability to adapt to changes and new working practices due to an experienced and flexible workforce, whilst improving quality and capacity to increase output. BEP's abilities were recognised in 1989 when the plant was awarded the contract to build the next generation of engine, the Zetec. This meant increased investment by the company and local government. The Zetec engines would power the Ford fiesta, Escort, Sierra, Mondeo and Focus models and were produced in 1.6L, 1.8L, and 2.0L variants (Ford Motor Company, 2017)

Ford took ownership of Jaguar cars in 1989, the continued success of Bridgend Engine Plant along with its close location to the Jaguar vehicle plants in the Midlands were the main

reasons for Bridgend being chosen to manufacture the new family of V8 engines to power Jaguar's XK, XJ, and S type luxury vehicles (Ford Motor Company, 2017).



Figure 1.5 - Bridgend Engine Plant (Ford Motor Company, 2017)

In 1997 BEP was awarded an investment to produce the next generation of small engines called Zetec SE. The engine family was more commonly known as Sigma and came in a variety of models, 1.25L, 1.4L and 1.6L. These engines would power the Fiesta, and the Focus. The first engine was produced in 1999 and there are currently between 500,000-600,000 engines produced each year on the Sigma line (Ford Motor Company, 2017). Ford purchased Volvo in 1999 and Land Rover in 2000, creating the Premier Automotive Group (PAG), which consisted of Jaguar, Land Rover, Volvo, and Aston Martin. This led to further investment at BEP totalling \$457m with the installation of state of the art, flexible machining and assembly lines to produce new model V8 and Short-Inline six-cylinder (SI6) engines. This installation allowed BEP to become more flexible and enable the plant to accurately deliver changing customer demands, enhancing its ability to succeed as a lean manufacturing facility (Ford Motor Company, 2017).

At that time BEP was capable of producing more than 1 million engines per year. This was achieved by a workforce of over 2,000 people covering 24hrs a day and five days a week, over two flexible machining lines and three separate assembly lines (Ford Motor Company, 2017).

This production line stopped in 2015, due to the sale of Volvo, Jaguar and Land Rover. However, Bridgend began producing V8 engines in 2009 on a dedicated assembly line for Jaguar Landrover. The AJ133 engine is a 5.0L V8 engine with direct fuel injection. This was followed by a 3.0L V6 engine which now has the majority of the customer volume (Ford Motor Company, 2017).

In 2010, Ford announced that BEP would be producing the new ultra-efficient 1.6L EcoBoost engine. The engine had the latest technology with turbocharging and direct injection, producing greater performance whilst saving fuel and produced lower CO2 emissions. This was followed up with a £24m investment for the 1.5L EcoBoost engine in 2013 (Ford Motor Company, 2017).

The latest investment at BEP was in 2017 for £100m, for the installation of a brand new, state of the art manufacturing and assembly facility that will produce a three cylinder 1.5L Dragon Engine with a volume of around 125 thousand engines a year beginning in late 2018 (Ford Motor Company, 2017).

BEP currently employs over 1500 people working 24 hours a day, 7 days a week on a variety of different shift patterns. The plant can produce over 800,000 engines per year in total and is the largest single employer in its locality (Ford Motor Company, 2017).

BEP's ability to manage changes and adopt new working practices along with a skilled and flexible workforce helped the facility to produce a record 20,000,000 engines in October 2016 (Ford Motor Company, 2017).

1.4 Overview of AJ Assembly

In 2008 Ford sold off Jaguar Land Rover (JLR) to TATA Motors to concentrate on the Ford brand. Nevertheless, Ford continued to produce AJ engines for TATA, but the sale meant Ford became a supplier to an external customer and was no longer part of the consortium. Ford have been producing Jaguar Land Rover engines since the 1990's with the latest V8 being the third generation which has seen the introduction of variable cam timing and high pressure direct injection with specifically positioned spark plug electrodes creating a more environmentally friendly engine, reducing emissions but also creating a higher performing engine (Ford Motor Company, 2017).

BEP received additional investment to enable a V6 (AJ126) to be built along the AJ line. The 3.0L Supercharged engine proved very popular and volumes increased to 240,000 annual units. This increased the derivatives on the AJ line to fifteen and demonstrated the capability of BEP and the flexibility to build a mixed line of engines to match the customer demands.

To enable the mix of engines to be built, there are four hundred and forty different components delivered to twenty-two locations around the AJ line, as shown in Figure 1.6. These are delivered at different volumes and frequencies to ensure continuous production of the changing build plans (Ford Motor Company, 2017).

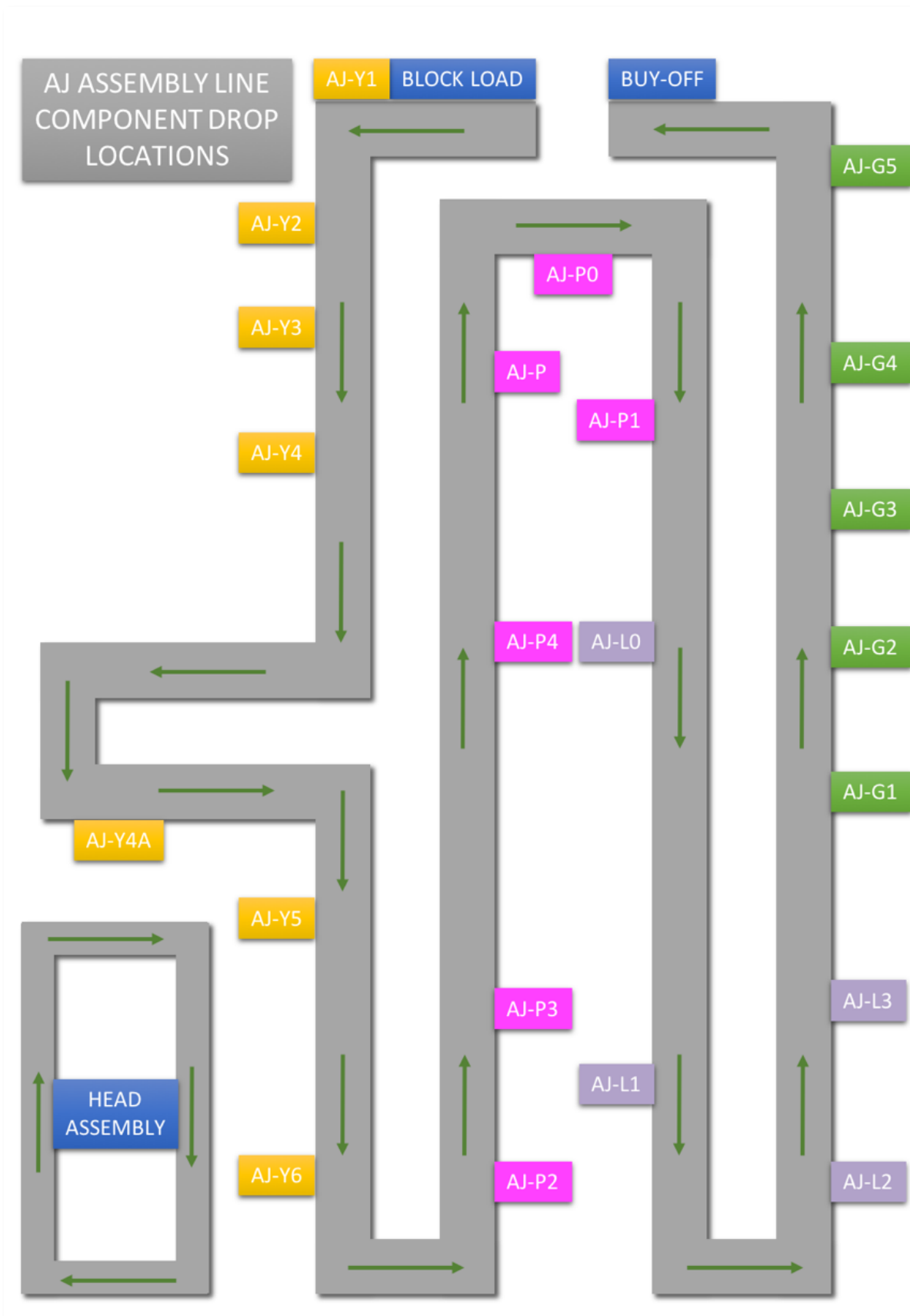


Figure 1.6 - AJ Assembly Line Drop Locations (Ford Motor Company, 2017)

1.5 Overview of Material, Planning and Logistics (MP&L)

1.5.1 Supply Chain Management

The supply chain management team (SCM) have to work with suppliers to ensure timely delivery of material into plant. This is achieved by the SCM team monitoring supplier demands, shipping dates and transit times. Working with the suppliers to safeguard BEP's production means that the plant can meet the demands of its customers, the Ford vehicle operations (VO) plants and Jaguar Land Rover.

Cooper, et al., 1997 disagree with many writers who are using the words supply chain management as a synonym for logistics and they argue that business operations that go beyond logistics need to be included and mixed into supply chain management. The overall planning and regulation of business operations are essential for BEP to maintain efficiency and continue to deliver quality products on time.

1.5.2 Material Movements in BEP

Material movements are critical to an assembly process and BEP's can be seen in Figure 1.7. BEP controls the ordering, receiving, storage and delivery of material to the relevant locations. Other factors to be considered are the return of suppliers empty packaging and the control and management of stock levels once material is inside the plant.

To assist with terminology and local jargon, see below a short summary of the locations used in Figure 1.7 during material movements.

Red Symbols:

- These are self-explanatory modes of transport used to import material

Grey Symbols:

- Bullpen – Area for loaded and empty lorry trailers
- Receiving Bay – Area where lorry trailers are off loaded (tipped)
- Low-Bay – Where train wagons and lorry trailers are tipped
- Sigma Buy-Off – Where empty engine racks are tipped

Blue Symbols:

- Review Area / New Parts Crib – Areas for prototype (non-production) parts
- Blue-Square – Area for fast moving parts
- High-Bay – Area for slower moving or high quantity parts
- Market Place – Area where parts are stored and picked from for assembly
- Machining Locations – Area used for rough stock to feed machining
- Engine Rack Storage – Area used to feed buy-off with empty engine racks
- Non Production Stores – Area for hardware, consumables, stationery etc.
- Tank Farm – Storage area for plant fuel and oils

Purple Symbols:

- Assembly & Machining Drops – Used to feed production with necessary parts

Yellow Symbols:

- Assembly lines – Area where engines are assembled

Green Symbols:

- Returned Packaging – Area where supplier packaging is sorted and returned
- Shipping Bank – Area where customer engines are stored before shipping

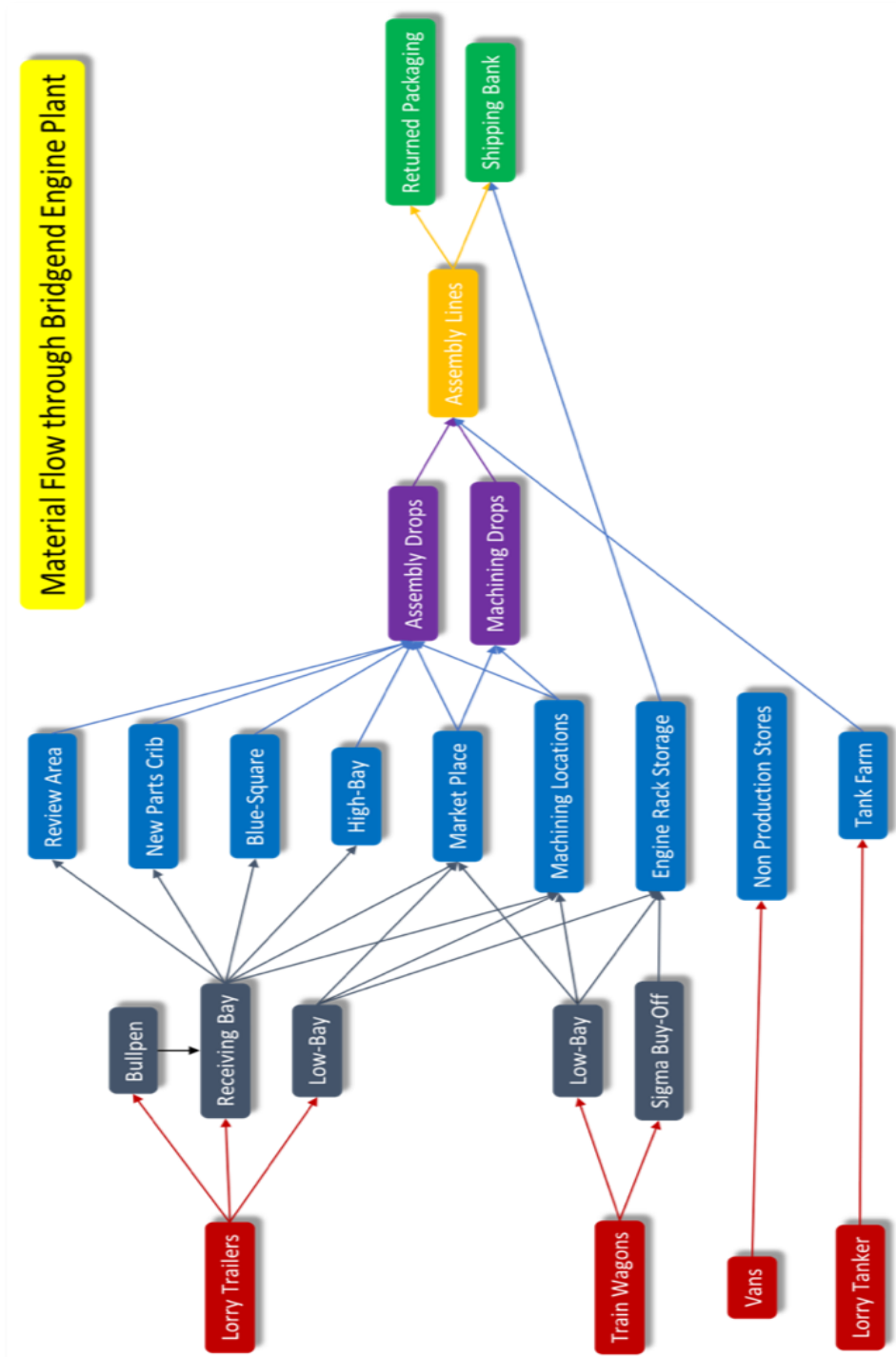


Figure 1.7 Material flow through Bridgend Engine Plant

1.5.3 Receiving

Table 1 shows the types of transport used to deliver material into BEP, including large cargo lorries with curtain sided trailers, train wagons and various types of vans. BEP can receive material 24hrs a day, seven days a week at numerous locations around the plant.

Table 1 - Receiving locations, types of material and transport used at BEP

Receiving Location	Type of Transport	Type of material
Bullpen	Cargo lorries	Production components
Main Receiving Bay	Cargo lorries & vans	Production components
Low-Bay	Train wagons & cargo lorries	Production components
		Rough stock
Non Production Stores	Vans	Miscellaneous
		Maintenance spares
		Tooling
		Special deliveries
Tank Farm	Tanker Lorries	Engine oils
		Assembly oil
		Petrol
		Diesel

Table 2 - Storage locations, types of and frequency usage of material in BEP

Storage Location	Type of material	Frequency Used
Review Area	Trial	As required
	Reject	As required
	Non or miss labelled	As required
New Parts Crib	Trial	As required
	Prototype	As required
Blue Square	Production components	High
High-Bay	Production components	Low, Medium & High that require large storage space
Market Place	Production components	High
Machining Locations	Rough Stock	High
Engine Rack Storage	Empty Engine Racks	High
Non-Production Stores	Miscellaneous	As required
	Maintenance spares	As required
	Tooling	As required
	Special deliveries	As required
Tank Farm	Engine oil	High
	Assembly oil	High
	Petrol	High
	Diesel	High

1.5.4 Storage

Material is stored at locations in BEP that ensure the frequency and time taken to move material is kept to a minimum. However, there are components that have a high usage rate, yet are bulky and require large storage areas which require an increase in the use of time. The main locations types of material and frequency usage stored at these locations can be seen in Table 2.

1.6 ONE Ford

Henry Ford introduced the moving production line in 1903 and with it came the benefits of mass production, allowing a famous Model T motor car to roll off the production line every 93 minutes. This was achieved by Ford implementing Frederick Winslow Taylor's scientific management theory and allowed Ford to successfully bring motorised personal vehicles to the masses (Leong, 2018).

The evolution of mass production continued and in the 1960's, a lean production system was crafted in Toyota Motors to tackle its automotive market acknowledged as TPS (Toyota Production System). The basic approach of the Toyota Production System is built on "the lean philosophy that all forms of waste have to be eliminated, as waste is defined as any activity which does not add value in the eyes of the customer" (Thuna, et al., 2010)

The lean production approach allowed companies to manufacturer products using less human effort by increasing autonomous processes. This approach is described in the book 'The Machine that Changed the World' by Womack, et al. (2007) which highlights less human intervention and a reduction in use of equipment, time and space can decrease errors and improve quality.

Alan Mullaly became CEO of Ford Motor Company in 2007. He revamped Ford's business strategy and introduced a four-point business plan called the One Ford plan. This re-energised Ford Motor Company and its focus on lean manufacturing. The acronym FORD seen in Figure 1.8 is used to illustrate the four-point business plan.



Figure 1.8 Four Point Business Plan & One Ford Logo (Ford Motor Company, 2017)

The one ford values are built on the foundation of the Ford Production System (FPS). The company uses this system to continually improve and align itself to the global business model. These values are summarised in the One Ford production mission statement,

“A Manufacturing strategic approach that includes the right Leadership Behaviours, Operating Systems and Processes supported by an aligned and capable organization to deliver ‘Best in World’ Results” (Ford Motor Company, 2017).

Throughout the spine of FPS is the constant recognition of how people, process and systems are working together, delivering the results demanded by the global business model. Figure 1.9 illustrates how FPS is the umbrella that covers the whole organisation and the metrics required to be the ‘Best in the World’.

The vision of FPS is a “lean, flexible and disciplined common production system, defined by a set of principles and processes, that employs groups of capable and empowered people, learning and working safely together, in the production and delivery of products that consistently exceed customers' expectations in quality, cost and time” (Ford Motor Company, 2017).

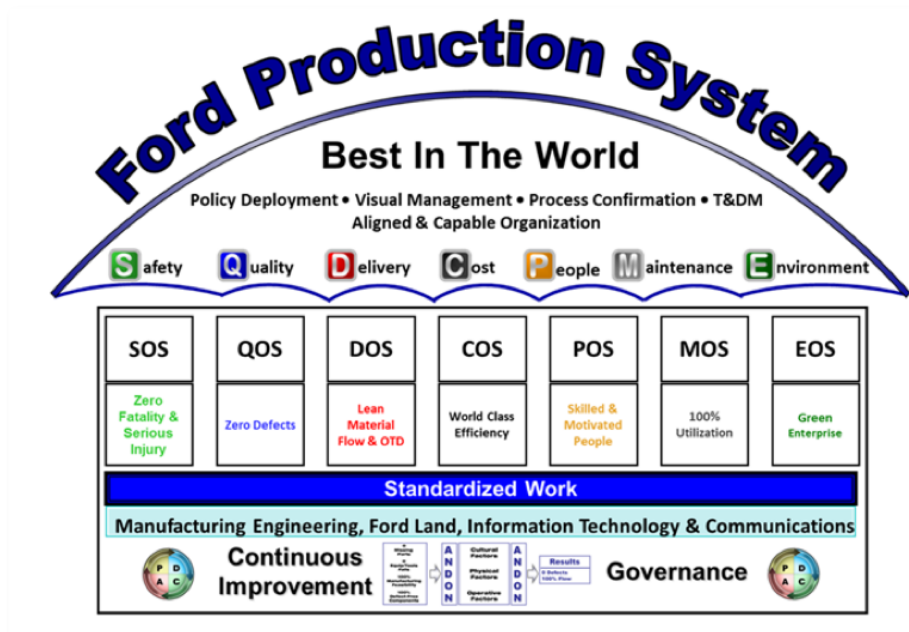


Figure 1.9 - The Ford Production System (Ford Motor Company, 2017)

The FPS covers several operating systems and utilises standard procedures to cover the global metrics. The operating systems shown in Figure 1.10 have specific and clear objectives which are measured to ensure the global business plan is on target.

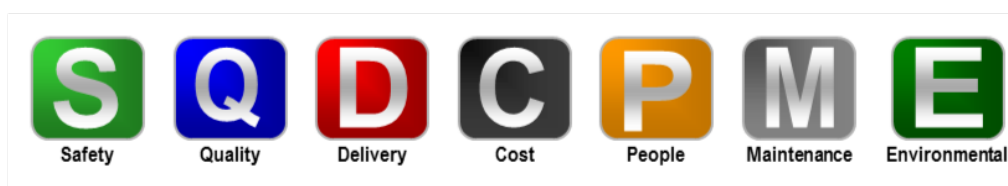


Figure 1.10 – The seven operating systems of FPS (Ford Motor Company, 2017)

1.6.1 One Ford – Delivery Operating System

The Delivery Operating System (DOS) is a disciplined and structured way to operate material logistics while focusing on the critical inputs, reacting to abnormalities and eliminating risk to the operation. It defines clear and simple interaction with the other operating systems while continuously improving the elimination of waste and minimising redundancy of work. DOS generates process stability which allows the operation to focus on value-add work and generates the integration with other operating systems but is also the tool needed to maintain the connection between internal and external logistics.



Figure 1.11 One Ford - Delivery Operating System Logo (Ford Motor Company, 2017)

The Delivery Operating System Vision

A standardised, proactive and disciplined operating system that delivers the right product, to the right place, at the right time in the right quantity while supporting the One Ford plan for manufacturing.

The Delivery Operating System Goal

Optimise material and information flow to achieve the lowest total cost that delivers zero misses to build schedule due to material or product shortage at the point of need.

Deliver Operating System Principles

- Use data to make decisions
- Utilise manufacturing support systems to prevent manual errors and ensure data integrity
- Safety and quality are never compromised
- Drive root cause and prevention through a continuous improvement process and innovation
- Total cost decision making - One Ford plan
- Communicate lessons learned and process improvements
- Use standardised tools, practices and procedures
- Maintain core competencies in the workforce

The Delivery operating System flow can be seen in Figure 1.12

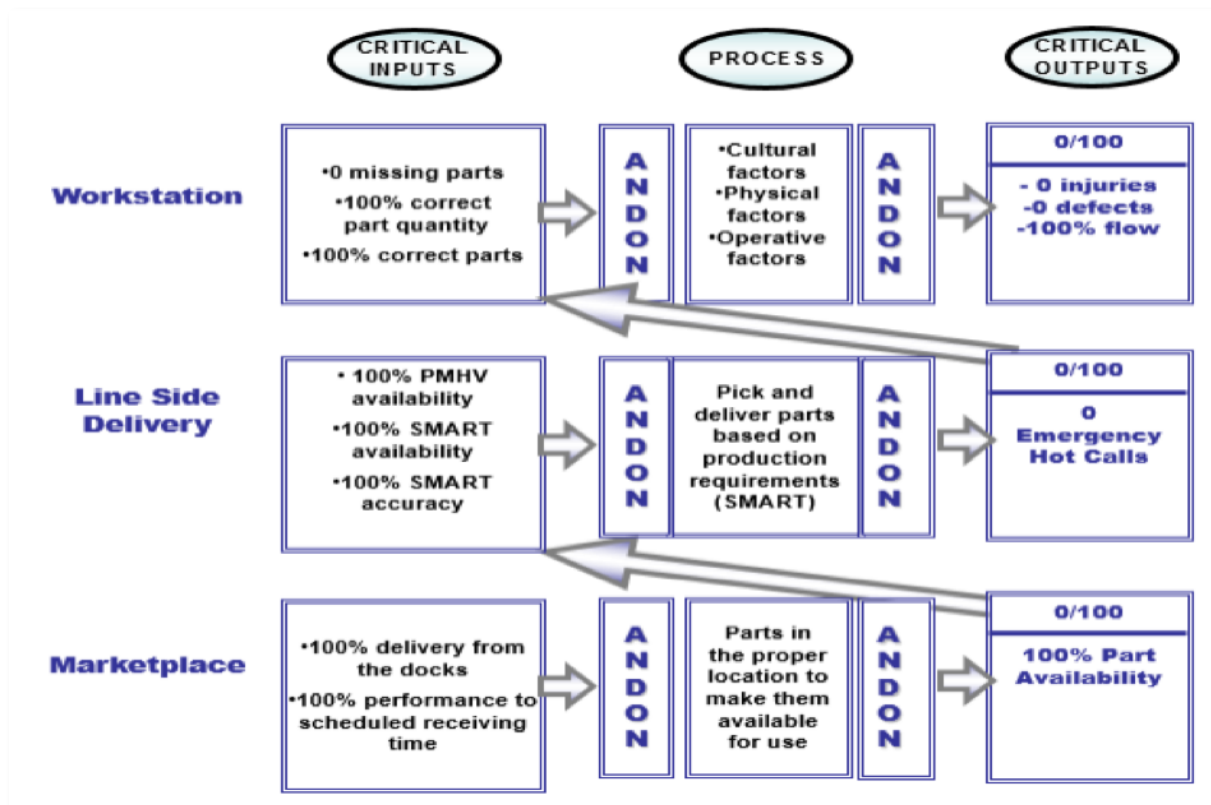


Figure 1.12 - Delivery Operating System Flow

1.7 Project Team Roles and Responsibilities

The main department affected by this project is Material, Planning and Logistics (MP&L). The author of this report is the champion of the project and will provide all aspects of research and investigation results. The project champion will also design and produce the proposed improvements to the delivery operating system whilst liaising with the relevant team members throughout. A hierarchical layout of the team can be seen in Figure 1.13. Process changes require manager approval therefore Huw Davies, Internal Logistics and Steve Murphy, Material Planning will cover this and ensure deadlines are met with minimal disruption to daily business. Additionally, the AJ assembly Production Team Manager, Leigh Morgan will also be included to ensure agreement by all stakeholders is granted before changes take place.

The internal logistics side of MP&L will use supervision, spread across four shifts to co-ordinate any process changes and help implementation along with Chris Goodier, material handling engineer, along with Data Capture and the Material Replenishment Co-ordinators (MRC). On the material planning side, Andrew Williams will provide data on the suppliers and make sure no gaps are created in the supply chain with any changes. The project champion will ensure all records are kept and will carry out process confirmation, whilst liaising Leigh Morgan to measure the results.

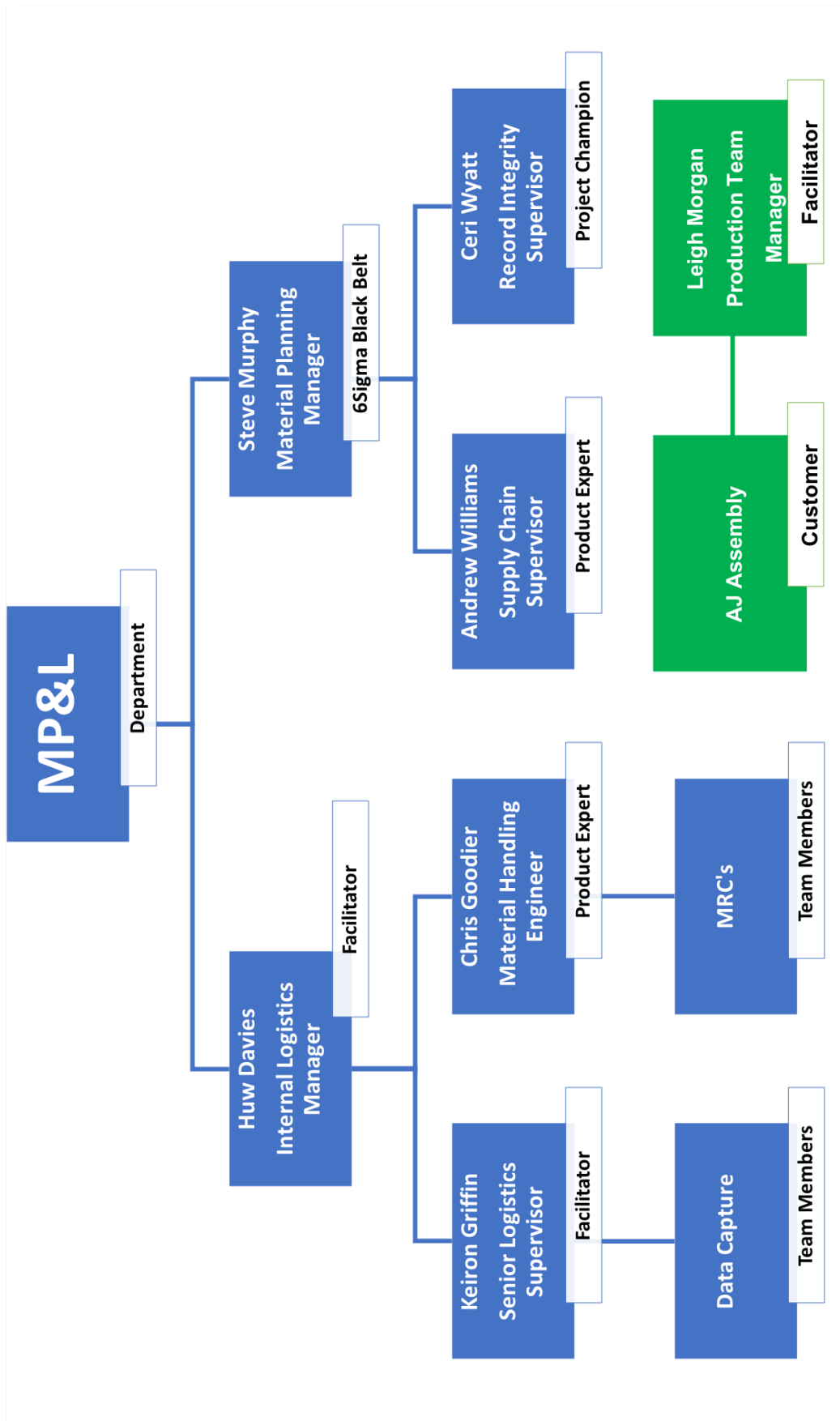


Figure 1.13 Hierarchical layout of the project team (Ford Motor Company, 2017)

1.8 Project Charter

A project charter is best achieved in the early stages of a project. The project charter is required to effectively complete a project, it transfers departmental agreements and facts into a documented project management approach. In addition, a project charter can be used as an information system to develop the project (Hayes, 2000).

1.8.1 Problem Statement

Current poor inventory management practices are resulting in production downtime on the AJ Assembly Line and from January to October in 2017 there were on average 32 hours lost production time per month. Taking all overheads into account this equates to a cost of approximately £330,000 to the company.

1.8.2 Business Case

There are approximately 150 line operators on AJ assembly whom are divided up into grades two, three and four depending on their responsibilities. A grade three line operator working a three shift pattern has an hourly labour cost of £75.10 (Ford Motor Company, 2017). Note: The labour cost takes into account wages and all associated overheads.

The estimated downtime due to stock shortages on AJ Assembly is on average 32hrs per month. If there is a full line stoppage this can equate to:

$75 \times 32 \times 150 = £360,480$ per month on idle assembly manning alone. Any improvement on the reduction of downtime will have a positive impact for the business.

Poor Inventory Control:

- Is constantly affecting performance across the whole business
- Is having a negative effect on AJ Assembly JPH
- Is potentially costing over £360,000 a month on idle labour alone

Improved Inventory Control:

- Will reduce unnecessary overspending
- Will maintain “The Delivery Operating System Vision” in ONE Ford
- Will improve measurables on multiple department scorecards in BEP

Will keep BEP competitive when looking for future business

1.8.3 Voice of the Customer

When customers purchase an item they expect it to satisfy their wants and needs.

Therefore, manufacturers need to include customer feedback throughout their development process. Product or process development needs to capture the voice of the customer (VOC) and translate it into the product or process's critical to quality characteristics (CTQC). The cost of product or process performance has a direct impact on customer satisfaction therefore, throughout the products life cycle their needs must be satisfied. (Ferryanto, 2015)

The immediate voice of the customer for this project is an internal one, The AJ assembly line. Production Team Manager for the AJ Assembly line, Mr. Leigh Morgan was interviewed about the VOC and he stated *“The AJ Assembly Line requires the MP&L Department to deliver qualified engine components for the required build schedule, to the correct point of fit (POF), in the correct quantity, and at the correct time. Failure to satisfy the demand of the line has a direct influence on our external customers at the Vehicle Operations (VO) plants. This can lead to a knock-on effect whereby late delivery of engines out of BEP results in the late delivery of vehicles out of our VO plants. This could ultimately result in a customer at a dealership having to wait for their vehicle! This outcome is not acceptable to our business customer, Jaguar Land Rover.”* (Morgan, 2017)

1.8.4 Critical to Quality Characteristics

Critical to quality characteristics (CTQC) are the functional requirements of a product or process. They identify the attributes and associated components and processes that affect the efficiency, safety and final cost of a product. Being able to identify CTQCs will help the team understand what the customer’s expectations are and will enable robust designs and improvements (Ferryanto, 2015).

Table 3 shows the VOC being used to identify the CTQCs.

Table 3 - VOC to CTQC

VOC	CTQ Measurable	Cost of Bad CTQ	Benefits of Good CTQ
<i>“deliver qualified engine components for the required build schedule”</i>	Frequency of incorrect parts delivered Target = zero	Downtime of production due to incorrect parts delivered	No downtime and production receiving correct mix of parts.
<i>“deliver engine components to the correct point of fit”</i>	Frequency of parts delivered to wrong point of fit Target = zero	Downtime of production due to re-delivery of correct parts	No downtime and parts received at correct location
<i>“deliver engine components at the correct quantity”</i>	Frequency of part shortages or over deliveries Target = zero	Downtime due to part shortages. Excess material at assembly line, leading to increased costs and safety concerns	No downtime and production receive required components at required quantities to fulfil the build schedule
<i>“deliver engine components at the correct time”</i>	Frequency of part shortages or over deliveries Target = zero	Downtime due to part shortages. Excess material at assembly line, leading to increased costs and safety concerns	No downtime and production receive required components at required intervals to fulfil the build schedule

1.9 Aims and Objectives

The aim of this project is to analyse and provide solutions to the current issues that negatively affect the delivery time of engine components to the AJ Assembly Line.

Implement new or improve current procedures to reduce production downtime and thus reduce the costs associated with delayed deliveries to BEP's customer.

The objectives are:

1. Improve Inventory Control
2. Improve Internal Logistics
3. Reduce Assembly Downtime
4. Reduce Cost and Waste

1.10 Process Improvement Tools

Six Sigma is a concept of managing the quality of a company as well as the individual departments within it. Six Sigma was generated by General Electric to improve the goal of customer satisfaction. Companies that implement Six Sigma benefit by reducing cycle time and improving the service provided by aiming to satisfy the needs of its customers. The successful application of Six Sigma is dependent on the people within the organisation.

If Six Sigma is implemented positively, the company will achieve long-lasting, positive results in business needs, improvements in costs and improved productivity. The success of Six Sigma provides a wholistic, value added solution for all stakeholders involved (Barjaktarovic & Jecmenica, 2011)

1.10.1 DMAIC

There are many improvement tools that could be utilised to increase inventory efficiency around the AJ line. Ford uses the Lean Six Sigma approach to situations like this and one of the tools that form part of this approach is the DMAIC strategy.

DMAIC is well aligned to the project needs as it a quality strategy used to improve systems and processes. The DMAIC tool is made up of five interlocked phases as shown in Figure 1.14, namely Define, Measure, Analyse, Improve and Control, these phases will be the foundation that the project is built on (Mast & Lokkerbol, 2012).



Figure 1.14 - Six Sigma - DMAIC Process Stages (Manning, 2014)

1.10.2 Process Maps

Process mapping allows the team to visualise the overall process. Figure 1.15 illustrates the AJ assembly line and Figure 1.16 shows the internal material flow for AJ components. These maps increase opportunities to discover bottle necks and pinch points.

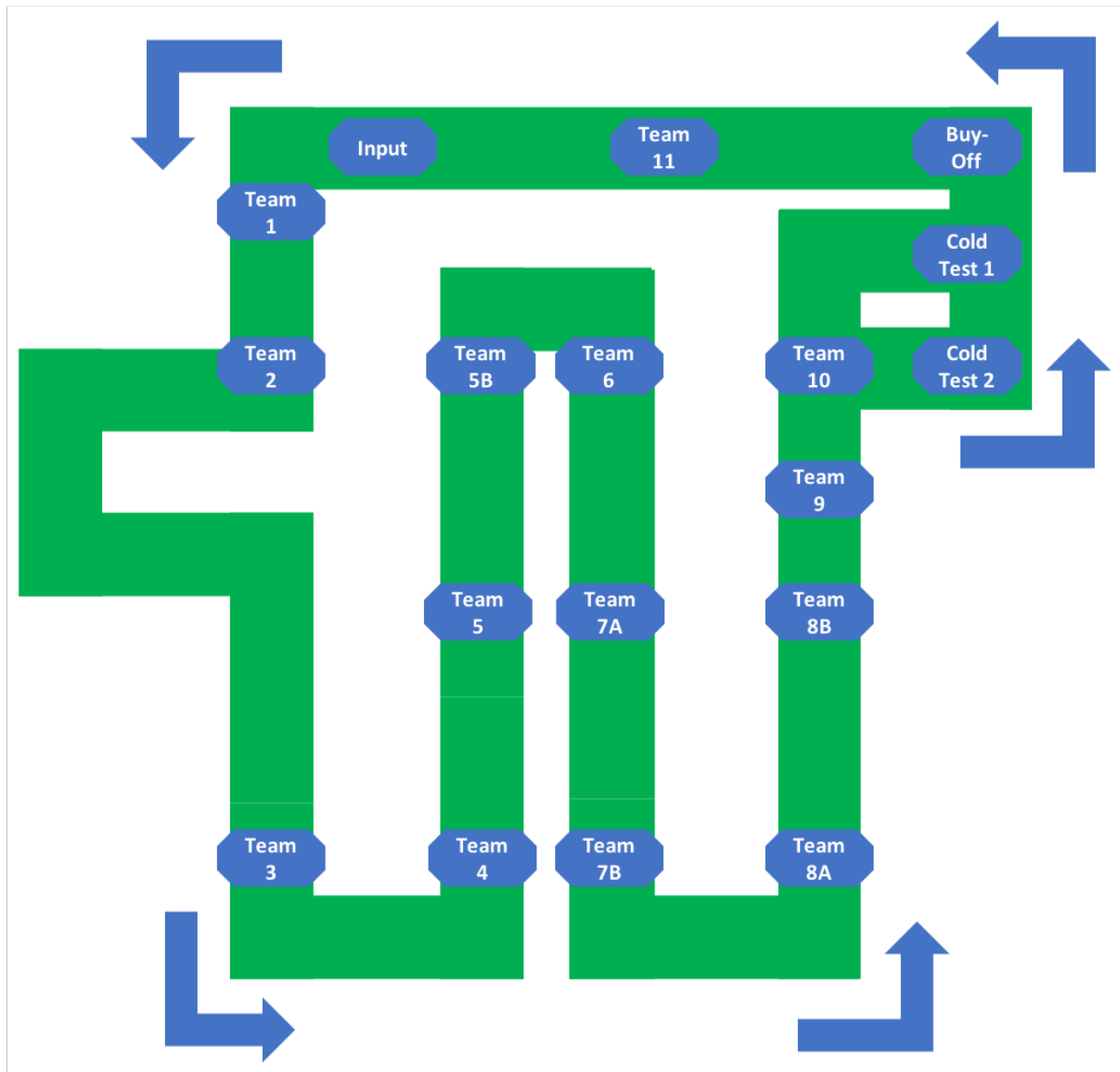
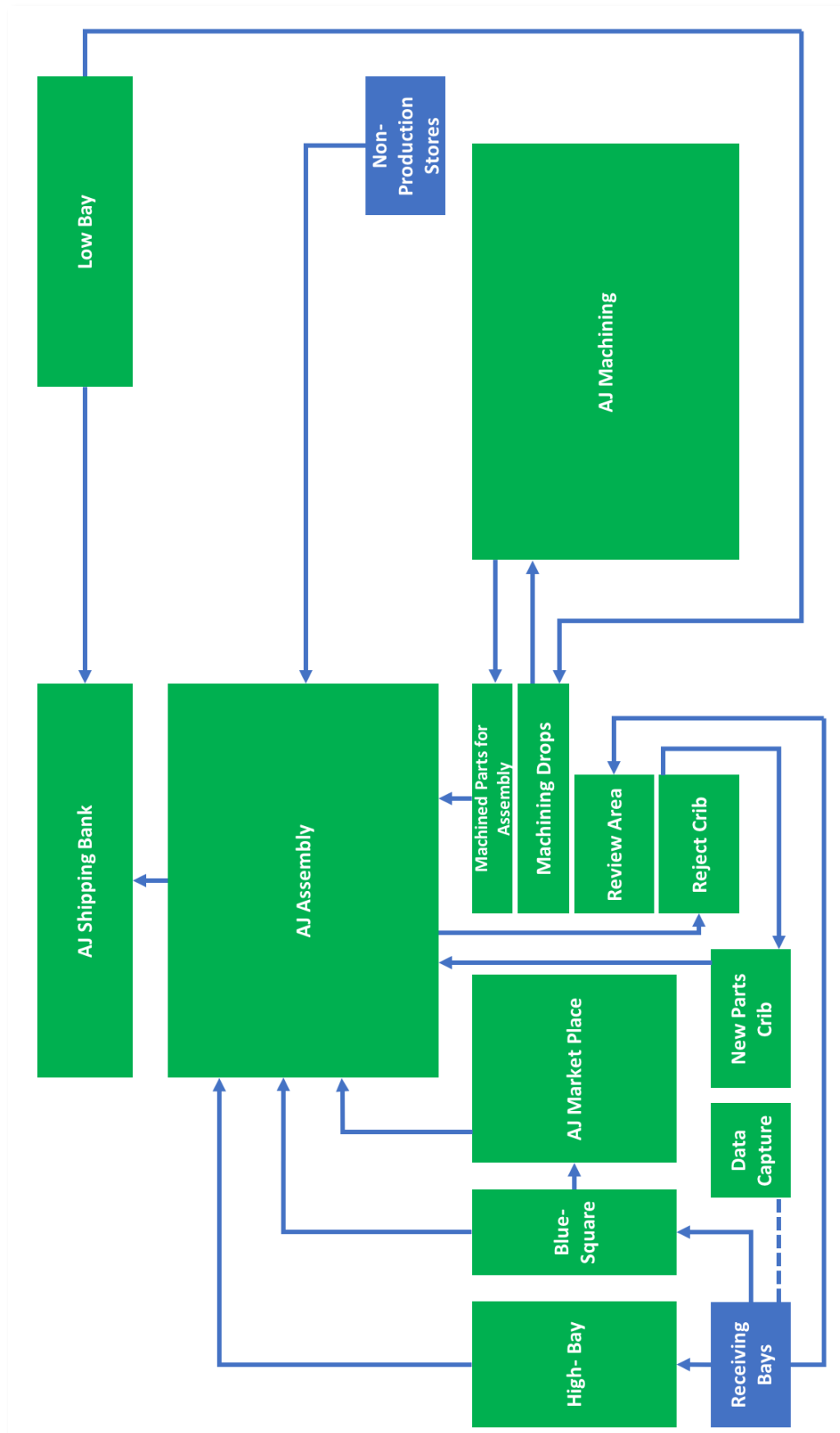


Figure 1.15 - AJ Assembly Line Process Map (Ford Motor Company, 2017)



1.10.3 SIPOC

Another useful six sigma tool is the supplier-input-process-output-customer (SIPOC) model. SIPOC is a tool to create a high level process map and is useful during the define stage of a project. It recognises all stakeholders and their roles in completing the process (Furterer , 2014). The SIPOC diagram is a useful tool for a manufacturing process. The acronym SIPOC derives from the five elements shown in Figure 1.17 (Yang, 2003).

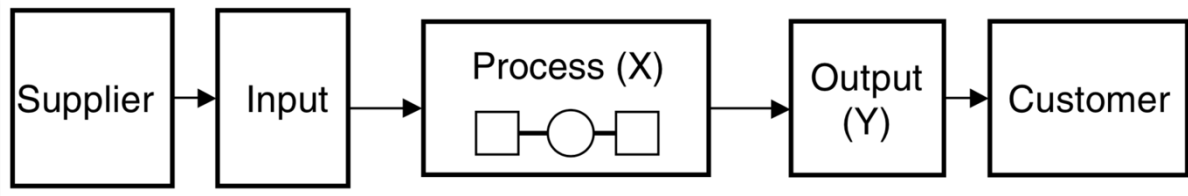


Figure 1.17 SIPOC diagram (Yang, 2003)

To further explain the SIPOC map an explanation of each element can be seen in Table 4.

Table 4 - SIPOC explanation (Yang, 2003)

Supplier	The person or group that provides key information, materials, and/or other resources to the process
Input	The “thing” provided
Process	The set of steps that transform and, ideally, add value to the input
Output	The final product of the process
Customer	The person, group, or process that received the output

The SIPOC diagram used for this project can be seen in Figure 1.18, depicting the material flow through BEP.

S	I	P	O	C
Suppliers	Inputs	Process	Outputs	Customers
Component Suppliers	High-Bay Tipping Performance	Start:	Late deliveries	AJ Assembly
Rough Stock Suppliers	Low-Bay Tipping Performance	Engine schedules	Part Shortages	VO Plants
	Warehouse Management	Parts received from suppliers	Linefeed issues	
	Line feeding performance	Engine racks received from customers	Wrong parts	
	CMMS		Quality issues	
		High-Level Description:	JPH	
		Parts tipped		
		Parts stored		
		Parts requested		
		Parts delivered		
		End:		
		Parts assembled into engines		
		Engines bought off		
		Engines shipped to customer		
		Return packaging to supplier		

Figure 1.18 - BEP Material Flow SIPOC (Ford Motor Company, 2017)

1.11 Constraints and Timing Plan

The project will be carried out with respect to business needs and restrictions on department budgets. The project will potentially require a change of workforce culture and attitudes, and to address this, support will be required from supervision and management. There will also have to be an acceptance across the required departments to allow access to data from within their teams, this may pose a problem initially as there may be concerns over efficiencies; however, this should be overcome through inclusion and clear explanations about the desired outcomes.

With regard to the project timing, Goldratt (1966 cited in Maylor, 2001, p. 95) argues that traditional methods of project scheduling should be rejected on the basis that there is too much uncertainty in longer term plans as there is more uncertainty and the timing has to be flexible as progression is made. Therefore, in order to ensure the project progresses efficiently, a Gantt chart was created, as shown in Figure 1.19, to monitor the target dates of the project.

“The Gantt Chart is a useful tool for the presentation of time information concerning plans. This can be a presentation of predictions of future timings or graphical representation of past achievements” (Maylor, 2001).

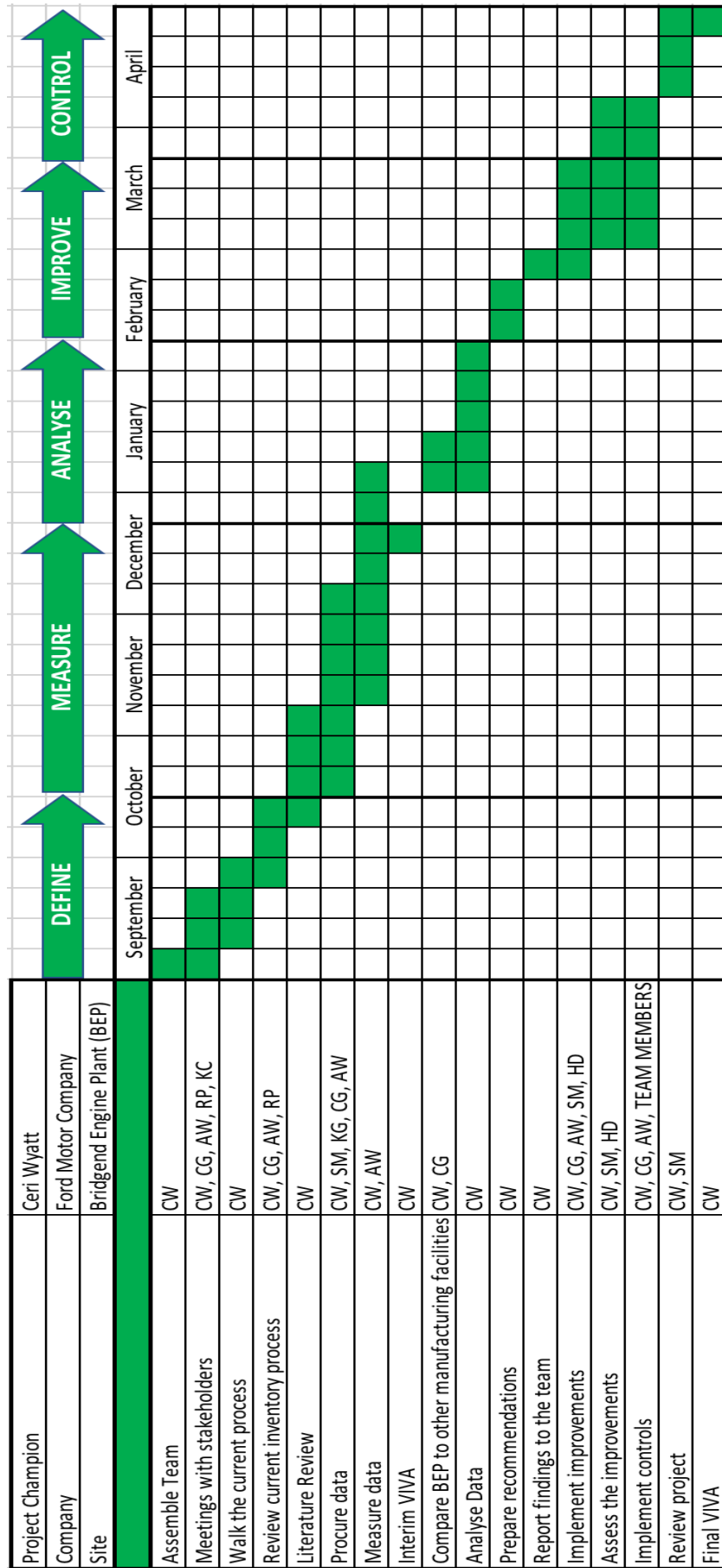


Figure 1.19 - Project Timeline (Ford Motor Company, 2017)

Chapter 2: Research Literature and Tools Used

2.1 The Purpose of Inventory

Inventory can be considered as a waste due to its overall cost. However, BEP has many factors to consider when controlling the flow of material; for example, electronic stock level alignment between departments and suppliers, lead times and quality of material on arrival. Therefore, inventory becomes very important and so holding enough inventory means BEP can plan for unpredicted production scheduling, fluctuation in demand, unreliable suppliers and the benefits of buying in bulk to gain discounts and lower ordering costs (Muller, 2003).

2.2 Inventory Control Overview

Businesses manage inventory to protect against the variations in supply and demand. Good inventory control will safeguard the customer even when shortfalls arise in the supply chain. However, good protection comes at a cost and businesses are constantly looking at ways of reducing inventory cost while maintaining customer service. Scientific inventory control remains the main management tool for inventory with the addition of requirements planning and just-in-time to produce a steady flow of material through the supply chain (Waters, 2003).

2.3 Continuous Improvement

The process of continuous improvement using a standard way of work originated from the word 'Kaizen', which is a Japanese word meaning: Kai (change) and Zen (for the better). It is built on making incremental changes to regularly reduce waste, continually improve productivity, safety and effectiveness, while reducing the cost of production (Singh & Singh, 2013).

2.4 Computerised Maintenance Management System (CMMS)

CMMS is a computerised system that manages BEP's inventory from component supplier demands to inventory balance on hand, to the finished engine shipping releases. Its accuracy is monitored by comparing the level in CMMS to the physical parts that have been cycle counted in plant.

CMMS reduces excess inventory by ordering material on accurate figures and not estimations. It also detects obsolete and duplicate parts and controls the release of parts from the stores (Cato & Mobley, 2001).

2.5 Lean Manufacturing

The goal of lean manufacturing system is doing more with less of time, space and human effort while giving the customer what they want in a highly economical manner (Chen, et al., 2006). Lean manufacturing is in essence the reduction of waste and producing what the customer wants within the limitations of what the customer is prepared to pay.

Womack and Jones (2003, p. 20) categorise this into three types of waste:

1. Those that add value.
2. Those that do not add value but are necessary with current production methods.
3. Those that do not add value and are unnecessary.

2.6 Wastes associated with inefficient inventory control

Simplilearn (2009-2018) define inventory waste as: “Any supply in excess to process requirements necessary to produce goods or services just-in-time”. Surplus inventory can create waste and increase cost due to excessive, handling, counting, tracking, reporting and management. Additionally, with investment tied up there will be a reduction in storage space and the added risk of perishable goods and parts becoming obsolete (Simplilearn, 2009-2018).

2.7 Total Quality Management (TQM)

To provide the highest service or best product to a customer the whole organisation and all employees must focus on using recognised management and control processes. Through these processes the constant fulfilment of customer needs and satisfaction is recognised and supported by the organisations philosophies, goals and vision. With a continuous improvement of processes and a customer focussed mind-set by all employees, the results will produce high quality products and services (Talha, 2004).

2.8 Material Requirements Planning (MRP)

MRP is one of the most widely utilised systems for production planning and in particular assembly operations, using interconnected elements that achieve one goal. MRP improves the efficiency and control of production, thus improving customer service. Material requirements planning is used to schedule material which indicates units made every week and a timetable for supplier shipments, resulting in calendars that show necessary materials, order frequency and when internal material is required. MRP stocks are generally low and increase as material comes off the line, just before the next production run begins. Stock levels are used during production and consequently reduce until the amount returns to a normal level. MRP enables the correct ordering of the right part, the right quantity at the right time, which minimises inventory investment, maximises production efficiency and improves customer satisfaction (Rusanescu, 2014).

2.9 Vendor Managed Inventory (VMI)

VMI is an approach whereby the supplier manages the customers inventory levels. Many companies believe this improves their supply chain operations, and for it to work, companies share their inventory data and demand schedules with both their suppliers and customers (Disney & Towill, 2003).

2.10 5S

The 5S methodology emerged from the Toyota Production System (TPS). It helps to create a well-organised work place utilising visual aids. A working environment that has a place for everything and everything in its place. 5S is a tool that can improve key performance indicators (KPIs) such as lead times, productivity and output (Ortiz, 2015).

The concept and elements of the 5S system can be seen in Table 5 and Figure 2.1

Table 5 - Elements of 5S (Randhawa & Ahuja, 2017)

Japanese Words (5S)	English Meaning (5S)	English Meaning (5C)	Meaning	Features
Seiri	Structure (sort)	Clear	Organisation	Discarding unnecessary items from the workplace
Seiton	Systematise (set in order)	Configure	Neatness	Arrange necessary items in good order for quick retrieval and storage
Seiso	Sanitise (shine)	Clean and check	Cleaning	Clean the workplace so that there is no dust on floor and equipment
Seiketsu	Standardise	Conformity	Standardisation	Maintain high standard of housekeeping, cleanliness and workplace organisation
Shitsuke	Sustain	Custom and practice	Discipline	Routine practice of 5S initiatives by imbibing it in the standard operating procedures and making it customary for everybody in the organisation

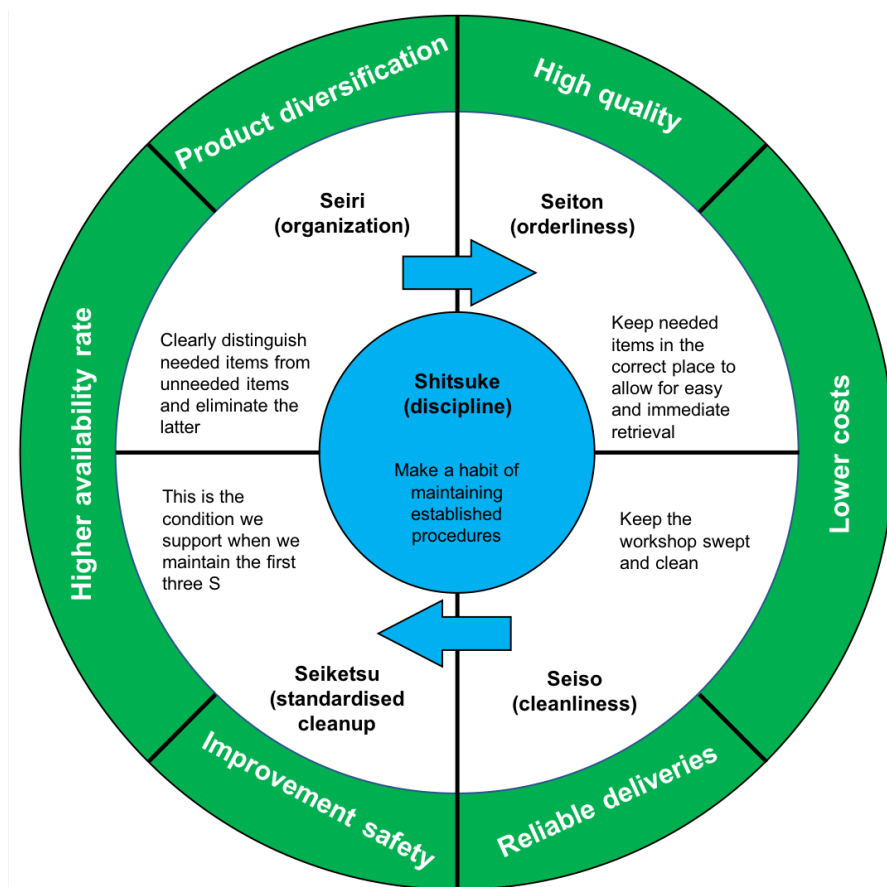


Figure 2.1 - 5S Concept (Randhawa & Ahuja, 2017)

2.11 Economic Order Quantity (EOQ)

EOQ balances the cost between storing inventory or re-ordering more. The required outcome of EOQ is ultimately avoid holding excess stock, as failures in the business needs may occur if the inventory levels get too high or too small.

To calculate a basic EOQ there are assumptions that need to be considered:

- Demand is uniform, constant and continuous over time
- The lead time is constant
- There is no limit on order size due either to stores capacity
- The cost of placing an order is independent of size of order
- The cost of holding a unit of stock does not depend on the quantity in stock;

(Agarwal, 2014)

The EOQ formula is derived below:

$$EOQ = \frac{2CoD}{Cc} \quad \text{Equation 1}$$

Where Co = ordering costs, Cc = carrying cost, D = annual demand

$$\begin{aligned} \text{Annual Stock} &= \frac{Q}{2} \\ \text{Total annual carrying cost} &= \frac{CcQ}{2} \\ \text{Number of orders per annum} &= \frac{D}{Q} \\ \text{Annual Ordering Cost} &= \frac{CoD}{Q} \end{aligned}$$

And

$$\text{Total Cost} = \frac{CcQ}{2} + \frac{CoD}{Q} \quad \text{Equation 2}$$

In the above formula, Q is defined as the result of the calculated EOQ. The order quantity, which makes the total cost (TC) at a minimum, is obtained by differentiating with respect to Q and equating the derivative to zero the above total cost equation 2.

Thus,

$$\frac{dTc}{dQ} = \frac{Cc}{2} - \frac{CoD}{Q^2} \quad \text{Equation 3}$$

and when

$$\frac{dTc}{dQ} = 0 \text{ cost is at minimum.}$$

$$\frac{DCo}{Q^2} = \frac{Cc}{2} \quad \text{Equation 4}$$

$$Q^2 = \frac{2DCo}{Cc} \quad \text{Equation 5}$$

and Q represents the EOQ formula (Agarwal, 2014).

A graphical presentation of the EOQ can be seen in Figure 2.2

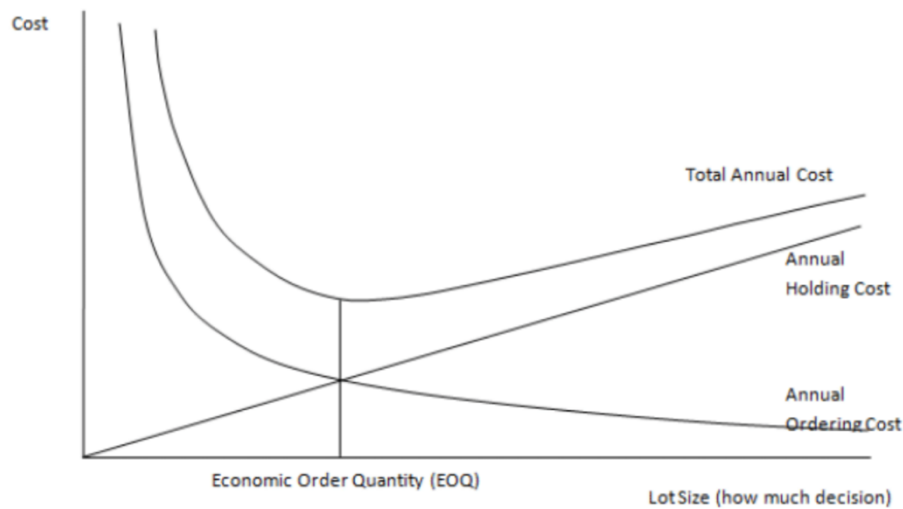


Figure 2.2 - Economic Order Quantity Graph (Agarwal, 2014)

2.12 ABC Analysis

Rusanescu (2014), describes ABC Analysis as a technique used by dividing inventory into groups based on cost and quantity which allows a variety of techniques to be used on a range of inventory to reduce cost and increase income by separating the important few from the majority.

- A. Category items generally represent approximately 15%-20% of an overall inventory by item, but represent 80% of value of an inventory. These are considered very Important.
- B. Category items represent 30%-35% of inventory items by item type, and about 15% of the value. These are considered important.
- C. Category items represent 50% of actual items but only 5% of the inventory value. These are considered marginally important.

ABC analysis allows inventory items to be controlled or measured in their own right.

(Rusanescu, 2014)

2.13 Just in Time (JIT)

The correct part of the correct quality and quantity at the correct location at the correct time. This Japanese management philosophy is what JIT is built on. With accurate deployment of JIT manufacturing improves productivity, efficiency and communication, along with quality and reduces cost and wastes. JIT is a consideration for many businesses due to the potential gains and benefits associated with the methods (Akbar, et al., 2013).

2.14 Kanban

Kanban is a method of controlling the flow of material which allows production to have the correct quantities of parts at the correct time. Kanban evolved from the Toyota Production System to improve the supply of components by the means of a card system which is used to trigger or signal a reaction to the current stock level (Muris & Moacir, 2010).

2.15 Safety Stocks

Modern organisations have discovered there are advantages to reducing production lot sizes such as material handling. However, this comes with the increased chance of stockouts.

Production uncertainties are the obvious reason for stockouts and even with a stable production plan there will always be a risk to exposing a weakness in the plan. Even with small lot sizes, a small unexpected occurrence can cause a stockout. Therefore, safety stocks will always be required to protect the customer against delays from delivery promises. Subsequently, business leaders must carefully consider safety stock levels whilst analysing opportunities and the cost of holding inventory (Luis & Raad, 1999).

2.16 Pareto Analysis

Italian economist Vilfredo Pareto realised the 80% of the effects are coming from 20% of the causes. From this the Pareto principle or the 80-20 rule was derived. The Pareto principle is used as a quality tool in Six Sigma and is used to identify the most common failures that impact a business the most. The principle uses current data and is not used to predict project movements, it can determine that 80% of the failures are produced by 20% of the potential causes. The Pareto chart below in Figure 2.3 graphically illustrates the vital few causes against the trivial many (What is Six Sigma, nd).

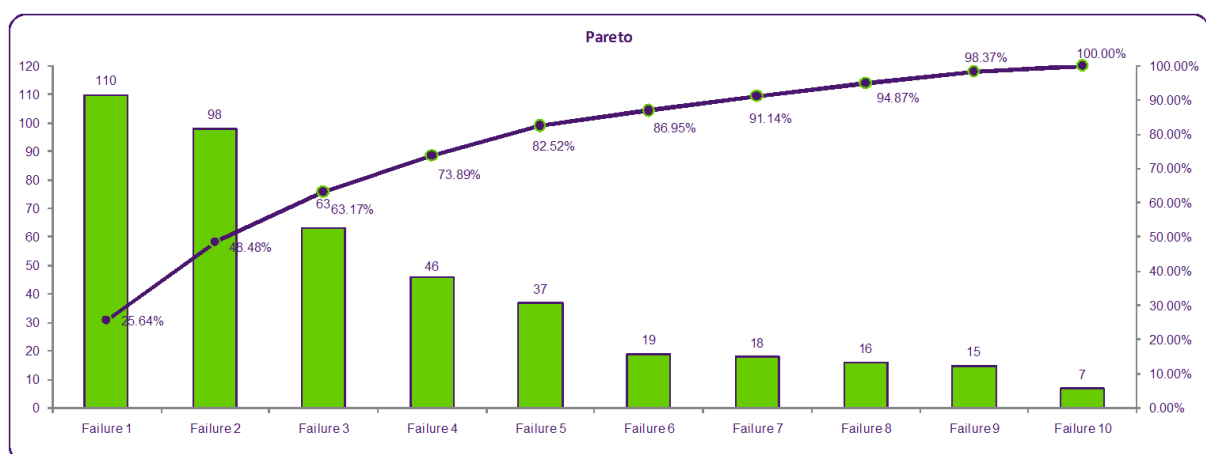


Figure 2.3 - Pareto Chart Example (What is Six Sigma, nd)

2.17 Process Failure Mode Effect Analysis

Process Failure Mode Effect Analysis (PMFEA) is a methodical approach used to analyse the risks on potential process changes and identifying the risks. PMFEA is used to identify the functions of a process, the potential failure modes and their effect on the process.

PMFEA is a tool used to analyse manufacturing or assembly processes with a focus on process inputs and subsequently addresses failure modes (Yang, 2003).

PMFEA is a living document as it is not necessarily for the end user, but for the next user in the process. The risk priority number (RPN) is calculated by multiplying the severity (S), Occurrence (O) and detection (D). RPN goes from 1-1000 and S, O and D goes from 1-10 with the higher values meaning the worst outcome (Banduka, et al., 2016).

2.18 Cause and Effect & Five Whys

The Five Whys approach is a way of continually asking why something happens until a root cause is identified. The question why does not have to be asked five times, the idea is to keep asking the question until a possible solution appears. A fishbone diagram or cause and effect diagram as shown in Figure 2.4, can also be used to analyse the five whys approach by graphically capturing the causes and effects, with the head of the fish being the effect, or the problem being analysed and the bones of the fish are the causes or the answers to the why questions that need further investigation. The five why and fishbone approaches both allow a problem to be split open allowing potential causes to be discussed further. However, it can become difficult to deep dive a problem which may have multiple effects (Hewitt-Taylor, 2012).

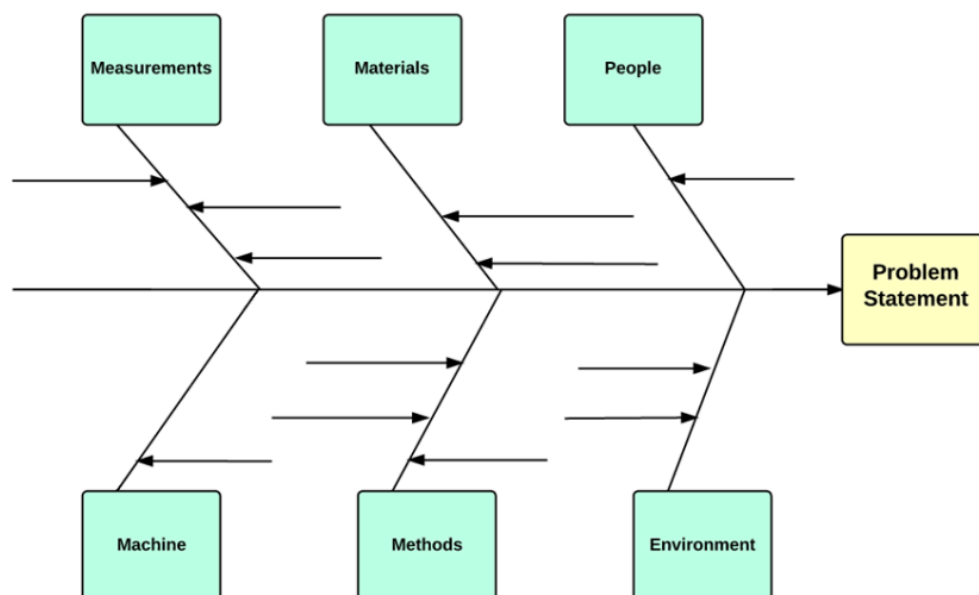


Figure 2.4 - Fishbone diagram example (Lucidchart, 2017)

2.19 Statistical process control (SPC)

A vital aspect to improving quality is by reducing variation and being able to control a process. This is achieved by using SPC to control and manage a process by using statistical data. The two main causes of variation, chance or special occurrences. Chance or common causes are intrinsic to a process and will affect it all. Examples of common causes the gradual reduction in equipment performance or fluctuations in the environment. Special causes are not intrinsic to the process and are usually easily identified. They are usually large and require intervention on the process to rectify the issue. Examples of special causes are operator errors and resetting of machinery due to incorrect measurements. Subsequently, the main reason to run control charts in SPC is to determine if the reason for the variation is down to a special or common cause (Mason & Jiju, 2001).

Chapter 3: Measure

Measurement is a critical part of any project. The baseline set by initial measurements creates reference points from which to determine if improvements have been made to the reduction of line stoppages. The measurement phase will derive a plan to understand what data to collect and the logical reasoning for doing so, along with what techniques to use when carrying out the measurements, and the extent of the data content (Pinjari, et al., 2017).

3.1 People

To be successful as a business and to continue to be a market leader, organisations have to keep evolving. For this to happen, the organisation has to introduce changes to working practices and procedures, along with operational changes to meet customer demands. The success of this requires the people within the organisation to adapt and accept the challenges (Burnes, 2004).

If necessary, the measurements needed to establish if the downtime could be attributed to the workforce would be to measure:

- Productivity across shift patterns
- Time of day stoppages occur
- Years' service across shifts (Experience v Green labour)

3.2 Machines/ Equipment

There are numerous pieces of equipment that could affect the efficiency of material flow in BEP.

- Performance and capability of the High-Bay cranes
- Age, reliability and suitability of material movement vehicles
- Reliability and suitability of lineside electronic call and Kanban card systems

3.3 Environment

The internal environment of the plant is good. It is well lit with sound surfaces in which vehicles and people can manoeuvre. Issues arise when external weather effects the site at BEP. In cold weather, all external doors are closed, which means additional time is necessary for a driver to manually operate electric doors. Winter weather affects ease of access for vehicles and employees which impedes on the ingress of material and the egress of engines and packaging.

3.4 Safety

Internal vehicles are limited to a company standard speed limit and are also prohibited to manoeuvre at certain times during the day to prevent accidents when there are mass

pedestrian movements at shift changeovers. There are also limits to the amount of material certain vehicles can carry with regard to height and weight of the loads.

There are also safety factors built into material stock floats. This is a measure to protect production by reducing the balance on hand quantity for parts by the average number of parts that maybe in the assembly process and cannot be verified when physically counted.

3.5 Method

There are predominantly two different methodologies for collecting data, qualitative and quantitative. Qualitative research involves analysis of data such as words collected from interviews or videos. Quantitative research involves analysis of quantities and numerical data. In Miles and Huberman's 1994 book *Qualitative Data Analysis*, quantitative analyst Fred Kerlinger is quoted as saying, "There's no such thing as qualitative data. Everything is either 1 or 0" (Miles & Huberman, 1994). An alternative approach by qualitative analyst, D. T. Campbell, stresses "all research ultimately has a qualitative grounding" (Miles & Huberman, 1994). The two different types are summarised by Neill (2007), in Table 6.

The majority of data collected for this project will be quantitative. This will allow statistical analysis and enable performance metrics to be delivered. Nevertheless, some qualitative data will be collected from assembly and MP&L personnel to enable opportunities to feedback opinions and suggestions.

Table 6 - Features of Qualitative & Quantitative Research (Neill, 2007)

Qualitative	Quantitative
The aim is a complete, detailed description.	The aim is to classify features, count them, and construct statistical models in an attempt to explain what is observed.
Researcher may only know roughly in advance what he/she is looking for.	Researcher knows clearly in advance what he/she is looking for.
Recommended during earlier phases of research projects.	Recommended during latter phases of research projects.
The design emerges as the study unfolds.	All aspects of the study are carefully designed before data is collected.
Researcher is the data gathering instrument.	Researcher uses tools, such as questionnaires or equipment to collect numerical data.
Data is in the form of words, pictures or objects.	Data is in the form of numbers and statistics.
Subjective - individuals interpretation of events is important ,e.g., uses participant observation, in-depth interviews etc.	Objective - seeks precise measurement & analysis of target concepts, e.g., uses surveys, questionnaires etc.
Qualitative data is more 'rich', time consuming, and less able to be generalized.	Quantitative data is more efficient, able to test hypotheses, but may miss contextual detail.
Researcher tends to become subjectively immersed in the subject matter.	Researcher tends to remain objectively separated from the subject matter.

2017		AJ ASSEMBLY																																
SELECT MONTH (ROLL)		October																																
DUPON'S CURR. →		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total Month	
		Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue		
SHIFT A																																		
Total Shift Hours		8.00	8.00	8.00	8.00	8.00				8.00	8.00	8.00	8.00	8.00			8.00	8.00	8.00	8.00	8.00			8.00	8.00	8.00	8.00	8.00		8.00	8.00	176.00		
Meatbreak		0.50	0.50	0.50	0.50	0.50				0.50	0.50	0.50	0.50	0.50			0.50	0.50	0.50	0.50	0.50			0.50	0.50	0.50	0.50	0.50		0.50	0.50	11.00		
Teabreak		0.63	0.63	0.63	0.63	0.63				0.63	0.63	0.63	0.63	0.63			0.63	0.63	0.63	0.63	0.63			0.63	0.63	0.63	0.63	0.63		0.63	0.63	13.75		
Net Working Time		6.88	6.88	6.88	6.88	6.88				6.88	6.88	6.88	6.88	6.88			6.88	6.88	6.88	6.88	6.88			6.88	6.88	6.88	6.88	6.88		6.88	6.88	151.25		
Down Day Allowances		Insert amount of operators effected (for HPU use only)																																
Restricted Workers																																	0	
Union Business																																	0	
Labour M/ment																																	0	
Downdays																																	0.00	
Unscheduled Maint		0.60		1.75						0.50		0.30													0.50		1.00				0.75	5.40		
Service																																0.00		
Cleaning																																0.00		
Plant Migs All Hands																																0.00		
Fire Drill																																0.00		
Stock Shortages				0.30	0.08	0.50	2.90				0.08		6.50			0.33	2.20	2.50		1.10							0.33			0.17		16.99		
Supp Qual Concerns			0.33													0.17	0.08							0.58	0.75							1.91		
Awaiting Tooling																																0.00		
Prog Work Work Order																																0.00		
FFS/DMS/TPM																																0.00		
Work For Other Plants																																0.00		
Launch Allowances																																		
Meetings																																0.00		
Line Trials																																0.00		
Capability Studies																																0.00		
SGA's																																0.00		
Stock Shortages																																0.00		
Total Allowances		0.00	0.93	0.30	1.83	0.50	2.90	0.00	0.00	0.50	0.08	0.00	0.30	6.50	0.00	0.00	0.50	2.28	2.50	0.00	1.10	0.00	0.00	0.00	0.00	0.75	1.00	0.33	0.00	0.00	0.92	24.30		
Operating Time (hrs)		0.00	5.95	6.58	5.05	6.38	3.98	0.00	0.00	6.38	6.80	6.88	6.58	0.38	0.00	0.00	6.38	4.60	4.38	6.88	5.78	0.00	0.00	6.88	6.88	6.13	5.88	6.55	0.00	0.00	6.88	5.96	126.95	
Buy-Off Score		196	209	162	210	134			211	207	207	215	12			212	146	138	213	180			210	213	193	201	210		216	200	4095			
JPH		#####	33	32	32	33	34	#####	#####	33	30	30	33	32	#####	#####	33	32	32	31	31	#####	#####	31	31	32	34	32	#####	#####	31	34	32.26	

Figure 3.2 - AJ Assembly monthly production report (Ford Motor Company, 2017)

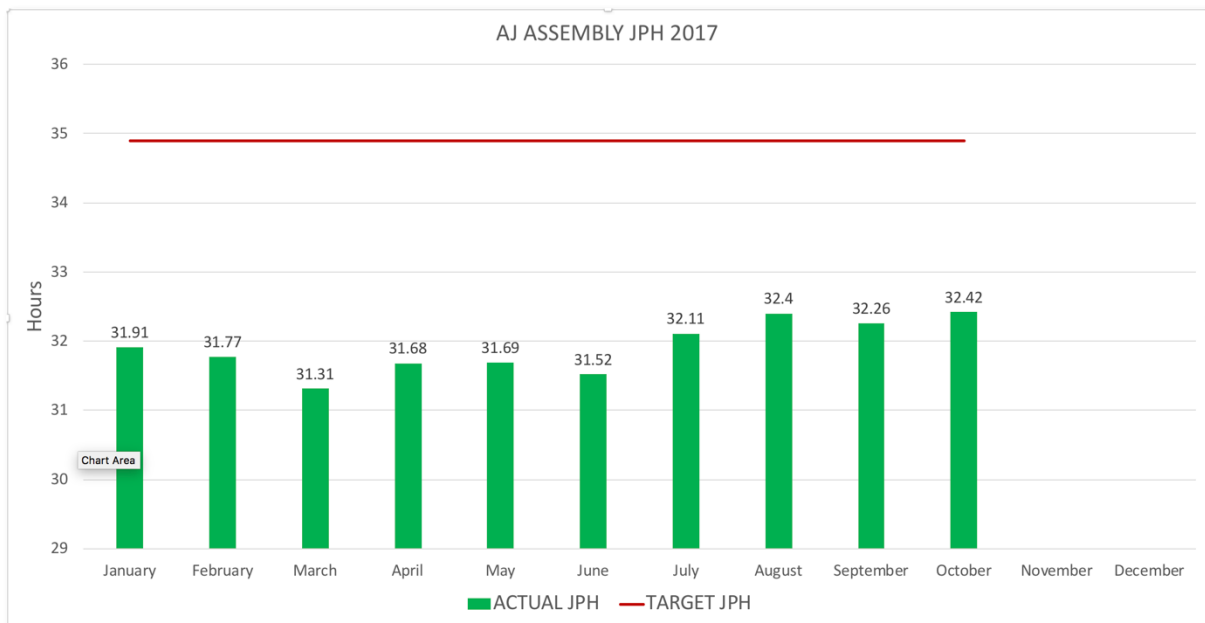


Figure 3.3 - AJ Assembly JPH performance 2017 (Ford Motor Company, 2017)

The demand on engines is very high and any reduction in output is always questioned and challenged by the wider team. Therefore, every stoppage has to be recorded to justify why the daily scores are not met. The data collected in Figure 3.1 and Figure 3.2 can be interrogated to drill down further and find the reasons for poor JPH.

Using the monthly production report from October 2017 in Figure 3.2, Table 7 shows the net working time available and the amount of stoppage time, resulting in the actual operating time left. This time when divided into the amount of engines bought-off, results in the monthly JPH.

Table 7 - AJ Assembly JPH data (October 2017) (Ford Motor Company, 2017)

Measurement	Totals
Net available working time (hrs)	453.75
Stoppage time (hrs)	73.64
Actual available working time (hrs)	380.11
Engines bought-off	12,323

Using these measurements the monthly JPH is calculated:

$$\text{JPH} = \text{Engines bought off} / \text{Available operating time}$$

$$\text{JPH} = 12,323 / 380.11$$

$$\text{JPH} = 32.42$$

However, the target JPH is 34.9 so the line could have potentially bought-off:

$$\text{JPH} = \text{Engines bought off} / \text{Available operating time}$$

$$34.9 = \text{Engines bought off} / 453.75$$

$$34.9 \times 453.75 = 15,835 \text{ engines}$$

If the assembly line was running to its potential during October, 15,835 engines could have been produced, meaning a further 3,512 engines could have been bought off.

The chart in Figure 3.4 shows the reasons for stoppages during October with stock shortages clearly representing the largest portion.

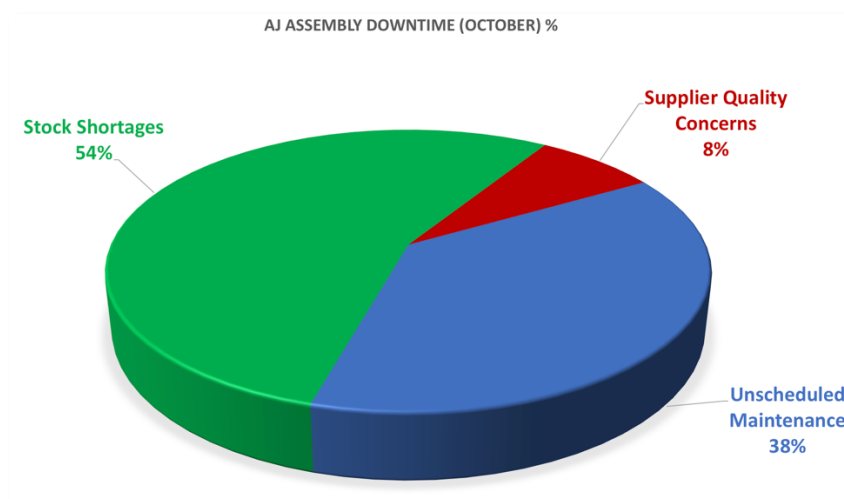


Figure 3.4 - AJ Assembly downtime (October) (Ford Motor Company, 2017)

The total stoppage time recorded for October was 73.64hrs, with 40.18hrs recorded as stock shortages, which accounts for 54% of the total stoppage time. When the line stoppage data for January to October 2017 is compiled, see Table 8, stock shortages are consistently identified as the main reason for down-time on AJ assembly, illustrated in Figure 3.5.

Table 8 – AJ Assembly data for JPH data (2017) (Ford Motor Company, 2017)

Reason for stoppage	Time
Cleaning	11.83
Unscheduled Maintenance	199.99
Fire Drill	2.67
Stock Shortages	355.37
Supplier Quality Concerns	63.09

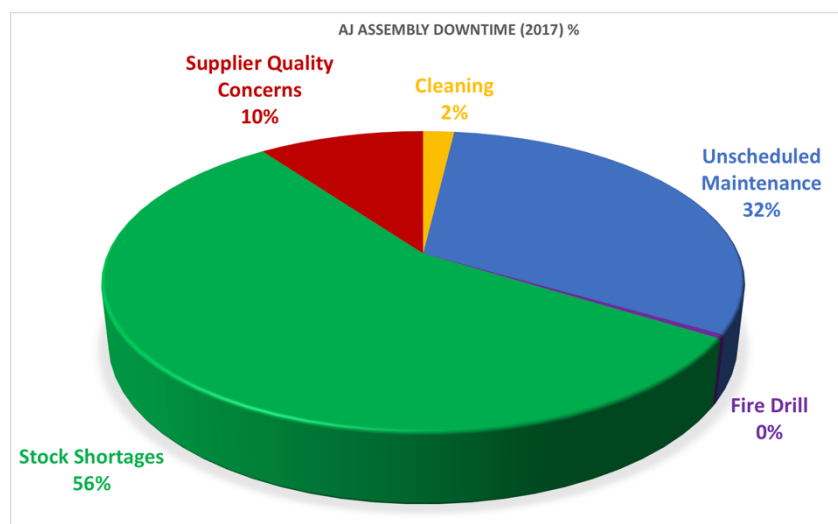


Figure 3.5 - AJ Assembly downtime (2017) (Ford Motor Company, 2017)

3.7 Data collection plan

Using the production data for line stoppages the team began drilling down into the reasons for stock shortages. Using PMFEA and Fishbone analysis, the team could begin identifying problem areas and start honing in on potential root causes.

3.7.1 PMFEA

The PMFEA used at this stage of the project can be seen in Figure 3.6. This allows a Risk Process Number (RPN) to be allocated to each element identified enabling the team to clearly identify areas of the process that are problematic and causing roadblocks.

The key terms used within a PFMEA are defined as follows:

- Process = Description of the process
- Failure mode = How the process could fail
- Effects = Result of the failure occurring
- Severity = Impact of the effect on the customer or process
 - Scale of 1 to 10 with 10 being the most severe
- Occurrence = Probability of the failure occurring
 - Scale of 1 to 10 with 10 being the most likely
- Detection = Possibility of noticing the failure
 - Scale of 1 to 10 with 10 being the slowest

The figures are multiplied together to reveal the RPN which provides a priority list of potential failures.

PROCESS FAILURE MODE AND EFFECTS ANALYSIS												
Process:	Delivery of engine components to AJ assembly					FMEA Number: 1						
Item:	Inventory flow within BEP					Process Responsibility: Huw Davies / Steve Murphy			Prepared by: Cert Wyatt			
Area(s) involved:	MP&L, tipping, receiving, warehouse, internal logistics, Spec & Audit								Date (Orig.) 06/12/2017			
Core Team:	Huw Davies, Steve Murphy, Cert Wyatt, Andrew, Williams, Keiron Griffin, Chris Goodier, Leigh Morgan and relevant teams								Date (Rev.) N/A			
Process Function/ Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Seriousness	Class	Potential Causes(s)/ Mechanism(s) of Failure	Occurrence	Current Process Controls -Detection	Detection	R. P. N.	Recommended Action(s)	Responsibility & Target Completion Date	Action Results
Tip trailers from Bulpen in order of priority	Parts not at assembly point of fit in time	No delivery of parts making the assembly line stop	10	Major	Shortage process not being followed	6	Shortage process	10	600	Revisit the shortage process and recommend a more robust process	N/A	N/A
			10		Cherry picking trailers and inventory records incorrectly captured	5	None. Relying on human intervention	10	500	Implement a process to force record integrity. Eliminate cherry picking, tip whole trailer or	N/A	N/A
Capture all incoming components accurately and in a timely manner	Incorrect stock levels	Supplier over shipments	5		Human error, green labour	6	Data capture procedures	7	210	Revisit the booking in process and recommend a more robust process along with additional training / re-training	N/A	
		Supplier under shipments	10	Major	Human error, green labour	6	Data capture procedures	7	420		N/A	
Components stored in correct locations	Inaccurate stock levels, missing components	Part shortage making the assembly line stop	10	Major	Human error, green labour	4	None. Relying on training and experience	10	400	Revisit part location signage and maps. Introduce process confirmation	N/A	
Delivery of parts to the line in recommended time frame and frequency	Parts not at assembly point of fit in time	Part shortage making the assembly line stop	10	Major	Part ordered by assembly at incorrect time or frequency	3	Rely on group leader to order parts in accordance with Min Max levels	3	90	Visual factory is in order. Sufficient and serviceable call buttons	N/A	
	Too many parts at assembly point of fit		10		Parts delivered by MP&L at incorrect time or frequency	6	Pick screen on local system	3	180	Analyse delivery times and confirm error profiling	N/A	
	Parts not at assembly point of fit in time	Excess parts at line causing safety hazard.	5		Part ordered by assembly at incorrect time or frequency	3	Rely on group leader to order parts in accordance with Min Max levels	3	45	Visual factory is in order. Sufficient and serviceable call buttons	N/A	
	Too many parts at assembly point of fit	Parts returned to storage location	5		Parts delivered by MP&L at incorrect time or frequency	6	Pick screen on local system	3	90	Analyse delivery times and confirm error profiling	N/A	

Figure 3.6 - PMFEA for inventory flow within BEP (Ford Motor Company, 2017)

3.7.2 Cause and Effect

The cause and effect diagram in Figure 3.7 was created by the team to further separate the issues and highlight which areas affected delivery performance and required the most attention.

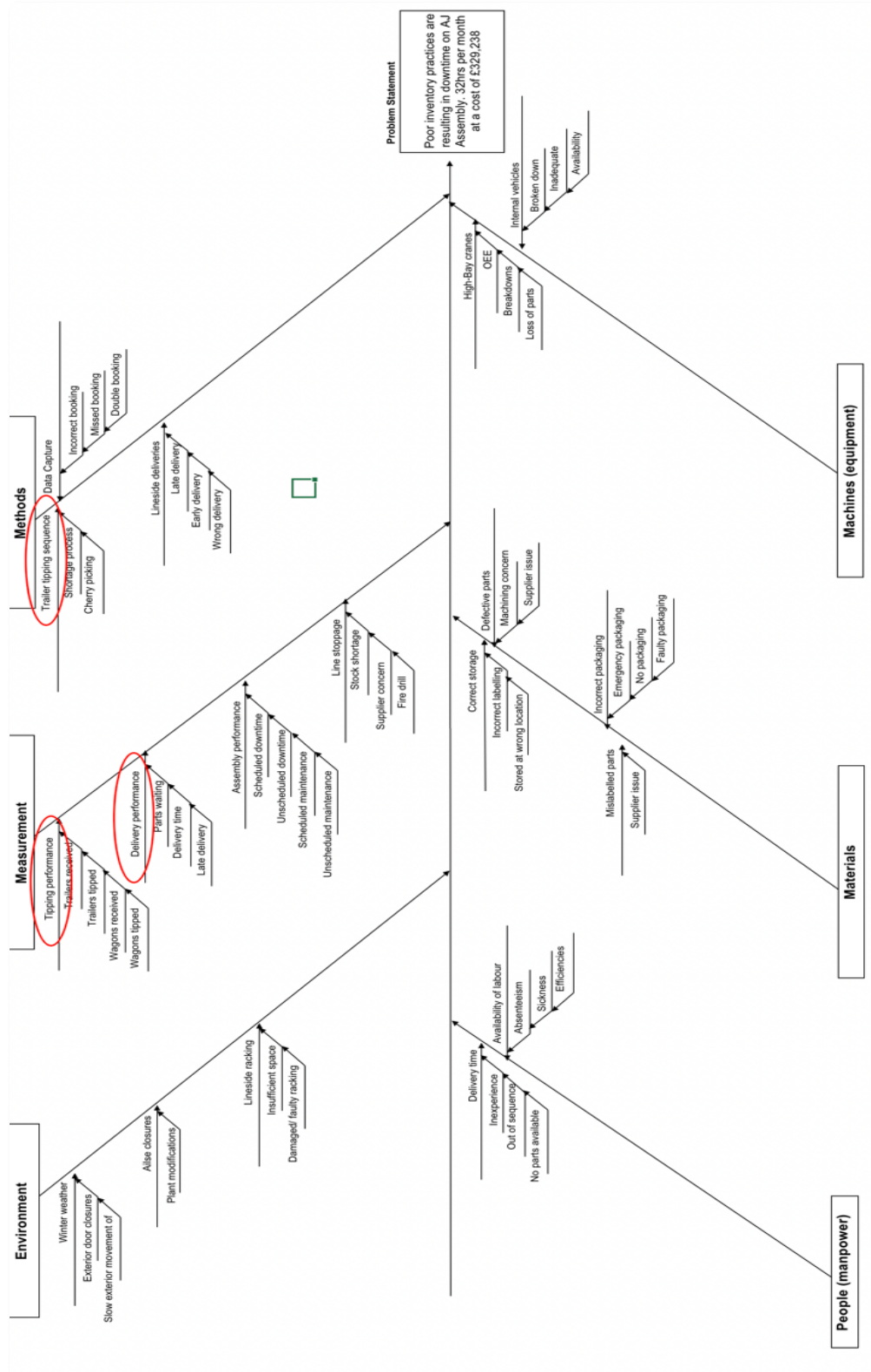


Figure 3.7 – High level Cause and Effect diagram (Ford Motor Company, 2017)

This early analysis using high level measurements resulted in the trailer tipping sequence, trailer tipping performance and line delivery performance being highlighted as areas that required further investigation.

3.7.3 Elements to Measure

Trailer tipping sequence

- Frequency of critical part trailer tipping requests
- Frequency of line stoppages due to parts not being tipped on time

This data will reveal the amount of times the AJ line has a part shortage when the parts are actually on site, but have not been prioritised and tipped in time.

Tipping Performance

- Receiving
 - Trailers received v Trailers tipped
- Low-Bay
 - Trailers received v Trailers tipped
- Rail
 - Wagons received v Wagons tipped
 - Returned engine racks v material

This data will uncover the time taken from when material arrives on site to when it is tipped onto the warehouse floor. The performance of tipping material from lorry trailers and rail wagons can be continually measured, allowing process change analysis to determine if improvements are being made.

Delivery performance

- Stock shortages
 - Nil stock
 - Parts not tipped in time
- Wrong parts delivered
- Supplier quality concerns
- Shift change overs
- MP&L late lineside delivery
- Assembly line late call

This data will list the reasons and duration of line stoppages to understand the causes for the stoppages and if they have a direct impact on productivity. Additionally, there may be discrepancies between operations whereby a manual call button is used by production to request a delivery and the reaction time of MP&L after receiving the request.

3.8 Recording the Data

For data collection to accurately represent the performance of a process it has to be validated regularly and the process of collection has to be consistently confirmed. The project team will cross examine results to ensure the process being used is reliable and can be reproduced.

3.8.1 Database records

Excel spreadsheets were created to allow data to be recorded. The team agreed that the MP&L department supervision across four shifts should collate tipping performance on a daily basis, see Figure 3.8 which shows the data for November 2017.

- High-Bay
 - Trailers received
 - Trailers tipped
- Low-Bay
 - Trailers & wagons received
 - Trailers & wagons tipped

HIGH-BAY		NOVEMBER																													
A SHIFT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trailers received	0	14	11	18	13	22	0	1	16	12	0	0	0	3	6	16	0	0	0	0	0	0	0	0	12	16	11	0	0	0
	Trailers tipped	9	10	9	10	11	11	0	9	10	11	0	0	0	11	10	11	0	0	0	0	0	0	0	0	0	10	10	10	0	0
B SHIFT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trailers received	9	11	15	0	0	0	0	8	12	0	0	0	0	0	0	0	0	16	10	8	0	0	0	16	17	13	11	0	2	0
	Trailers tipped	10	8	10	0	0	0	0	9	10	8	0	0	0	0	0	0	0	11	10	12	0	0	0	0	9	10	10	10	0	8
C SHIFT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trailers received	0	0	0	0	0	0	0	0	0	0	14	11	8	0	0	0	16	15	19	15	0	1	13	14	0	0	0	4	6	10
	Trailers tipped	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	0	7	9	11	0	0	0	0	11	10	10
D SHIFT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trailers received	0	0	0	14	13	6	0	0	0	16	10	15	14	0	3	8	10	0	0	0	0	9	10	0	0	0	0	0	0	0
	Trailers tipped	0	0	0	11	10	9	0	0	0	11	10	10	10	0	9	10	10	0	0	0	11	10	9	0	0	0	0	0	0	0
LOW-BAY		NOVEMBER																													
A SHIFT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trailers received	1	1	1	0	2	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	2	0	0	0
	Trailers tipped	1	4	1	2	2	2	0	2	5	3	0	0	0	2	2	3	0	0	0	0	0	0	0	0	5	3	2	0	0	0
B SHIFT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trailers received	2	2	4	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	3	0	0	0
	Trailers tipped	1	3	4	0	0	0	3	1	3	0	0	0	0	0	0	0	0	5	3	5	0	0	0	4	3	1	3	0	4	4
C SHIFT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trailers received	0	0	0	0	0	0	0	0	0	0	3	4	2	0	0	0	2	0	4	4	0	0	3	4	0	0	0	0	0	4
	Trailers tipped	0	0	0	0	0	0	0	0	0	0	2	4	2	0	0	0	2	0	4	1	0	3	3	4	0	0	0	2	3	0
D SHIFT		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Trailers received	0	0	0	4	0	0	0	0	0	1	2	3	4	0	0	1	3	0	0	0	0	0	2	0	0	0	0	0	0	0
	Trailers tipped	0	0	0	4	1	4	0	0	0	2	3	1	0	0	0	4	3	0	0	0	1	2	3	0	0	0	0	0	0	0
RAIL		NOVEMBER																													
WAGONS RECEIVED		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Total Wagons	10	15	0	0	15	12	8	0	6	0	8	7	16	10	0	6	0	6	7	14	6	0	8	8	6	7	10	6	0	8
	Material	6	7	0	0	13	0	6	0	6	0	4	6	7	5	0	5	0	5	6	3	4	0	5	5	4	6	6	6	0	3
	Racks	4	8	0	0	2	12	2	0	0	0	4	0	9	5	0	1	0	1	1	10	2	0	0	0	2	1	4	0	0	5
	Empty	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	3	3	0	0	0	0	0	0
WAGONS TIPPED	A SHIFT	0	0	0	2	5	7	0	3	3	1	0	0	0	5	4	2	0	0	0	0	0	0	0	0	0	2	2	0	0	0
	B SHIFT	0	4	0	0	0	0	5	7	3	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	5	4	5	0	1	3
	C SHIFT	3	0	0	0	0	0	0	0	0	0	1	2	3	0	0	0	5	0	3	7	0	3	1	0	0	0	0	4	3	0
	D SHIFT	0	0	0	0	3	0	0	0	0	0	3	5	5	7	0	5	1	2	0	0	0	5	3	3	0	0	0	0	0	0
TOTALS		NOVEMBER																													
HIGH BAY	Trailers received	9	25	26	32	26	28	0	9	28	28	24	26	22	3	9	24	26	31	29	23	0	10	23	30	29	29	22	4	8	10
	Trailers tipped	19	18	19	21	21	20	9	19	18	22	20	21	21	11	19	21	20	21	20	22	11	17	18	20	20	20	20	11	18	10
LOW BAY	Trailers Received	3	3	5	4	2	2	0	2	5	1	5	7	6	0	0	1	5	0	4	4	0	0	5	4	9	1	5	0	0	4
	Trailers tipped	2	7	5	6	3	6	3	3	8	5	5	5	2	2	2	7	5	5	7	6	1	5	6	8	8	4	5	2	7	4
RAIL	Wagons received	10	15	0	0	15	12	8	0	6	0	8	7	16	10	0	6	0	6	7	14	6	0	8	8	6	7	10	6	0	8
	Wagons tipped	3	4	0	2	8	7	5	10	6	4	6	7	10	5	9	3	7	0	6	7	5	6	4	1	5	6	7	4	4	0

Figure 3.8 - Recorded tipping performance (Nov 2017) (Ford Motor Company, 2017)

Using AJ production reports, MP&L supervision across four shifts will record the duration of line stoppages caused by material shortages and place them against one of the reasons listed below. Table 9 shows the data collected during November 2017.

- Nil stock in plant
- Stock not tipped in time
- Late calls from the line
- Late delivery from Market Place
- Shift change
- Wrong delivery
- Supplier concern

Table 9 - Line stoppage for material shortages (Nov2017) (Ford Motor Company, 2017)

Date	Shift	Part Number	Production Reported Reason	MP&L Report Reason						
				Nil stock in plant	Stock not tipped on time	Late assembly call	Late MP&L delivery	Shift change	Wrong delivery	Supplier concern
01-Nov	Day	FPLA 12B637 AD	Waiting for delivery					5		
01-Nov	Night	8W93 6P052 AF	Waiting for delivery			5				
01-Nov	Night	DX23 12A366 AC	Waiting for delivery			5				
02-Nov	Late	DX23 9448 AA	Wrong part delivered						15	
02-Nov	Late	8W93 6P052 AF	Waiting for delivery			5				
02-Nov	Night	HK83 12C508 AB	Parts outside on truck		20					
03-Nov	Day	8W93 6M052 CA	Parts outside on truck		30					
03-Nov	Day	9W83 8A520 CC	Parts outside on truck		45					
04-Nov	Day	HK83 6C674 AA	Wrong part delivered						10	
04-Nov	Day	DX23 6P036 AC	Waiting for delivery				10			
08-Nov	Late	8W93 6L073 AB	Waiting for delivery			5				
08-Nov	Night	8W93 6L073 AB	Waiting for delivery					10		
09-Nov	Night	8W93 6L073 AB	Waiting for delivery				10			
09-Nov	Night	HK83 6C674 AA	Wrong part delivered						10	
10-Nov	Day	DW93 6C674 CA	Wrong part delivered						10	
10-Nov	Late	8W93 6L073 AB	Waiting for delivery				15			
10-Nov	Late	DX23 12025 BC	Parts outside on truck		5					
10-Nov	Night	FX23 9G774 AC	Waiting for delivery					5		
10-Nov	Night	DX23 6A270 AA	Parts outside on truck		20					
11-Nov	Late	CPLA 6061 AC	Parts outside on truck		10					
11-Nov	Late	9W83 8555 CC?	Parts outside on truck		5					
11-Nov	Night	8W93 6P052 AF	Waiting for delivery					5		
11-Nov	Night	8W93 6L073 AB	Waiting for delivery					5		
11-Nov	Night	8W93 6M052 CA	Waiting for delivery					5		
16-Nov	Late	FPLA 12B637 AD	Waiting for delivery					5		
17-Nov	Day	EX53 292759 AC	No stock in plant							70
17-Nov	Late	CPLA 6061 AC	Parts outside on truck		30					
17-Nov	Night	JPLA 6K868 AA	Parts outside on truck		10					
17-Nov	Night	DX23 6M280 AA	Waiting for delivery			5				
18-Nov	Day	JPLA 6K868 AA	Parts outside on truck		40					
18-Nov	Day	8W93 6M052 CA	Parts outside on truck		10					
18-Nov	Late	9W83 8A504 DC	Parts outside on truck		30					
18-Nov	Late	8W93 6L073 AB	Waiting for delivery				5			
18-Nov	Night	8W93 6L073 AB	Waiting for delivery					10		
18-Nov	Night	FX23 9T518 AB	Parts outside on truck		15					
18-Nov	Night	V6 Cams	Parts outside on truck		35					
21-Nov	Day	GX53 12C508 BC	Waiting for delivery			5				
23-Nov	Late	FX23 6600 BA	Wrong part delivered						5	
24-Nov	Day	FX23 9G802 AC	Waiting for delivery				5			
24-Nov	Day	9W83 8A504 DC	On stop SOS					10		
24-Nov	Day	CPLA 6037 AC	On stop SOS					5		
24-Nov	Day	DX23 9430 AA	On stop SOS					5		
24-Nov	Late	8W93 9A462 BB	On stop SOS					5		
24-Nov	Late	9W83 8A504 DC	On stop SOS					10		
24-Nov	Late	CPLA 6037 AC	Waiting for delivery					5		
24-Nov	Late	FX23 9G802 AC	Waiting for delivery					5		
24-Nov	Late	DX23 9430 AA	Waiting for delivery					5		
24-Nov	Late	FPLA 12B637 AD	Waiting for delivery					5		
24-Nov	Night	9W83 98659 BC	Parts outside on truck		10					
25-Nov	Day	8W93 6L073 AB	Waiting for delivery				5			
25-Nov	Late	DX23 9424 AC	Parts outside on truck		10					
25-Nov	Late	DX23 6A270 AA	Parts outside on truck		15					
25-Nov	Night	FPLA 12B637 AD	Waiting for delivery				5			
25-Nov	Night	FX23 6600 BA	Waiting for delivery				15			
29-Nov	Day	HK83 6C674 AA	Waiting for delivery				10			
29-Nov	Night	FX23 9G802 AC	Waiting for delivery				5			
Total				0	340	30	85	105	50	70
Total time				00:00	05:40	00:30	01:25	01:45	00:50	01:10

3.9 Weekly Meeting

The project team felt there was a requirement to hold a short weekly meeting to ensure consistency across all shift patterns and to feedback any concerns about the recording strategy and to raise any points that created opportunities for improvement. A continued weekly meeting was agreed to enable feedback on any changes that were introduced and to gauge the feeling of the workforce.

3.10 Calculation of baseline OEE (Nov 2017)

Note: Data provided from AJ Assembly production reports (Ford Motor Company, 2017)

3.10.1 Quality

$$\begin{aligned}\text{Quality} &= \text{Good pieces} / \text{Total pieces} \\ &= 11617 / 12323 \\ &= 0.943\end{aligned}$$

3.10.2 Availability

This calculation is the actual operating time divided by the planned production time. Actual operating time is calculated by taking lost production time away from planned production time. Lost production time is calculated by finding the product of:

$$\text{Engine cycle time (1.716 mins)} \times \text{rejected engines (706)} = 1211.5 \text{ minutes}$$

Understanding that AJ assembly operates Monday to Friday, November has 22 days of production. So the lost production time is::

$$1211.5 / 22 = 55.07 \text{ minutes per day}$$

Planned production time is equal to the actual time available for production, so 24hrs a day, less 67 minutes of planned break time per day, over a 5 day working week results in the planned production time:

$$\begin{aligned}24 \times 60 &= 1440 \text{ minutes} \\ 1440 - (3 \times 67) &= 1239 \text{ minutes}\end{aligned}$$

$$\begin{aligned}\text{Actual operating time} &= \text{Planned production time} - \text{Lost production time} \\ &= 1239 - 55.07 \\ &= 1183.93 \text{ minutes per day}\end{aligned}$$

Therefore;

$$\begin{aligned}\text{Availability} &= \text{Actual operating time} / \text{planned production time} \\ &= 1183.93 / 1239 \\ &= 0.955\end{aligned}$$

3.10.3 Performance

Performance is measured by dividing the total pieces by the operating time and dividing the solution by the run rate.

$$\begin{aligned}\text{Total pieces for November} &= 12323 \text{ units} \\ \text{Daily operating time} &= 1183.93 \text{ minutes} \\ \text{Monthly operating time} &= 1183.93 \times 22 \text{ days of production} \\ &= 26046.46 \text{ minutes} \\ \text{AJ Assembly run rate} &= 1.716 \text{ minutes per unit}\end{aligned}$$

Therefore;

$$\begin{aligned}\text{Performance} &= (\text{Total pieces} / \text{Operating time}) / \text{Run rate} \\ &= (12323 / 26046.46) / 1.716 \\ &= 0.28\end{aligned}$$

$$\begin{aligned}\text{November OEE} &= \text{Performance} \times \text{Availability} \times \text{Quality} \\ &= 0.28 \times 0.955 \times 0.943 \\ &= 0.252 \\ &= 25 \% \text{ Overall Equipment Efficiency}\end{aligned}$$

Due to the poor performance figure of 0.28, the OEE is out of tolerance and any reduction in line stoppages due to material shortages will have an immediate and positive impact on AJ productivity.

3.11 Understanding the Cost

Cost is a major driving factor in any sustainable manufacturing business. With the capability to quantify cost an organisation can manage and prioritise the business needs and identify areas of weakness. Having the ability to become a lean manufacturer and eliminate wastes such as unforeseen line stoppages will reduce the amount of wasted time and resources which will in turn improve productivity and ease the pressure of meeting cost targets (Gopalakrishnan, 2010).

The financial loss in quarter 4 of 2017 was £1,305,145.27 due to lost engines. This is a very 'high level' overview, but Figure 3.9 clearly indicates that opportunities are available to improve the systems and processes in place and to investigate the utilisation of people. Financial losses like this make the business unsustainable and to turn the situation around, the project group agreed that a refocus on delivery and material flow was needed.

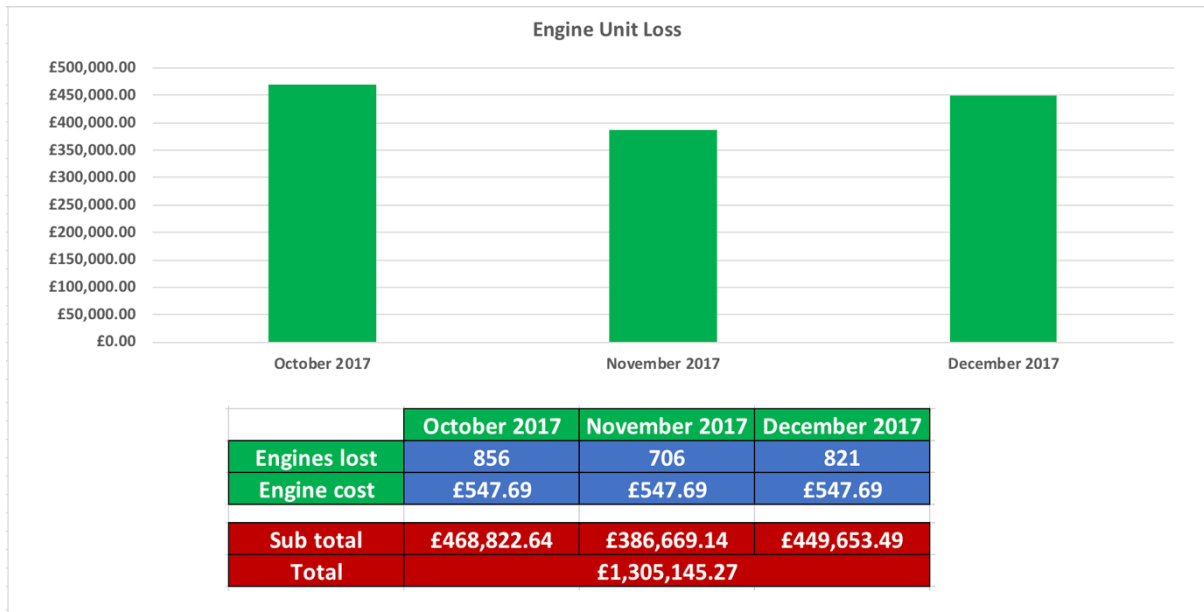


Figure 3.9 - Engine Unit Losses, Oct - Nov 2017 (Ford Motor Company, 2017)

By utilising the Delivery Operating System (DOS) referenced in Chapter 1.6.1 as the perfect template and improving the delivery processes, the cost associated with downtime due to poor inventory control can be reduced. Illustrated in Figure 3.10.

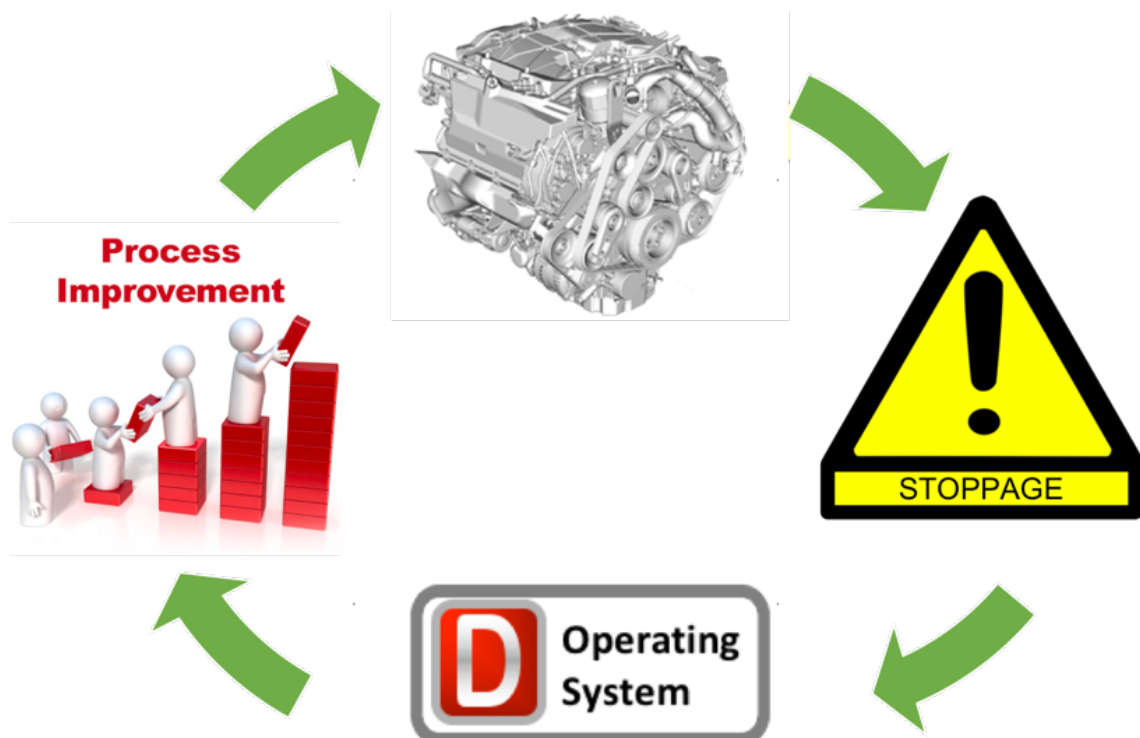


Figure 3.10 - Process improvement to reduce waste (Wyatt, 2018)

3.12 Breakdown of cost

When the line stops due to a material shortage there are a number of related costs that have to be taken into consideration. There are 110 manual work stations located from the input to the buy-off on AJ assembly with around 150 operators. A more accurate cost can be calculated when using the location of the shortage when it occurs on the line. This provides the number of operators that are effected between the shortage and the buy-off. Therefore the total stoppage cost is calculated:

Cost of engine loss:

Cost of engine x Loss of JPH

Cost of labour loss:

Lost production cost per operator x number of operators to buy-off x length of stoppage

Cost of engine loss + Cost of labour loss = Total cost of stoppage

3.13 Real time scenario

A real time line stoppage due to an inventory shortage can be seen in Figure 3.11 which is a screenshot from a production report.

Stock issues (MP&L/Machining)						
Stn #	Part #	Part Description	Team	Duration	Mins Lost	Engines
5460	EX53-12B559-AB	On stop waiting for Knock sensor harness to be tipped	7B	75	45	27

Figure 3.11 - Production records showing line stoppage (Ford Motor Company, 2017)

- 38 manual operation points between Team 7B and buy-off
- Loss of JPH = 27
- Minutes lost = 45 minutes
= 0.75 hours
- Cost of engine unit = £547.69 (Ford Motor Company, 2017)
- Hourly labour cost per assembly operator = £75.10 (Ford Motor Company, 2017)

Note: The labour cost takes into account wages and all associated overheads.

Cost of engine loss = Loss of JPH x Cost of engine
 = 27 x £547.69
 = **£14,787.63**

Cost of labour loss

$$\begin{aligned} &\text{Lost production cost per operator} \times \text{number of operators to buy-off} \times \text{length of stoppage} \\ &= 75.10 \times 38 \times 0.75 \\ &= \mathbf{£2140.35} \end{aligned}$$

$$\begin{aligned} \text{Total cost of stoppage} &= \text{Cost of engine loss} + \text{Cost of labour loss} \\ &= £14,787.63 + £2140.35 \\ &= \mathbf{£16,927.98} \end{aligned}$$

When AJ Assembly comes to an unpredicted stop, the cost suffered by the company is considerable due to the unit price and labour rates. Therefore, it is critical that situations like this are reduced and the line remains running. Changes are required to improve the baseline and increase the JPH. However, understanding the baseline data and analysing why these stoppages occur is key if the company is going to improve and become more productive.

Chapter 4: Analyse

The analyse phase establishes the process capability and uncovers sources of variation. It achieves this by applying statistical tools to the data and revealing the critical few issues which are negatively affecting the outputs such as product flow (Salah, et al., 2011).

4.1 Data Results

During November 2017, data was collected to establish a base line to enable the project team understand if improvements were being made or not. November's data over the 4 shifts is shown in Figure 4.1, while the overall tipping performance can be seen in Figure 4.2



Figure 4.1 - Tipping performance by shift (November) (Ford Motor Company, 2017)

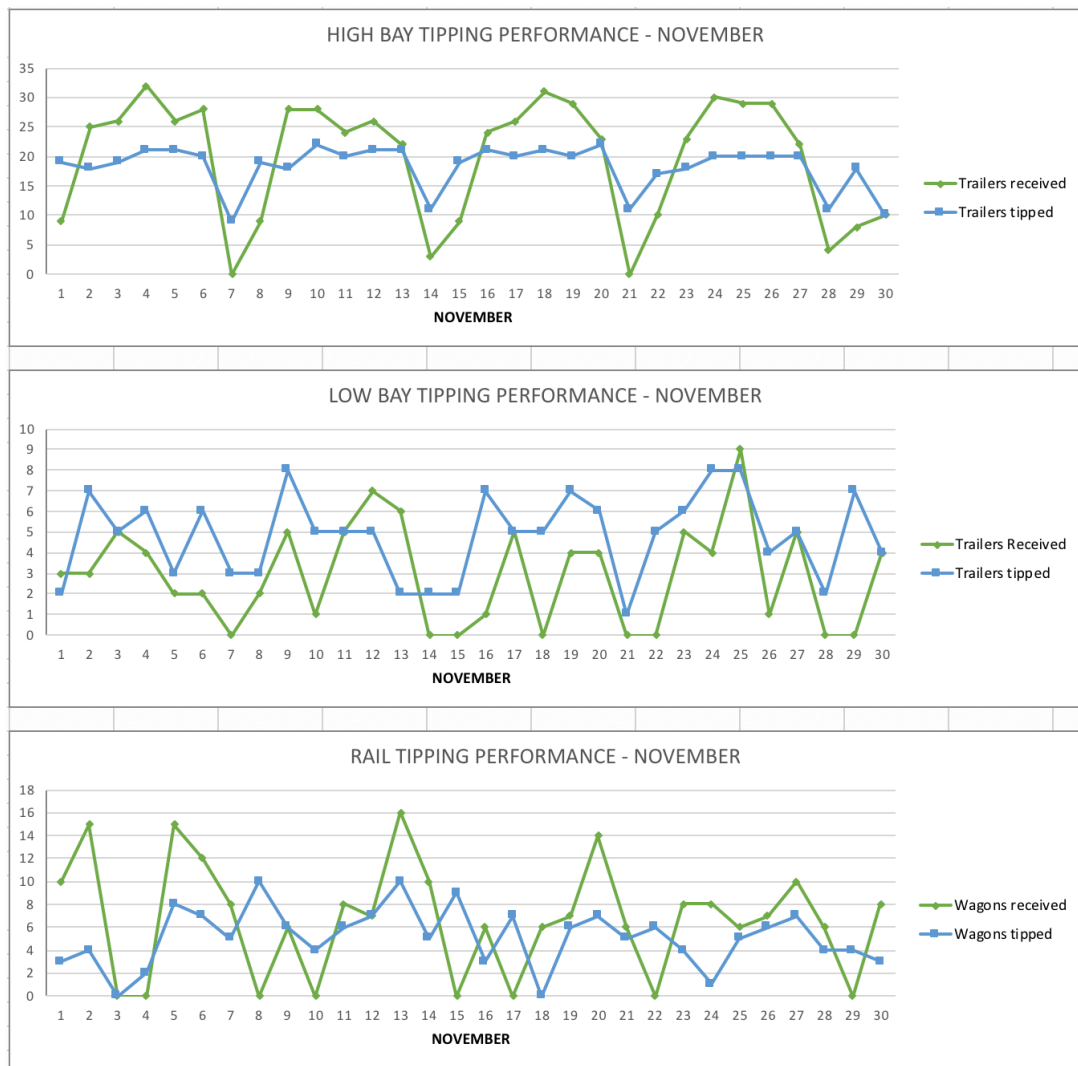


Figure 4.2 - Overall tipping performance (November) (Ford Motor Company, 2017)

From the results, the project group agreed that the current Low-Bay trailer and wagon tipping performance was not stable and through investigation work, it was discovered irregularities were down to inconsistent train arrivals and unpredictable trailer access to the Low-Bay. Additionally, at this point of the project there were a number of issues relating to the performance of the High-Bay storage facility. These issues included crane breakdowns which hindered the flow of material from trailers into the High-Bay further compounding the trailer tipping performance. MP&L internal logistics manager Huw Davies, reported to the project team that the High-Bay issues were ongoing and recommended that data collection in the High-Bay be postponed. The company was not in a position to waste valuable labour hours collecting unreliable data. Therefore, as the data proves, performance in the Low-Bay is good and through November there was no evidence of line stoppages directly linked to the Low-Bay. Additionally, tipping performance data at the High-Bay was unreliable due to machinery breakdowns, it was agreed by the team that the measuring and analysing of tipping performance would have to be postponed until stability was returned.

The reasons and duration of line stoppages caused by material shortages were recorded as shown in Table 9. When the data was pulled together into a graph, shown in Figure 4.3. It revealed that on many occasions line stoppages were caused by material that was on site at BEP, but the trailer had not been prioritised and tipped in time.

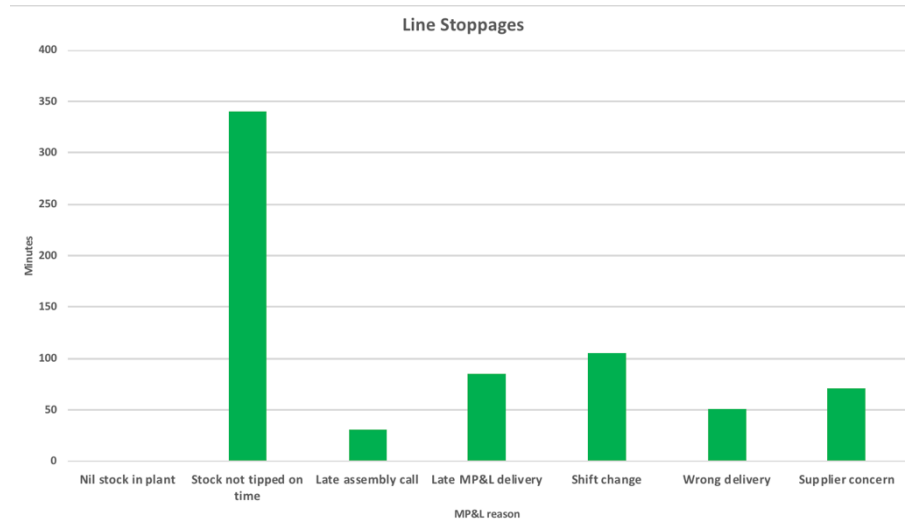


Figure 4.3 - MP&L reason for line stoppage (Nov 2017) (Ford Motor Company, 2017)

4.2 Pareto Analysis

From this data a Pareto chart was created, as seen in Figure 4.4. The purpose of a Pareto chart is to analyse the constraints and reveal the critical issues. The Pareto method uses the 80/20 rule and so assumes that 80% of issues are influenced by only 20% of the causes. Meaning that solving 20% of the identified problems will eliminate 80% of the issues. The principles behind this method help to identify the main problems and prioritise the corrective actions (Pavel, et al., 2015).

A Pareto chart is a bar chart that illustrates from left to right, the frequency of stoppages, highlighting the most significant subject. The bar chart is overlaid with a line graph that shows the cumulative percentage of the stoppages.

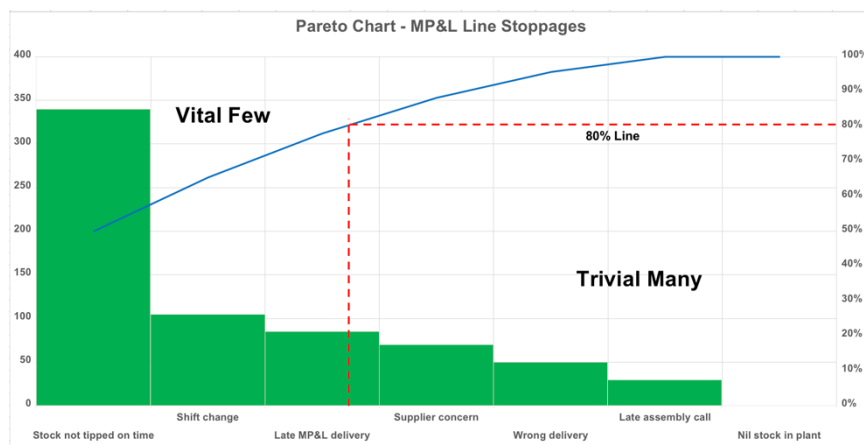


Figure 4.4 - Pareto Chart showing MP&L line stoppages (Ford Motor Company, 2017)

Pareto analysis is very good at prioritising the corrective actions but as in this case, it cannot be taken truly accurate. The stock not being tipped on time is clearly an issue as it accounts for 50% of the issues. However, the analysis has raised attention to shift change overs; therefore, once the trailer tipping prioritisation has been improved, it puts in place the next issue to be resolved.

Drucker (1990), discusses how interruptions to flow can reach 50 percent of the manufacturing time available and that downtime can cost as much as production time when considering wages, heating and lighting.

At this stage of the project, with the analysis performed to date, the team agreed that further analysis should be focussed on the priority of tipping trailers.

4.3 2nd PMFEA

PFMEA is usually carried out in the “Analysis and Improve” stage of a project but it can be used in other phases of the DMAIC process. It is a powerful analytical tool which can be easily adapted to reveal potential failure modes and the impact they will have if they do occur (Tague, 2010).

The PMFEA shown in Figure 4.5 has been used to analyse the failure modes of not prioritising tipping trailers correctly and the potential effects they have on the delivery process. The mode with the largest RPN is the shortage process and the fact there is no recognised shortage process across all shifts.

PROCESS
FAILURE MODE AND EFFECTS ANALYSIS

Process: Priority Tipping of Trailers FMEA Number: 2

Item: Shortage of parts Process Responsibility: Huw Davies / Steve Murphy Prepared by: Ceri Wyatt

Area(s) involved: MP&L, tipping, receiving, warehouse, internal logistics, Spec & Audit Date (Orig.) 03/01/2018

Core Team: Huw Davies, Steve Murphy, Ceri Wyatt, Andrew, Williams, Keiron Griffin, Chris Goodier, Leigh Morgan and relevant teams Date (Rev.) N/A

Process Function/ Requirements	Potential Failure Mode	Potential Effect(s) of Failure	S e v e r i t y	C i a s s	Potential Causes(s)/ Mechanism(s) of Failure	O c c u r r e n c e	Current Process Controls -Prevention -Detection	D e t e c t a b i l i t y	Recommended Action(s)	Responsibility & Target Completion Date	Action Results				
											Actions Taken	S e v e r i t y	O c c u r r e n c e	D e t e c t a b i l i t y	R e s p o n s i b i l i t y
Agreed Shortage Process	Parts not identified as a shortage in a timely manner	No delivery of parts making the assembly line stop	10	Major	No recognised shortage process across all shifts	8	Shortage process	10	800	Revisit the shortage process and recommend a more robust process	MP&L managers and supervision. March 2018				
					Knowledge and training of the area	5	None	10	500	Single Point Lesson of agreed shortage process. Area stand-down to cascade agreed process	Project Champion. March 2018				
					Missed communication between key personnel in MP&L	6	None. Relying on training and experience	10	600	Revisit the shortage process and recommend a more robust process	MP&L managers and supervision. March 2018				
Priority trailers tipped first	Critical parts not tipped in a timely manner	No delivery of parts making the assembly line stop	10	Major	Knowledge and training of the area	5	None	10	500	Single Point Lesson of agreed shortage process. Area stand-down to cascade agreed process	Project Champion. March 2018				

Figure 4.5 - PMFEA for priority trailer tipping (Ford Motor Company, 2017)

4.4 2nd Cause and Effect

Using the results of the analysis the project champion was able to question supervision and warehouse personnel about the current shortage process and the manner in which trailers are prioritised. The results of the questionnaire were added to a cause and effect diagram specifically aimed at trailer tipping priorities, as seen in Figure 4.6 for the project team to discuss.

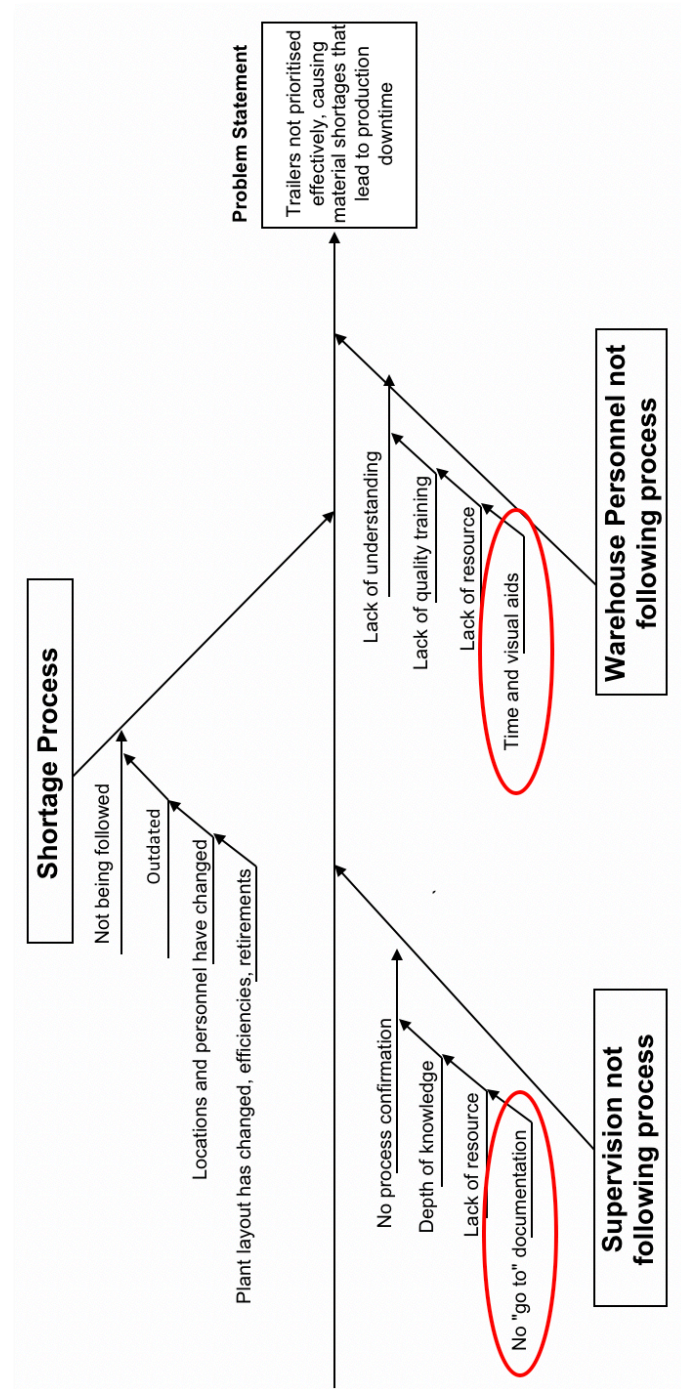


Figure 4.6 - Specific Cause and Effect diagram (Ford Motor Company, 2017)

4.5 5 whys analysis

After identifying an area of the business where an issue may lie, there is a need to reduce or remove it. The '5 whys' method is a process whereby the issue is written down followed with the question why. The answer is written underneath and so this continues until the root cause of the issue is identified. The questions are not fixed to five, the question why keeps getting asked for as long as required (Chen, et al., 2010).

Using the previous results a 5 why analysis was carried out.

- Why are we scheduling engines into the line if we are short of parts in plant?
 - The parts are on site but not in the warehouse yet
- Why are we scheduling engines when the parts are not available?
 - The parts are available but trailers have not been prioritised in time
- Why aren't trailers prioritised in time?
 - Communication not quick enough; therefore, team unable to react in time.
- Why isn't the communication quick enough?
 - No recognised process, different shifts have different ways of communicating
 - **Root cause: No formally recognised process across all shifts**
- 2nd Why isn't communication quick enough?
 - Shortages are dealt with in isolation and not shared with the wider team
- Why aren't issues shared with the wider team?
 - Lack of understanding and partnership between SCM, Data Capture and MP&L
 - **Root cause: No formally recognised process across all shifts**

A variation of the '5 whys' analysis is the 3 legged 5 why approach. This method of analysis is described by Frank (2009, p.6) as a method widely used by industry leaders. It is an approach that not only looks at the original customer issue, but also the detection and business process root cause. This means that the failure of the detection and management systems are also investigated and resolved. As described in the '5 why' analysis method, the issues are written down, followed by the question why, until a root cause is established. See Figure 4.7 that illustrates the outcome of the 3 legged 5 why analysis. There is no up to date, formally recognised and agreed process across all shifts for the prioritising of trailer tipping.

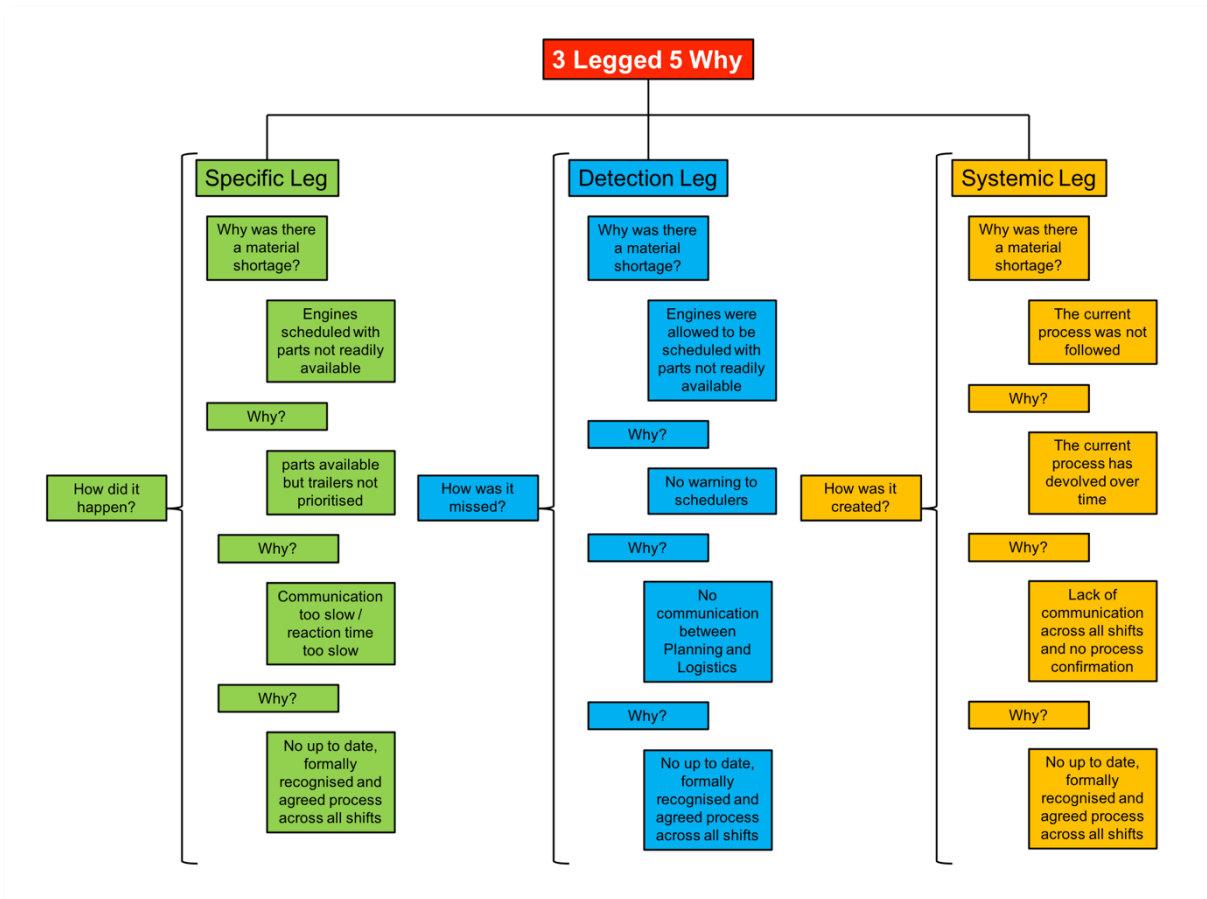


Figure 4.7 - 3 Legged 5 Why Diagram (Ford Motor Company, 2017)

4.6 Priority Tipping of Trailers

From the analysis carried out to date, the potential reason for material shortages in BEP is the incorrect prioritising of trailers located on site at BEP. The current process for prioritising trailer tips is as follows:

- Line feeders identify parts at a minimum level in the Market Place when taking stock to the assembly line.
- Take associated T-card from Market Place location and place it on the shortage board.
- Warehouse personnel pick T card, replenish the Market Place from the High-Bay or Blue Square area and return T-card.
- If no stock available place T-card on Material Replenishment Co-ordinators (MRCs) board.
- MRC physically counts the quantity of parts in plant, checking all locations including the High-Bay and any overspill locations.
- MRC compares physical count against CMMS book stock and checks for parts that have arrived or are in transit.

- MRC updates electronic shortage board with:
 - Runout time against build schedule
 - Trailer number carrying the critical parts
 - Location of trailers
- MRC updates trailer tipping sequence with priority trailers
- Supervision are informed and they follow up on priority trailers

4.7 General Observations

The project team carried out a number of brainstorming sessions ensuring all associated job functions were included. The outcome was a realisation that the current trailer tipping process was not operating effectively and there are too many opportunities for error due to the evolution of the area. The plant layout has changed slightly, there has been movement of employees and efficiencies along with retirements has meant a reduction in experienced personnel in the warehouse. A lack of documentation was also identified which inhibited staff in their ability to correctly follow a process and also prevented supervision from carrying out any training or process confirmation. This lack of process was compounded by the lack of positive communication between all levels of employees. Therefore, as the data and analysis suggests, the process is not robust, reliable or agreed by all stakeholders and there are many opportunities for improvement.

Chapter 5: Potential Obstacles

When people have been carrying out daily tasks on a regular basis, a request to alter their process can be met with some resistance. People are creatures of habit and there is often occasions when daily rituals become more important than the business needs. Management need to introduce process changes with the minimum of disruption to ensure there are no damaging effects that could negatively affect the customer.

5.1 Change Management

The management of change is recognised as a fundamental process across numerous manufacturing organisations and likewise throughout many types of industry. There are two approaches that have been acknowledged and regarded as successful at managing the change or introducing new working practices at a workplace. They are Kurt Lewin's Management of Change Model (Lewin, 1947) and Kotter's Eight Steps Change Model (Kotter, 1990). Lewin's model can be viewed as basic, however it incorporates three key elements which concentrate on achieving changes in people's behaviour more than the processes of an organisation.

5.1.1 Kurt Lewin's Change Management Model

Phase 1 – Unfreeze

This phase is about “selling” the reasons for change to the workforce. It is about helping the employees recognise that the proposed changes will almost certainly be successful. Lewin explains how this approach uses a force field analysis whereby the evaluation demonstrates how the advantages outweigh the disadvantages to making a change.

Phase 2 – Change (Transition)

This is the phase that initiates the change. This change has to be supported by continued education and training, ensuring the new or modified practices are followed. Mistakes will inevitably happen, but there should not be a blame culture and employees should be empowered to be part of the solution process and develop the best way forward.

Phase 3 Freezing (Refreezing)

This can sometimes be the hardest phase as there is always the temptation to revert back to the former processes until the change is fully stabilised and becomes part of everyday practices.

5.1.2 Kotter's 8 Steps Change Model

Kotter's 1990 model has similar values to Lewin's but goes into more detail and hence has more steps. A summary of the eight steps are as follows:

Step 1 – Create Urgency

Without causing panic, the workforce needs to feel a sense of urgency. This can be created by showing the need for a change by undertaking some kind of analysis like SWOT (Strengths, Weaknesses, Opportunities and Threats), this will encourage employees to realise the need for change.

Step 2 – Establish a Powerful Coalition

To create the best possible chance of success, it is essential to gather influential people, preferably from inside the business, who have the required skill and capability to focus on the major areas of the business. This team can include people from all levels in the organisation, not just engineers and management.

Step 3 – Create a Vision for Change

The view-points and concepts created by the team need to be arranged in order to devise a vision or mission statement. The vision will be used to develop a strategy that will help to turn the statement into a reality.

Step 4 – Communicate the Vision

When delivering the vision, opportunities may arise to listen openly to concerns that may appear about the vision and that solutions are clearly delivered and understood to ensure the vision is maintained.

Step 5 – Remove obstacles

Roadblocks such as existing processes and procedures or even individuals need to be focussed on and dealt with in order for the change to continue. Likewise, it is also important to focus and encourage good practices and people who help to deliver the change by means of financial or recognition within the organisation.

Step 6 – Create Short-term Targets

Short-term goals are important milestones that need to be included in the overall vision. These act as clear indicators that demonstrate to the workforce that progress is being made.

Step 7 – Build on Change

To ensure progression continues, measurements need to be taken that allow an analysis of what is going well and what needs attention. This will safeguard the progress and make sure organisation continues to move forward.

Step 8 – Anchor the Changes in the Corporate Culture

The vision of the organisation is the foundation it is built on. It is vitally important to build on a solid platform and reinforce the success that has come about because of the company vision. It is important to recognise long standing staff who have helped and supported the company's vision and likewise, the vision should also be part of the recruitment of new employees (Burnes, 2004)

For smaller companies the use of Lewin's model may be more adaptable as the deliverables are simpler and therefore easier to set up guidelines (Vassiliadis, 1999). On the other hand,

for larger organisations like Ford, Kotter's model has a larger scope and more of a corporate prominence. This will allow goals and milestones to be set and roadblocks to be removed which are essential in supporting the needs of larger organisations (Horenbeek, 2013).

5.2 Management

A successful DMAIC driven project requires the support of senior management from a Six Sigma approach. The process reviews and the importance to continually improve was supported and guided by Steve Murphy, a black belt in Six Sigma and Huw Davies the area manager. Additionally, the resistance between shifts was reduced as both Steve and Huw were able to drive the change from the top down and keep people focussed on the bigger picture and the business needs.

Chapter 6: Improvements

“An increased awareness of the occurrence of disturbances and their sources of origin in the supply chain may create substantial improvements in handling and preventing them” (Svensson, 2003). Therefore, helping employees to understand how often and why stoppages occur can in itself reduce them.

During the process of producing a product or service, it is important to gather information needed by internal customers for process control activities to ensure that the product is meeting the CTQs. If the CTQs are not being met, then the organisation needs to develop a better measurement and control system (Evans & Lindsay, 2014). This approach has been carried out in the project and the improve stage is where the measurement and control systems will be developed.

6.1 Identifying Potential Solutions

The Improve phase of the DMAIC methodology is used to recognise reasonable solutions to the project problem. It is advantageous to carry out trial phases of process improvements to allow for brainstorming and assessment before full implementation is carried out (Gopalakrishnan, 2010).

When deciding on solutions it is important to involve all employees that will be affected by proposed changes. Additionally, the fine tuning and effectiveness of the solutions rely on the people actually carrying out the work therefore, all group leaders were consulted in the warehouse along with supervision and management. This allows for brainstorming sessions to be carried out during the introduction of changes which minimised disruption.

6.2 Objectives of Improvements

The improvement objectives for this project were generated from the Pareto chart and Five Whys analysis. These objectives were created to develop the shortage process and establish an efficient method of prioritising trailers which will reduce or eliminate AJ line stoppages due to material shortages.

The Improvement phase objectives are:

- Improve shortage process across all shifts that will in turn:
 - Improve the tipping sequence
 - Improve communication across all shifts and affected departments
 - Produce a recognised and agreed document
- Create easily identifiable, designated overspill locations
- Engines should not be scheduled unless parts are 100% available

6.3 Improved Shortage Process

The current shortage process relies heavily on experience and employees being proactive to ensure trailers are prioritised efficiently. As shown in the measure and analysis phase, this led to MP&L line delivery performance being insufficient. Not having a formally recognised and agreed process across all shifts was revealed as the main root cause. The project champion used all the resources available which included the expertise of experienced personnel and produced a new single point lesson. A single point lesson (SPL) is a Ford, standardised and recognised document used in BEP that requires all employees affected by the action or change to agree to it before it becomes effective.

During the discussions with warehouse personnel it was discovered that time could be saved if the critical part was characterised as High-Bay or Blue-Square, this meant that one stage of the investigation could be removed and the High-Bay database could be interrogated quickly and only if required. Colour coded cards would be the simplest and cheapest way of identifying High-Bay (slower moving) and Blue-Square (fast moving). Blue for Blue-Square and green for High-Bay.

The SPL created for the agreed process can be seen in Figure 6.1. This document is a ready reckoner for current employees, it can be used as a training aid for new employees and can assist supervision when carrying out process confirmation.

MARKET PLACE SHORTAGE REPORTING PROCESS

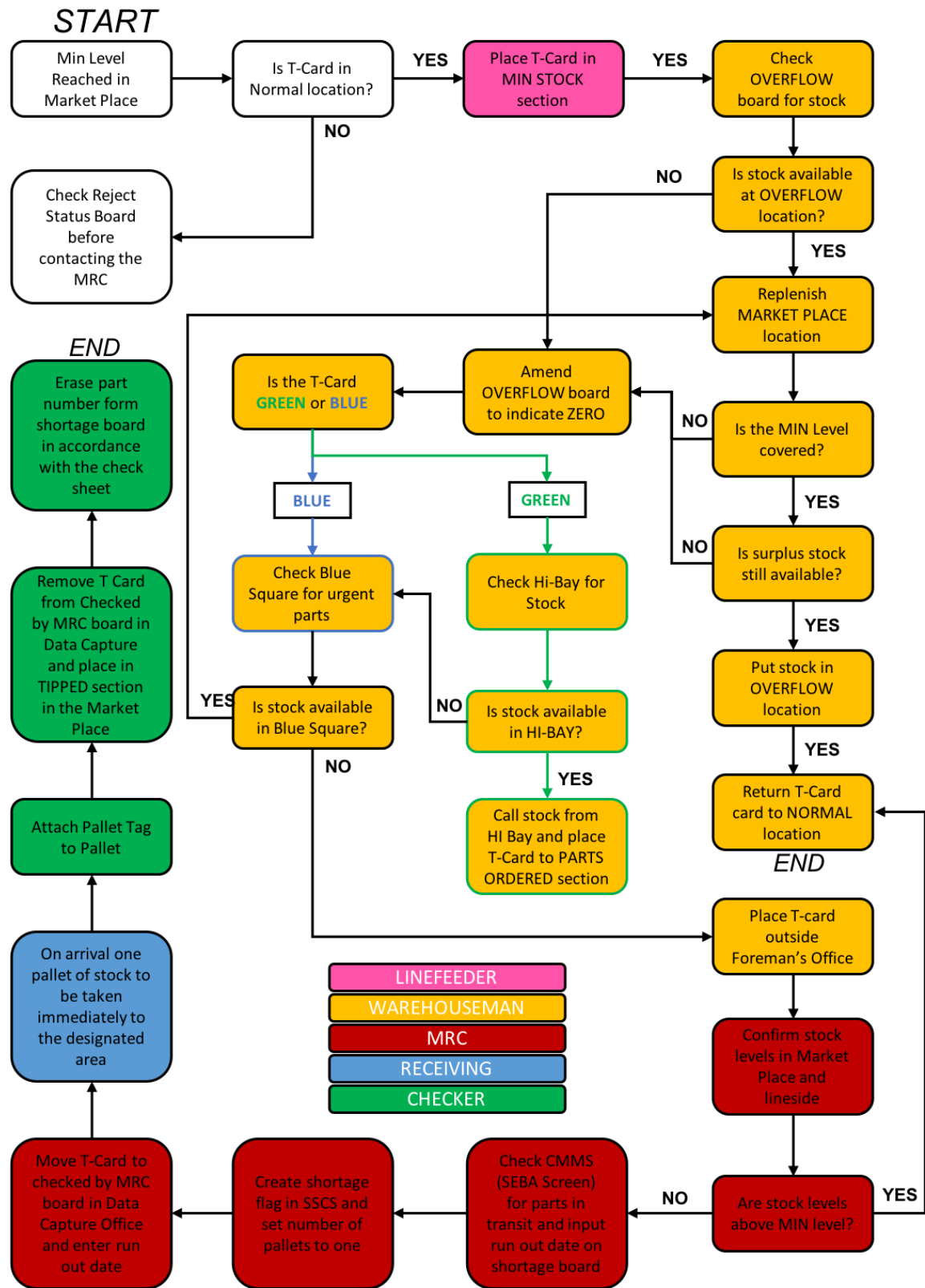


Figure 6.1 - Agreed shortage process in BEP Market Place (Ford Motor Company, 2018)

6.4 Improved Tipping Sequence

The tipping process is reliant on the shortage process. As stock levels reach the minimum level, the trailer containing those parts are added to the shortage board, which is a piece of standalone software that produces an electronic board and shared across the BEP internal network. However, this technology is reliant on the input data and so to avoid the garbage in garbage out (GIGO) principle, It is vital that all sources of variation are eliminated and once the agreed process is up and running there is no deviation (Good, 2005).

The shortage board was not being used effectively by the whole department and there were cases of 'cherry picking' from trailers, whereby a trailer carrying a shortage part would only have that particular part offloaded and the trailer returned to the trailer park.

Therefore, an improved shortage process will improve the tipping sequence, allowing the priority list of trailers to be processed in a calm and methodical way and not in a rushed and reactive manner.

6.5 Improve communication to the wider team

During the project it became apparent that any previous shortage or tipping process had fallen by the way side and this had inadvertently reduced the communication levels between the different shifts about the tipping sequence. Producing an agreed process and documenting it as a SPL has allowed constructive discussions across the department and because it is agreed by all shifts there is now a responsibility to abide by the process and be accountable if it is not followed.

6.6 Improved Inventory Storage Locations

A valid point that came out of the analysis was the storage of overspill material in the Market Place. On occasions, material had been found in adjacent locations that had not been labelled up correctly. When surveying the Market Place it was discovered that the racking running along the side wall was not being used effectively. There were a few locations for material but the majority had been used as a dumping ground with broken or unused pallets, bases and lids. The improvement agreed by all stakeholders was to use this racking as the designated overspill location for each aisle in the Market Place as shown in Figure 6.2. This improvement will allow warehouse personnel and the MRC's to easily identify if there is surplus stock available.

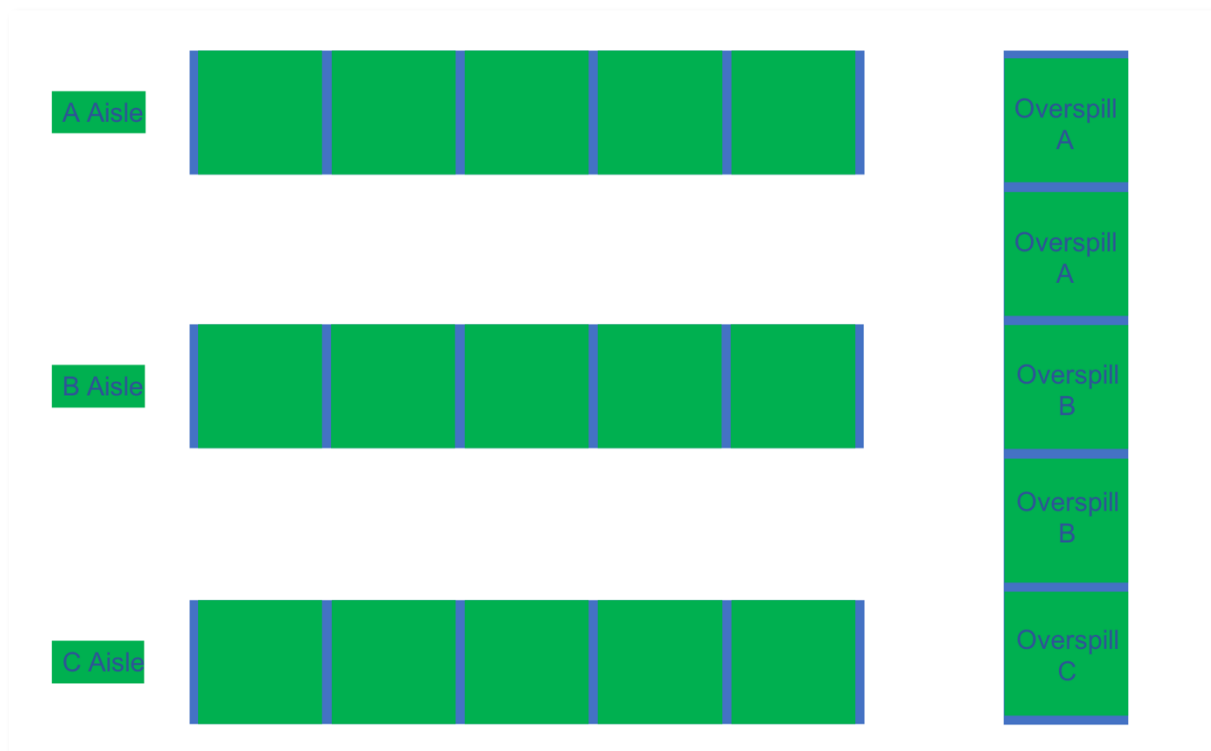


Figure 6.2 - Overspill locations in the AJ Market Place (Ford Motor Company, 2018)

6.7 Part availability for engine build plans

There are opportunities to improve the process further by means of the production schedulers being informed if the material required for the daily build schedule is still on a trailer and not inside the four walls. However, this idea has not been followed up at this moment in time due to resistance from key personnel:

- The schedulers feel that, if the parts are on site they should be available for production and this should not influence the build plan.
- MP&L Supervision feel that, they will have the parts tipped in time and there is no need to communicate their tipping constraints.

Due to the remaining project time it was agreed to postpone this element as more time would be needed to follow up and implement.

Chapter 7: Project Results and Verification

In order to verify the project and consider if there had been any improvements, it is necessary to compare AJ Assembly downtime caused by material shortages from before and after the implementation of the new agreed shortage process. The implementation of the new shortage process was introduced through February and the first full month captured by the new process was March.

The JPH monthly average for 2017 was 31.92 and for March 2018 the JPH was 32.73. The data for March can be seen in Table 10 followed by the calculation.

Table 10 - AJ Assembly JPH data (March 2018) (Ford Motor Company, 2018)

Measurement	Totals
Net available working time (hrs)	453.8
Stoppage time (hrs)	27.97
Actual available working time (hrs)	425.8
Engines bought-off	13937

Using this data the JPH for March 2018 is calculated:

$$\text{JPH} = \text{Engines bought off} / \text{Available operating time}$$

$$\text{JPH} = 13,937 / 425.8$$

$$\text{JPH} = 32.73$$

For a comparison Figure 3.4 in the measure phase of the project showed that in October 2017, stock shortages were responsible for 54% of downtime and in contrast, Figure 7.1 shows how stock shortages have reduced to 13% in March 2018.

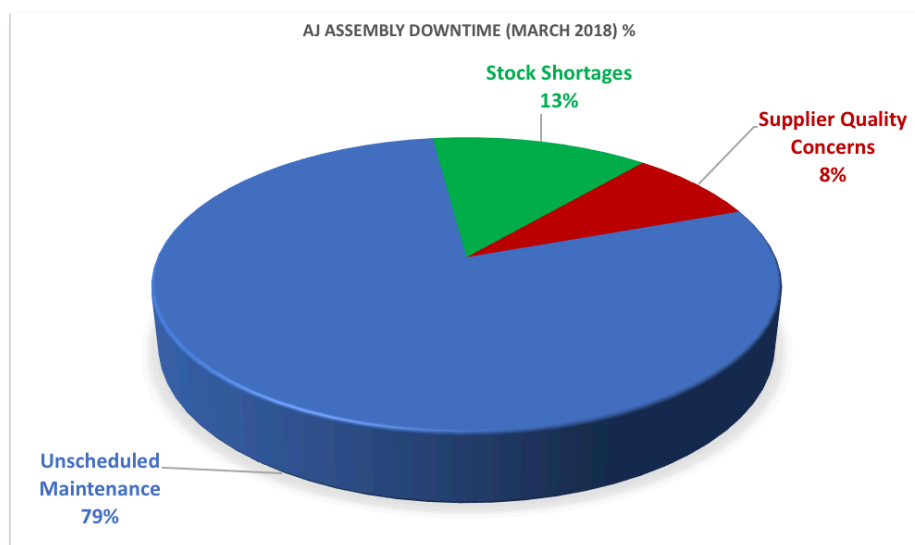


Figure 7.1 - AJ Assembly downtime (March 2018) (Ford Motor Company, 2018)

The 41% reduction in line stoppages due to stock shortages is an improvement when compared to the 2017 data shown in Figure 4.3. The reasons for this can be seen in Figure 7.2 where the data collected during March for the 'stock not tipped in time' category, shows a reduction from 5 hours and 40 minutes to 1 hour and 28 minutes, a reduction of over 4 hours.

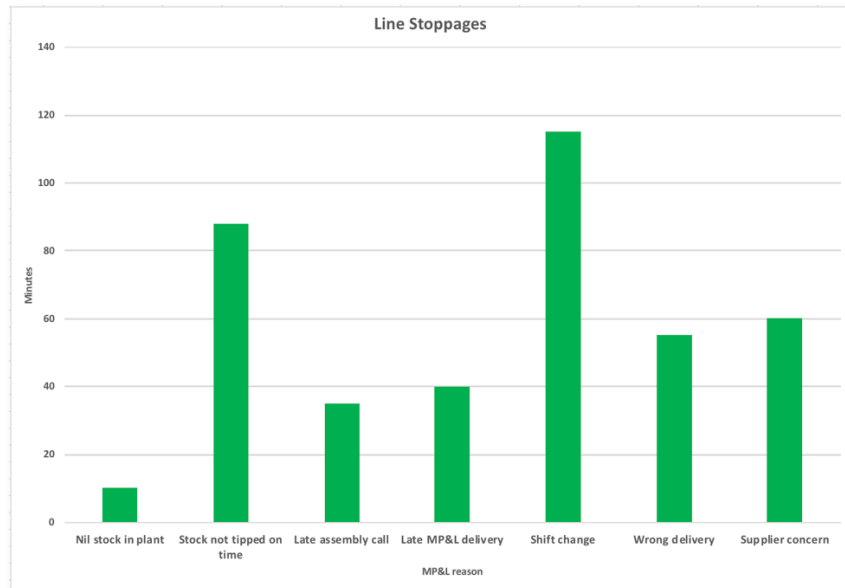


Figure 7.2 - MP&L reason for line stoppage (Mar 2018)

This improvement has had a positive and direct effect on AJ assembly and its productivity.

7.1 Calculation of OEE (March 2018)

Note: Data provided from AJ Assembly production reports (Ford Motor Company, 2018)

7.1.1 Quality

$$\begin{aligned}
 \text{Quality} &= \text{Good pieces} / \text{Total pieces} \\
 &= 12854 / 13937 \\
 &= 0.922
 \end{aligned}$$

7.1.2 Availability

This calculation is the actual operating time divided by the planned production time. Actual operating time is calculated by taking lost production time away from planned production time. Lost production time is calculated by finding the product of:

$$\text{Engine cycle time (1.716 mins)} \times \text{rejected engines (1083)} = 1858.43 \text{ minutes}$$

Understanding that AJ assembly operates Monday to Friday, November has 22 days of production. So the lost production time is:

$$1858.43 / 22 = 84.47 \text{ minutes per day}$$

Planned production time is equal to the actual time available for production, so 24hrs a day, less 67 minutes of planned break time per day, over a 5 day working week results in the planned production time:

$$24 \times 60 = 1440 \text{ minutes}$$

$$1440 - (3 \times 67) = 1239 \text{ minutes}$$

Actual operating time = Planned production time – Lost production time

$$= 1239 - 84.47$$

$$= 1154.53 \text{ minutes per day}$$

Therefore;

$$\text{Availability} = \text{Actual operating time} / \text{planned production time}$$

$$= 1154.53 / 1239$$

$$= 0.932$$

7.1.3 Performance

Performance is measured by dividing the total pieces by the operating time and dividing the solution by the run rate.

$$\text{Total pieces for November} = 13226 \text{ units}$$

$$\text{Daily operating time} = 1154.53 \text{ minutes}$$

$$\begin{aligned} \text{Monthly operating time} &= 1154.53 \times 22 \text{ days of production} \\ &= 25399.66 \text{ minutes} \end{aligned}$$

$$\text{AJ Assembly run rate} = 1.716 \text{ minutes per unit}$$

Therefore;

$$\text{Performance} = (\text{Total pieces} / \text{Operating time}) / \text{Run rate}$$

$$= (13226 / 25399.66) / 1.716$$

$$= 0.303$$

$$\text{March OEE} = \text{Performance} \times \text{Availability} \times \text{Quality}$$

$$= 0.303 \times 0.932 \times 0.922$$

$$= 0.26$$

$$= 26 \% \text{ Overall Equipment Efficiency}$$

The performance figure of 0.303 is a slight increase from 0.28 in November 2017. However, the OEE is still very low and further investigation work on the line performance, using data from March 2018 showed an increase in unscheduled maintenance and supplier quality issues, which have potentially masked the good improvements made. As this is only one month, the data will continue to be measured to get a larger spread to enable more accurate analysis. This result does however demonstrate how there are many contributing factors that influence the performance of AJ assembly and how difficult it can be to make improvements.

7.2 Inventory Cost Reduction

There were a total of 353.33 hours lost on AJ Assembly during 2017 due to inventory shortages (Ford Motor Company, 2017). That is an average of 29.44 hours per month. The chargeback labour cost per operator is £75.10 per hour. With an average 152 assembly operators shared between 11 teams the hourly cost per month could range from:

Buy-Off team

$$(8 \text{ operators} \times £75.10) \times 29.44\text{hrs} = £17,687$$

Assembly Line

$$(152 \text{ operators} \times £75.10) \times 29.44\text{hrs} = £336,063$$

The total amount of downtime caused by inventory shortages during March 2018 has decreased significantly to 1hr 28 minutes. The hourly cost could range from:

Buy-Off team

$$(8 \text{ operators} \times £75.10) \times 1.47\text{hrs} = £883$$

Assembly Line

$$(152 \text{ operators} \times £75.10) \times 1.47\text{hrs} = £16,780$$

This calculation demonstrates that even if the line stoppage in March 2018 was a worst case scenario of an entire line stoppage, it would still be under the 2017 monthly average, best case scenario.

7.3 Results summary

Even though inventory shortages have been reduced and the OEE of the line has been improved slightly, AJ Assembly has continued to underperform due to an increase in unscheduled maintenance and quality concerns. For OEE to improve there has to be a focus on the lines maintenance needs and supplier quality. However, the reduction in shortages has significantly reduced the costs accrued by AJ Assembly as explained in paragraph 8.2. This is a large step in the right direction for AJ Assembly and due to the project taking MP&L out of the internal constraints spotlight it has enthused the MP&L team to further develop the continuous improvement cycle.

Chapter 8: Control Phase

The results from the project have proven that inventory related assembly line stoppages have been reduced. For this to continue there has to be an element of control and the control phase of the project is where long lasting efficiency can be achieved by introducing methods that recognise changes to performance and delivering training in the use of these methods to improve results (Torres & Temblador, 2011).

8.1 Standardised Procedures

The goal of standardised work is for continuous improvement and its purpose is to reach an agreement on the one best way to perform a process. This ensures safety and the ability to perform accurately while consistently maintaining high standards by reducing variation (Newton, 2018). The SPL created for the new shortage process can also be referred to as a control feature, as it allows all personnel to monitor and check the process if they see something abnormal.

8.2 5S methodology

A 5S approach explained in paragraph 2.10 can be used to help in maintaining the new process.

- **Sort:** Follow the correct process and select the priority trailer.
- **Set:** Arrange the T cards and boards so they are easily identifiable and accessible.
- **Shine:** Keep everything clean which also applies to process maintenance and inspection.
- **Standardise:** Integrate sort and set in order and allow shine regularly to ensure standards are kept and they don't fall over.
- **Sustain:** Keep good discipline with good leadership and process confirmation.

(Bullington, 2003)

8.3 Process confirmation

The new shortage and tipping process has been agreed across all shifts. This was the most important part of the improvement. This ensures standards are kept and each part of the process is adhered to and is carried out exactly as agreed. This will allow the standard to be scrutinised and make it easier to identify variation. The three questions asked when carrying out process confirmation are:

1. What is the standard?
2. Was it followed?
3. Is it adequate?

(Radley, 2018)

8.4 Control Documentation

Three process confirmation check sheets have been produced. One for the MRCs, one for supervision and one for the MP&L manager. The documents allow for a daily check by the MRCs, a weekly check by the supervisor and a monthly check by the manager.

Daily MRC Process Confirmation

- All Market Place locations are labelled correctly for location, part number and min/ max levels.
- T cards are in correct locations, readable and in good condition.
- All shortage trailers are live on the system.
- Confirm surplus stock is correctly located and accounted for.

Weekly Supervision Process Confirmation

- Select random Market Place aisle and confirm if labelling is correct for location, part number and min/ max levels.
- Check surplus stock areas with shift MRC and confirm stock is accounted for.
- Select T card at a random location in the process and check if it is located correctly, readable and in good condition.
- Stop and question a warehouse person tipping a trailer as to the position of the trailer in the tipping sequence.

Monthly Manager Process Confirmation

- Walk the shortage process route.
- Select a random Market Place location and confirm labelling is correct for location, part number and min/ max levels.
- Scan random T cards for correct location, is it readable and in good condition.
- Confirm surplus stock is accounted for.
- Interrogate the shortage board with the shift MRC looking for 'dead' trailers.
- Randomly select a trailer being tipped with the shift supervisor and check its position in the tipping sequence.

8.5 Culture Control

In order to maintain the control of a process, there is an expectation on the workforce to maintain a continuous improvement mindset. This can only be achieved by the people involved feeling there is a benefit to the process being carried out. This has been achieved by the project team getting the MP&L process confirmation included in MP&L supervision

and managers Time and Data Management (TDM), which is a recognised point of time during the working day that has to be adhered to. This allows the control to be driven from the top down along with the warehouse personnel seeing the management taking ownership of an area.

The shortage process and trailer tipping sequence has also become a point on the agenda of daily production meetings between MP&L staff members and managers.

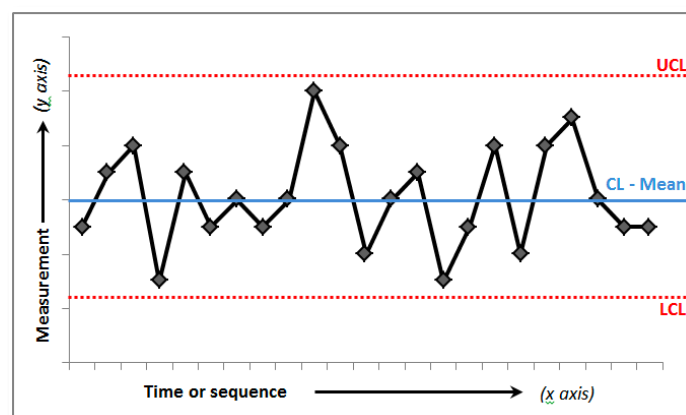
However, there will always be challenges in controlling the culture of a process change which has been covered in Chapter 6 of the project with Lewin and Kotter identifying the need to remove barriers and empower the workforce. A culture change will require constant enthusiasm from all warehouse staff, supervision and management which needs to be continually monitored before it becomes permanent.

8.6 Monitoring Plan

The monitoring plan has been agreed to allow the shortage and tipping performance to be monitored using process confirmation and TDM meetings. MP&L supervision are the owners of the plan but the MRCs will carry it out. Any major deviations can be escalated to management for decisions on the best way forward. The plan will systematically monitor the metrics and highlight both good and poor performance levels. The frequency of monitoring is still fluid as the agreed process has only just started. The metrics used will be the downtime recorded by production against material shortages.

8.7 Control Charts

Control charts provide simple visual ways of illustrating the inputs or outputs of a process. They allow you to know easily when action is needed and they allow a continual view of the process performance and can help to realise if alterations to a process are having a positive impact or not (Gygi, et al., 2012)



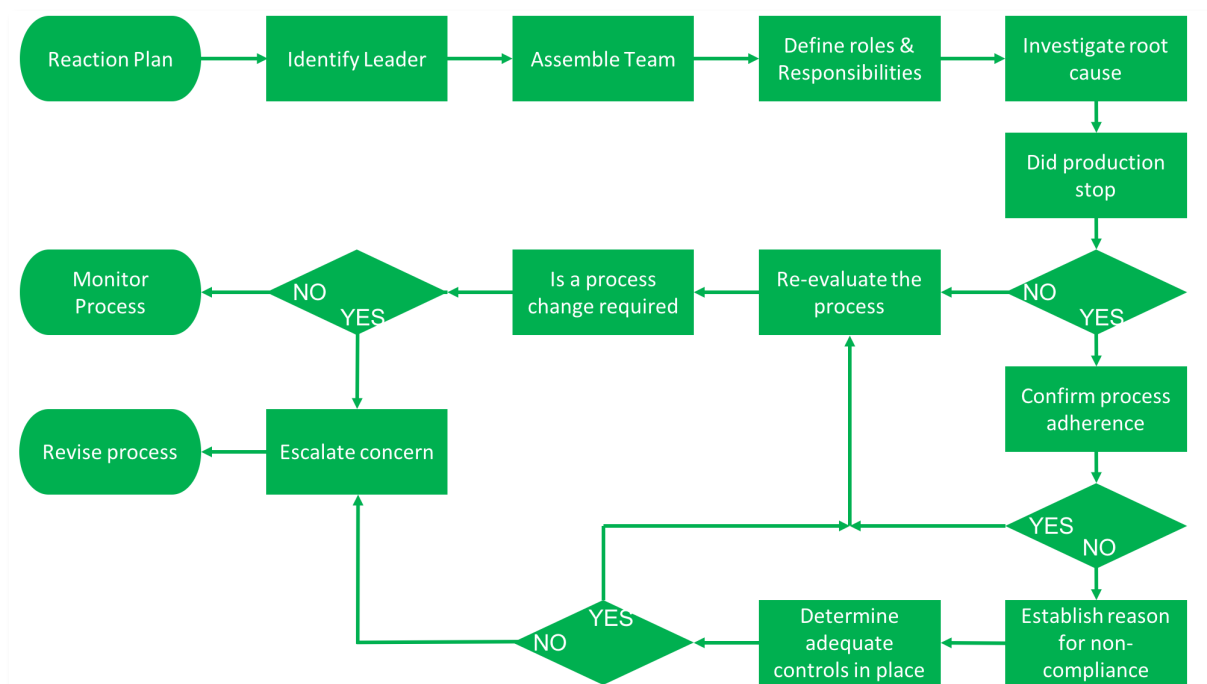
8.1 – A typical control chart (East London NHS Foundation Trust (ELFT), 2018)

An example of a control chart can be seen in Figure 8.1 that shows the central line which is at the mean of the process and upper and lower control limits which are set at three standard deviations from the mean. The chart is used to control the variations in the average of the measurable in a process. In order to accurately use the chart it should be continually updated so changes from expected outputs can be clearly identified. These changes could be caused by changes in personnel, design specs and the use of new technology.

Unfortunately, due to the process being so new, there is insufficient data available at this time to produce a working example of a control chart.

8.8 Reaction Plan

A process under control is easy to monitor and maintain. However, there must be a reaction plan in place to protect the business if the process starts to fall down. The plan will safeguard production but will also allow the process to be interrogated to establish what steps need to be taken to regain control.



8.2 - Shortage process reaction plan (Ford Motor Company, 2018)

The shortage process seen in Figure 8.2 was created in order to quickly establish what had gone wrong and to prevent a repeat occurrence. This standard reaction plan is a mechanism that allows logical steps to be taken which ensure the process regains and maintains control.

Chapter 9: Conclusions

The purpose of this project was to improve lost production time due to poor inventory control at Bridgend Engine Plant on the AJ assembly line. Throughout the project the DMAIC and six sigma methodologies have been explained and there is evidence of how the approach has been adhered to. However, it is often difficult to compare the methods used against the reality of human behaviour when executing a project like this. Strong characters in large groups of people can be very influential and increase the challenges of a new process. To evaluate the effectiveness of the project and evaluate its success the objectives set out at the start of the project must be reviewed and their outcomes considered.

9.1 Objective one – improve Inventory Control

The control of inventory has been improved. This can be seen with the process improvements and the control elements that are now in place. All shifts have agreed to the new shortage process and are continuing to carry out process confirmation which is being driven by the MP&L Time and Data Management

9.2 Objective two – Improve Internal Logistics

The internal logistics have been improved. This is visible throughout the Market Place due to a 5S strategy and an agreed shortage process that has aligned all shifts and has seen an improvement in tipping performance. The improved T cards and designated overspill areas have meant warehouse personnel can go about everyday business with more efficiency.

9.3 Objective three – Reduce Assembly Downtime

This objective has been improved in the fact that downtime caused by no stock available has been reduced. However, due to reasons out of MP&L's control, the downtime remains high and JPH low due to an increase in unscheduled maintenance. So with the hard work being appreciated by our production department in AJ Assembly, they are yet to see a noticeable improvement in JPH. The maintenance team may well look at the MP&L process improvement approach and take some lessons learnt from the success of the project.

9.4 Objective four – Reduce Cost and Waste

The cost and waste produced by poor inventory control and stock availability has been reduced dramatically. AJ assembly were on stop for 37.3 days during 2017 at a cost of £67,223. That is an average of 3 days or over £5,000 a month. With the final implementation of the process completed in February 2018, the first fully measured month was March 2018, which saw the line stop for a total of 3.74 hours at a cost of £280. This is huge achievement by the project champion and the project team.

Chapter 10: Recommendations

The recommendations are based on feedback given from the project team, the various departments directly and indirectly involved with the project along with the project champion.

10.1 Short Term 0-3 Months

Involve fleet in further discussions to enable rotation of trailers in the parking lot so the next priority trailer is the closest to the plant. This will need to include the trailer shunters who manoeuvre the trailers for tipping and storing the empty trailers. An increase to the proximity of the next priority trailer will reduce the selection, moving, tipping and relocation of the trailers and improve tipping performance. Conversely, there may be additional cost to implement this due to more shunting movements and labour hours.

Develop the process confirmation process to include the quantities of material being tipped. This will improve our booking in of parts and increase the accuracy of cycle counting. This will require very little cost or resource to implement and could be added to the MP&L supervision task list. However, there may be resistance from supervision as this will take more time out of their shift. Nevertheless, this would make further improvements to the efficiency of the MP&L department and so time should be made for a trial run.

10.2 Medium Term 3-6 Months

Spread the Continuous Improvement methodology to other MP&L locations within the plant. The improvements seen in the AJ Market Place can be transposed into the Sigma Market Place and can influence the structure and footprint of the new Dragon Market Place. This will improve and safeguard Sigma assembly from downtime caused by inventory shortages and with the success shown from the AJ Market Place, the resource for this should be easier to call on from the senior management team. The other area that would benefit would be the Dragon Market Place. As this is yet to be erected, a lessons learned or brainstorming sessions could be implemented which would only require time from the relevant people involved.

10.3 Long Term 6 Months+

Dagenham Engine Plant (DEP) has developed a shortage process whereby they use an excel based BoM to calculate the amount of parts required to fulfil the engine build schedule. The benefits from this type of planning means that all parts can be counted and allocated before a build is committed to. This would have inputs from cycle counters and supply chain to ensure accuracy and would completely prevent the production line stopping for part shortages. This process would completely change the mindset of BEP as the trailer tipping priorities would be planned and would make the shortage process a proactive one instead of being reactive to stock levels in the Market Place.

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