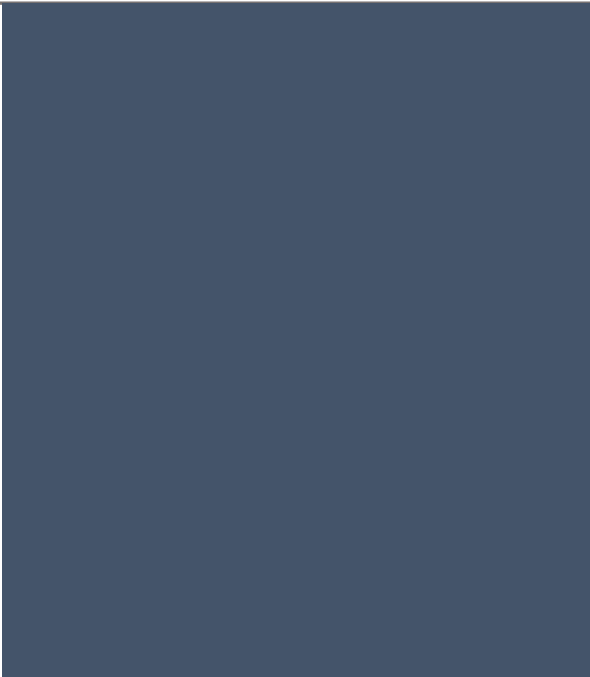




BEng Engineering

Advanced Manufacturing Systems

University Of Wales Trinity Saint David

School of Logistics and Manufacturing

M6X02307

Paul Thomas –1708327

Manufacturing Systems Engineering



Executive Summary:

Implementing lean methodologies within manufacturing is vital to improving a company's efficiency and performance. The Toyota Production System (TPS) was the pioneer of lean practices. The fundamental objective of TPS is identifying the 8 wastes, this is critical to a company's performance.

This report investigates some of the lean tools available and discusses how they must be correctly implemented to provide insight into identifying and eliminating the 8 types of waste within a process. These include value stream mapping (VSM), Process flow, Throughput, bottleneck identification, 5s and standardised work practices.

It also discusses the potential problems and costs associated with implementing lean methodology in manufacturing. These include many important considerations in relation to overcoming workforce behaviours and resistance.

1 Contents

Executive Summary:	1
2 Introduction	3
3 Toolroom Waste Identification	4
3.1 Overproduction	4
3.2 Inventory	5
3.3 Scrap and Defects	6
3.4 Waiting	6
3.5 Motion	6
3.6 Transportation/ Conveyance	7
3.7 Over processing	8
3.8 Knowledge, skills and creativity	8
4 Value from the customers perspective	9
Does a Toolroom add Value?	11
5 Evaluation of how the process may be made leaner	12
6 Potential problems, costs and rectification of problems	15
7 References	17

2 Introduction

Toyota were the pioneers of lean mass production; this philosophy became known as the TPS (Toyota Production system). The system was designed to identify and eradicate inherent waste within the manufacturing process. Womack and Jones (2003), describe lean production as "doing less, with less human effort, less equipment, less time and less space while coming closer and closer to providing customers with what they wanted". Whilst (Pieńkowski, 2014) state, TPS involved empowering the workforce to drive lean practices, this would result in increased quality, efficiency and reduced costs.

TPS recognises three basic forms of waste, Mura (unevenness), Muri (overburden) and Muda (wastefulness). According to (Chahal & Narwal, 2017) these wastes are in-stringently interlinked and their classification was vital to the success of the TPS system. These are then further broken down into the eight wastes recognisable within an organisation, see Figure 1 (Lean Enterprise Institute, 2018).



Figure 1 - The eight wastes of lean manufacturing

The TPS philosophy has been embraced by Ford Motor Company, they have used the fundamental ideologies and developed the FPS (Ford Production System). The tools within the six-sigma philosophy are critical to a lean production system. (Chandran & Nair, 2018) describe that the aim is to eliminate variation, six sigma in its basic form is the struggle for minimal variation, it is a clear illustration of how well a process performs. The system must also create value from the customer perspective and fundamentally create flow from the customer, this pull effect must drive production demand.

This report aims to identify the different types of waste that occur within the toolroom at Bridgend Engine Plant (BEP). These types of waste can be identified and eliminated through use of Six Sigma techniques, highlighting the possible problems, costs and solutions of these wastes. Lean manufacturing identifies waste as any activity within a process, that does not add value to the finished product (Wilson, 2009). Further to this (Pieńkowski, 2014) describes the considerable waste within manufacturing, highlighting the small proportion of time which can be considered value-added.

The toolroom is an indirect area which offers a service to all departments within BEP plant. Think of an indirect maintenance department as serving internal customers: the various departments and workers in the company. Typically, the work that is required of the toolroom department, is the manufacturing of parts from either samples or detailed part design drawings, these are submitted to the machine shop. The

shop then sources the material, manufactures the part(s), and returns the finished part(s) to the customer. There is also another function performed by the toolroom dept, this is the rework of components used in the engine assembly process. This can involve many functions, ranging from the drilling of holes, machine oversize/undersize dimensions or forming missing features such as chamfers.

3 Toolroom Waste Identification

3.1 Overproduction

Overproduction is repeatedly identified as the fundamental category of the eight wastes. (Kobayashi, 1995) describes it as a fundamental driver of waste and excess of work in process (WIP) and finished goods. In its most basic form, it can be defined as production out stripping demand.

However, it may be claimed that overproduction at the toolroom in BEP, is not typically recognised as a waste. The customer or receiving production areas in BEP, will often request unnecessary spares. This is to ensure that there are buffer stocks, these are often held back by different shifts ready to be utilised in machining and assembly maintenance issues, see Figure 2. This strategy of trying to protect BEP in the event of major equipment failure and lost production, is short sighted. Whilst the potential of stopping customer plants and the associated fines is considerable. Ordering and making parts purely for speculative maintenance issues, will result in overproduction of parts which are often out of date to current specifications. Whilst this seems a sensible solution, it can lead to considerable levels of redundant inventory.



Figure 2 - Stored inventory of finished parts

Though overproduction is often driven by the customer, this is not always the case. The complex machining of small batches is unlike the mass production environment. The toolroom environment is truly prohibitive to just in time (JIT) manufacturing. There are numerous limiting factors which don't allow for the JIT methodology to be effectively implemented. The balance of selecting the right batch size and not overproducing is vital to the implementation of lean methodology within a toolroom. The toolroom has a varied mix of volume and batch sizes to consider at any one time. Simple parts can be completed in minutes, whilst complex high-volume items can take several weeks or months. The complexity of machine setups can add considerable time to any job, so it needs careful consideration when deciding batch sizes.

3.2 Inventory

The TPS methodology identifies excess inventory as one of the primary wastes. (Jeffrey K. Liker, David Meier, 2005) describe this waste as the excess of raw materials, work in progress (WIP) and finished goods. This wasted inventory, is clearly evident within the toolroom. Increased inventory is incompatible with lean manufacturing methodology. One area where this is apparent is within the steels store. The toolroom holds a wide variety of stock, different types of materials, sizes and shapes, see Figure 3.



Figure 3 - Toolroom Steel Store

The balance between having available material for a quick turnaround and carrying excess inventory is a difficult one. According to (Tatikonda & Tatikonda, 1991) this form of inventory will incur additional costs to the company as result of increased carrying, storage, handling, time and opportunities for damage. A solution to this would be to use the services of a local steel supplier. The intangible increased cost of material would be offset by the ability to order the exact amount of material required. This would address the need for material to be carried, stored, handled and reduce opportunity for damage. This would be of particular use when using more expensive materials.

WIP can also be identified as inventory, this is evident within the toolroom. The reworking of out of tolerance parts, results in various parts of WIP being held. These parts are either being processed or

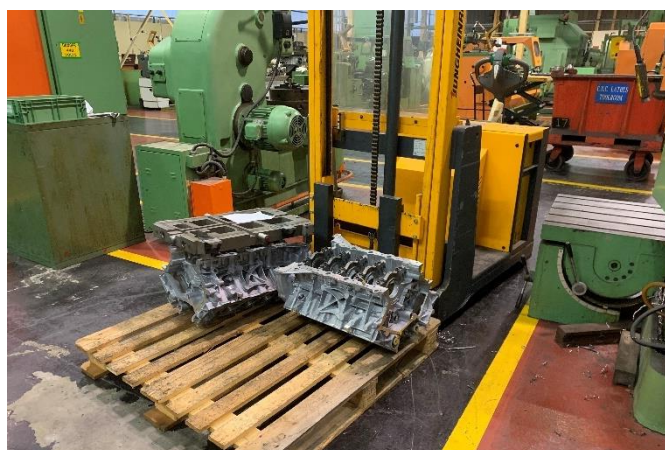


Figure 4 – WIP of reworked parts.

waiting to be processed. This is an opportunity for WIP inventory to be easily unaccounted for, this results in reduced quality control and stock control.

3.3 Scrap and Defects

Defects are a form of waste that comprise of parts that are scrapped or require rework. This form of waste is an expense in relation to both labour and raw material cost. The type of work undertaken in the toolroom is predominately the manual use of machines to produce various parts. This increases the possibility of defective parts, as human error is a mitigating factor in machine shop defects. Whilst the production of defective parts is infrequent, the result of an unidentified defect can be significant. A defect should be easily identified, at each phase of a correctly controlled production process. But due to the batch production nature of a toolroom manufacturing, when a defect is found, then the whole batch may be defective. In the toolroom environment, defects contribute significantly to increased lead time and to lost production. The scrapping or reworking of parts increases the amount of material required, amount of allocated machine time and tooling wear. This considerably increase costs which must be absorbed by the machine shop as they cannot be passed on to the customer.

Generally, when a defect is identified in the batch manufacturing of parts it can create both idle man and machine time. The manufacturing process can often involve many different machines and operations. A single defect could affect the flow through this process.

3.4 Waiting

Waiting can be simply defined as idle time within a process, an idle toolmaker can be the result of many influencing factors. The waste of waiting is also referred to as queuing, (Sternberg, et al., 2013) defines the process as one step waiting for another. The toolroom invokes a different way of thinking in relation to idle time. The batch nature of manufacture within a machine shop, denotes that idle time can either be attributed to the part waiting or the toolmaker waiting. The manufacturing flow can frequently result in a part waiting for the toolmaker to complete a part so that he can complete the next, on large batches this can be considerable. The opposite of this would be the toolmaker waiting for material stock to be sourced and cut, heat treatment to complete or simply a cnc operation to complete. The cumulation of this idle time adds considerably to part completion time, WIP and inventory of finished parts waiting to be despatched within the toolroom.

3.5 Motion

In lean manufacturing, unnecessary motion refers to employee movement which does not add value to a process or product. The waste of motion can take many forms, such as searching for parts, drawings or



Figure 5 - Examples of motion waste within the toolroom.

equipment. According to (Rawabdeh, 2005), poor ergonomics initiate waste once employees excessively bend, stretch or walk. More specifically any excess movement between machines and associated tools or controls. To improve an inefficient process, such actions must be avoided (Haider, et al., 2015).

Figure 5 above clearly illustrates how a poorly organised toolroom can affect waste in terms of motion. The lathe and tool cupboard are both very unorganised, tools and chucks are left in disarray. There is no standard to be maintained by employees, the result is the machinist's searching for the correct tools and machine accessories. The toolroom environment results in machinists being exposed to excessive wasted motion due to the hugely varying flow of production. The type of part being produced can be as simple as using one machine to be completed or multiple machines and processes, both require completely differing levels of motion. To keep any waste to minimum, toolmakers must strive to be as efficient as possible. When starting a job, a clear strategy of the process and equipment would be hugely beneficial. Utilising CNC cycle or heat treatment times to set up or plan other jobs, or simply deburring parts between cycle times to maximise efficiency. Ultimately wasted motion must be limited by applying lean methodology such as work balancing, visual factory and standardised work practices.

Further to considering the waste within motion, the cascading effect must also be considered. Any wasted motion will potentially produce other waste, for example waiting. This is due to the wasted motion slowing down a process and making another process wait, resulting in work imbalance.

3.6 Transportation/ Conveyance

Any unnecessary transportation or conveyance within any process is considered waste. This form of waste considers the movement of material or goods. (Chahal & Narwal, 2017) discuss double handling and excessive handling of material, with the increased risk of damage and decline. Further to this (Rawabdeh, 2005), consider the distance between processes and the proportional relationship to waste. They demonstrate clear evidence of the relationship in identifying quality issues, reporting time and corrective measures. The overall value of a product is directly affected by unnecessary transportation, resulting in increases in time and expense. Transportation must be kept to a minimum within the JIT manufacturing methodology. (Kootanaee, et al., 2013) states that for a JIT system to work effectively, waste must be reduced in all areas.

The manufacturing process within a toolroom starts with raw material, this is transported to the toolroom from the steel stores or an outside supplier. Then parts are transported from process to process as each feature is processed in sequence. Finished parts are then picked up by the relevant department. The flow



Figure 6 - Toolroom shop floor layout

of a workpiece through the toolroom, results in parts being potentially handled multiple times; the consequence is habitually excessive levels of waste. Figure 6 above shows the vast area of the toolroom. The toolmaker benches are located at the bottom left of the picture and the steel stores is out of picture at the far end. Parts flow through the department requiring toolmakers and the parts to potentially cover large distances between processes.

3.7 Over processing

The waste of Over processing can be defined as manufacturing products to a higher standard than required. The addition of futile processes or features generates unnecessary work. These processes or features require time and resources but don't create added value. (Rampersad, K. El-Homsi, A., 2007) define added value, as something a customer is willing to pay for. An example of this would be specifying a ground finish where a standard machined finish would be acceptable.

When considering over processing specifically within a toolroom, numerous issues can be identified. Parts are often created from part drawings; these include tolerances of part dimensions. Machinists time can often be spent trying to create parts of mean size or the perfect part. Making full use of any tolerances is perfectly acceptable, making perfect parts is potentially creating waste.

This type of waste may be incorporated in the hidden factory and may not be clear until detailed process verification has been carried out.

3.8 Knowledge, skills and creativity

The 8th waste considers the untapped human potential. (Liker, 2004) discusses the waste of an employee's knowledge and natural creativity. (SKhmot, 2017) investigates lean methodologies need to specify standard operating procedures, and how this can be counterproductive if an employee input is stifled.

This type of waste can be identified in the toolroom as toolmakers complete their work at a level that does not exceed their training level. It could be beneficial for the company to encourage employees to suggest new ideas to improve their working methods or provide additional training.

These 8 categories of waste have one significant characteristic in common. They add cost to the manufacturing process and reduce the overall profitability of the company as a whole.

4 Value from the customers perspective

In lean manufacturing, value is measured from the customers perspective. (Wilson, 2015) states that when a customer does not see value in a product, then they will be reluctant to pay for it. A fundamental component of the six-sigma methodology is appropriately understanding a customers needs. This is defined as the Voice of the Customer (VoC) (Griffith & Hauser, 1991). Identifying the VoC is essential to gaining the necessary information needed to provide a satisfactory product or service to the customer (Martin, 2008). This information is regularly referred to as Critical to Quality (CTQ), CTQ's define the customer critical requirements for a product or service. Table 1 is an example of typical CTQ requirements.

Product Quality	Service Quality	Cost
Performance	Competence	Total Costs
Features	Reliability	Terms and warranties
Timeliness	Timeliness	
Conformance	Accuracy	
Serviceability	Responsiveness	
Reliability	Access	
Aesthetics	Communication	
Durability	Courtesy	
Reputation	Credibility	
Completeness	Security	

Table 1 - CTQ Customer requirements example

Lean methodology uses numerous tools to analyse and understand a customer's requirements. The Kano model is one such tool for understanding the VoC. According to (Wang & Ji, 2010), the Kano model is vital for measuring customer satisfaction. There are 5 basic classifications within the Kano model. These 5 categories highlight different areas of customer satisfaction, these are: - basic, primary, excitement, indifferent and reverse. Table 2 below explains the different categories and their basic requirements.

Classification	Contents
Basic Attributes (Must Be)	These needs are expected by the customer. If they are unfulfilled, the customer will be dissatisfied, but even if they are completely fulfilled, the customer would not be particularly satisfied.
Primary Satisfier (More is Better)	These needs have a linear effect on customer satisfaction. The more these needs are met, the more satisfied the customer will be.
Excitement Attributes (Delighters)	These needs do not cause dissatisfaction when not present but satisfy the customer when they are present.
Indifferent Attributes	These are attributes to which the customer pays no attention. If they are present, it is nice. If they are not present it does not matter.
Reverse Attributes	If needs are fulfilled, the customer will be dissatisfied. If they are unfulfilled the customer will be satisfied.

Table 2 - Kano Model

Value stream mapping is a lean methodology tool used to define a process into separate activities, these activities are then categorised into value or non-value added (Onofrejova & Janekova, 2015). Value added (VA) or Nonvalue added (NVA) are activities that either did or did not add value to a product or service. (Crawford, 2016) states that correctly understanding customer requirements is critical to correctly determining if activities are VA or NVA. Furthermore, nonvalue added NVA's can be divided into necessary or unnecessary NVA's. When considering the fundamentals of lean manufacturing, eliminating waste is the definitive requirement. Therefore, reducing unnecessary NVA's from a process is vital as the customer is unwilling to pay for such NVA's.

Bandsaw	Turning	Milling	Grinding	Heat-treatment
Select material (NVA)	Set up Machine (NVA)	Set up Machine (NVA)	Set up Machine (NVA)	Set up Machine (NVA)
Load into saw (NVA)	Select tools (NVA)	Select tools (NVA)	Select tools (NVA)	Insert box in furnace (NVA)
Measure (NVA)	Set up tools (NVA)	Set up tools (NVA)	Set up tools (NVA)	Temperature control (VA)
Machine Setup (not cutting) (NVA)	Load material (NVA)	Load material (NVA)	Load material (NVA)	Remove box from furnace (NVA)
Machine Cut material (VA)	Machine movement (not machining (NVA))	Select speeds and feeds (NVA)	Machine movement (not machining (NVA))	Cooling period (NVA)
Inspect (NVA)	Machine workpiece (VA)	Machine movement (not machining (NVA))	Machine workpiece (VA)	Reheating (VA) (0:30)
Return material to racks (NVA)	Measure (NVA)	Measure (NVA)	Measure (NVA)	Quench workpiece (VA)
Clean machine (NVA)	Adjustment of tools (NVA)	Adjustment of tools (NVA)	Adjustment of tools (NVA)	Temper workpiece (VA)
Transport workpiece to process (NVA)	Remove workpiece (NVA)	Remove workpiece (NVA)	Remove workpiece (NVA)	Shot-blast workpiece (NVA)
	Clean machine (NVA)	Clean machine (NVA)	Clean machine (NVA)	Clean area (NVA)
	Transport workpiece to next process (NVA)	Transport workpiece to next process (NVA)	Transport workpiece to next process (NVA)	Inspect hardness (NVA)
				Transport workpiece to next process (NVA)

Table 3 - VA and NVA in toolroom manufacturing

Table 3 demonstrates the different toolroom processes and how they can be broken down into VA and NVA's. VA's are the elements of the process which are considered essential to satisfy the customer requirements. According to (Thorn, 2018) VA activities can be defined as those which alter fit, form or function. The elements of the process which are essential to customer requirements, are the elements which remove material as they alter fit, form and function of a part machined within the toolroom. Therefore, in the toolroom machining ordinarily indicates VA (value added) and non-machining indicates NVA (non-value added). Table 3 also identifies NVA's within the process, many of the NVA's can be considered necessary as a part cannot be produced without them. The NVA's can be identified from the eight basic wastes of lean methodology, including over-processing, defects, reworks, inventory, waiting-time, handling, and motion (Rawabdeh, 2005). Examples of the unnecessary NVA's are, the Idle time between machine cycle times, excessive transport time between processes or excessive time selecting or locating material or tools.

Ultimately, the customer will not be prepared to pay for any elements of waste or NVA within a process. According to (Davis & Davis, 2011) NVA's do not contribute to value, they merely deplete resources. Whilst (Fernández-Solís & Rybkowski, 2012) maintain that to achieve value, the provider must fulfil customer requirements.

4.1 Does a Toolroom add Value?

A toolroom can provide a valuable service to modern manufacturing facilities. But the toolroom can only be valuable if its service is deemed as adding value. To do this, the toolroom must be able to produce a service equal or superior to an outside provider. This requires a service which can turn around parts quicker, cheaper and of improved quality. When the volume of mass-producing parts is considered, time is of the upmost importance. The result of having an in house toolroom, a company will save time and most importantly money from reduced downtime. But only the functions which add value are of advantage to the company. The burden of overheads such as wages, materials and energy bills do not add value. As a result, a toolroom must apply lean practices to ensure it value to the company.

5 Evaluation of how the process may be made leaner

There are many investigative tools and procedures available to make processes leaner, among them is the Lean Six Sigma DMAIC methodology. DMAIC is fundamental to the Ford Motor Company lean strategy. This is as a consequence of its ability to aid problem solving in mass production environments. Figure 7 below is a breakdown of the DMAIC categories and they're objectives.

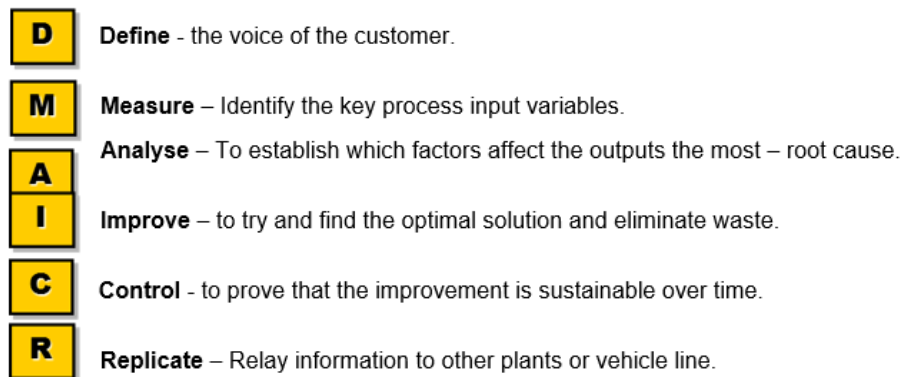


Figure 7 - DMAIC categories explanation

The DMAIC strategy incorporates a range of tools that establish the root cause of a problem and facilitate implementation of continuous improvement. Two fundamental tools within lean methodology are process mapping and Value stream mapping (VSM). A process map is a detailed analysis of the process, including all steps of the process however insignificant. Undertaking this correctly identifies any hidden factory within the process. According to (Wilson, 2015), correctly understanding product value is critical to clearly understand a process. This understanding is fundamental to create pull within product flow.

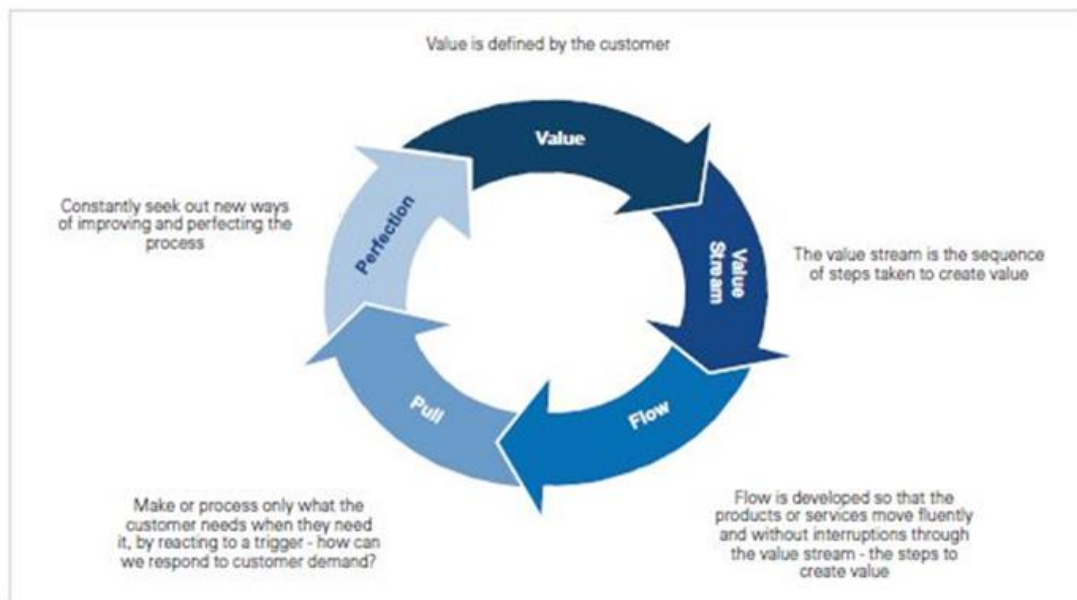


Figure 8 - Continuous improvement cycle (Lean Enterprise Institute, 2018)

(Balaji, et al., 2016) describe VSM ability to analyse a current state and allow for the proposal of the required future state. The TPS system referred to VSM as "material and information flow mapping" (Jeffrey K. Liker, David Meier, 2005). Figure 8 displays the cycle of continuous improvement with the aim of

removing all unnecessary waste within a process. When the optimal state for a process has been accomplished, the continual improvement cycle simply starts again, waste must be constantly identified and eliminated (Lean Enterprise Institute, 2018)

As previously discussed, Table 3 establishes VA and NVA within different toolroom processes. This can help understand throughput for a part in the toolroom. Throughput is a measure of the time taken from raw material to finished item. Increasing part throughput improves on delivery time and the burden on toolroom resources. (Koenigsaecker, 2016) discusses the ability of increased throughput to reduce costs, WIP inventory and ultimately waste.

Increasing throughput can be achieved by identifying and eliminating bottlenecks. (AlManei, et al., 2017) states for continuous processes, eliminating bottlenecks is vital to speed up a process and increase throughput. (Wilson, 2015) describes how careful management of bottlenecks, will result in reduced work in progress (WIP) inventory and increased throughput. Improvements can be made by investing in the weakest machine component of any process (Rampersad, K. El-Homsi, A., 2007). This increase in efficiency is measured by Overall Equipment Efficiency (OEE). OEE considers the machines within a process and their capacity, quality and performance. By improving the OEE of bottleneck processes, throughput efficiency will increase.

According to (Balaji, et al., 2016) a clear strategy for any lean methodology should aim to:-

- Establish the process flow in a production line.
- Evaluate cycle time for each process.
- Generate VSM of the current state.
- Identify the bottleneck of current state value stream map.
- Ascertain the value added (VA) and non-value added (NVA) activities.
- Employ lean tools to curtail non value added activities.
- Create a VSM for the future state value.

Whilst the toolroom is unlike the mass production environment, it must also eliminate all unnecessary waste. The TPS system is tuned for low mix high volume (LMHV) and not the high mix low volume (HMLV) of toolroom work. As a result, special thought is required when trying to implement lean methodologies. According to (Fabtech, 2016), there are many special characteristics which separate the toolroom from high volume production. They need careful consideration, these include: -

- A diverse mix of products and batch sizes.
- The manufacturing process can differ widely for each type of product.
- The facility layout is based around machine type, where each product can pass through several areas of the facility, possibly several times.
- Product demand fluctuates extensively.
- Production bottlenecks vary for each product.
- Production scheduling and control is complex and varies daily

According to (Fabtech, 2016) the HMLV requirements of the toolroom necessitate the need for a different strategy to the LMHV. Table 4 below identifies lean tools which are appropriate for implementation within a machine shop.

Tools that <i>will</i> Work in Most Jobshops	Tools that <i>will not</i> Work in Most Jobshops
Strategic Planning (aka Hoshin Kanri)	Value Stream Mapping
Top-Down Leadership	Assembly Line Balancing
Employee Involvement	One-Piece Flow Cells
5S	Product-specific Kanbans
TPM (Total Productive Maintenance)	FIFO Sequencing at Workcenters
Setup Reduction (SMED)	Pacemaker Scheduling
Error-Proofing (Poka-Yoke)	Inventory Supermarkets
Quality At Source	Work Order Release based on Pitch
Visual Controls & Visual Management	Production based on Level Loading (Heijunka)
Product and Process Standardization	Mixed Model Production with Takt Time
Right-sized Machines	
Jidoka	
Standard Work	

Table 4 - Lean tools for machine shops

When applying lean tools within the toolroom, adding value must be of the upmost importance. The cutting of material is the fundamental requirement of a toolroom's function. The critical objective is to reduce waste, add value and eliminate nonvalue added processes. The correct selection of lean tools and their precise application is vital to the successful implementation of any lean strategy.

6 Potential problems, costs and rectification of problems

Adoption of lean methodology requires a combination of resources, these include time, manpower, materials and finance. Implementation of change frequently encounters strong resistance from employees. To overcome this, strong management is critical as it must lead and support employees. According to (Wilson, 2015) employee resistance to change is driven from the cultural influences in a workplace. In addition to this (Alhuraish, et al., 2017), describe the difficulties of implementing the most basic of lean tools, this is due to overcoming ingrained workplace behaviours.

Typically, within Ford Motor Company, all six sigma projects must undergo detailed financial analysis before implementation can begin. The DMAIC approach typically used within FMC, is driven from data collected from critical Ford measurables. The accuracy of this data is vital to the correct understanding of a process's performance. The cost of implementation of any lean practice must not outweigh the perceived benefits, the correct analysis of data is vital to this. The expected benefit will often fall short of expected return, if this detailed analysis is not undertaken correctly. (AlManei, et al., 2017) outlines figures as high as 58% fail rate in achieving expected returns in lean project implementation.

Although six sigma can be beneficial to an organisation, the identification of multiple root causes can also be detrimental in the short term. This is in respect to the number of projects created, and the resultant burden on company resources. (Achanga, et al., 2006) discovered that up to 90% of lean projects are over budget or late. The disruption caused by implementing multiple lean tools can affect both employers and employees. To correctly manage these lean practices, requires excellent communication, training and leadership (Achanga, et al., 2006). Table 5 displays some of the potential physical obstacles which must be overcome in any lean and agile workplace (Palsodkar & Pansare, 2018).

Barriers to Lean Manufacturing
Lack of top management support and commitment
Fear of and resistance to organizational change
Lack of methodologies to enhance agility
Insufficient training, education and rewards system

Table 5 - Barriers to lean manufacturing (Palsodkar & Pansare, 2018)

Further to this, problems can occur with machines which cause disruption to a process. Machines performance is critical to flow within manufacturing. The balance between introducing preventative, planned or a similar maintenance plan is critical to achieving maximum efficiency from manufacturing machines. The management of inventory and maintenance must be monitored to limit the effect of product flow.

7 Conclusion

This report has highlighted that the correct implementation of lean methods can be a very productive course of action for any company. The precise identification of any waste that exists within a process is vital to its success. The 8 different wastes must be clearly identified and as much waste removed from the process as possible.

The voice of the customer (VoC) is of the upmost importance, the ability to understand a customer's needs and specifically provide a product which meets all their fundamental requirements is crucial. Once this is understood, value and non-value must be identified and targeted using the lean tools at a manufacturer's disposal. In particular all unnecessary NVA must be eliminated from a process, the result will be a leaner process. The toolroom should target the removal of material in respect to fit, form and function as its primary objective, as this creates the maximum VA within its function.

The flow through a process must be one that creates pull between processes, as this pull is critical to a lean manufacturing process, this must be a fundamental objective. The correct identification of bottlenecks processes and subsequent increased throughput are also vital. The Toolroom would particularly benefit from the implementation of 5s and standardisation of work practices, these would lead to using more advanced tools once the basics are established. The objective of continuous improvement is unchanging, once the optimal state is reached then the process will start again. The result is a continual improvement in its lean performance.

There are many challenges that must be overcome when implementing lean methodology in the workplace. The introduction of new work practices will undoubtedly face resistance from ingrained work behaviours, resistance to change and a poorly informed workforce. This must be overcome by clear communication from leadership within a lean and agile organisation. Finally, the necessary resources must be made available. This could be in the form of time, manpower or finally financially.

8 References

- Achanga, P., Shehab, E., Rajkumar, R. & Nelder, G., 2006. Critical success factors for lean implementation within SMEs. *Journal of Manufacturing Technology Management*, 17(4), pp. 460-471.
- Alhuraish, I., Robledo, C. & Abdessamad, K., 2017. A comparative exploration of lean manufacturing and six sigma in terms of their critical success factors. *Journal of Cleaner Production*, Volume 164, pp. 325-337.
- AlManei, M., Salonitis, K. & Xu, Y., 2017. Lean Implementation Frameworks: The Challenges for SMEs. *Procedia CIRP*, Volume 63, pp. 750-755.
- Balaji, K., Hari Prasad, V., Gopi, S. & Karthick, N., 2016. APPLICATION OF LEAN TOOLS (VSM, SMED, KAIZEN) IN MINIMIZING THE LEAD TIME IN GEAR MANUFACTURING PROCESS. *International Journal of Scientific & Engineering Research*, 7(5).
- Bjorklund, S., Pribytkova, M. & Karaulova, T., 2010. *DEVELOPMENT THE MAINTENANCE PLAN: MAINTENANCE ACTIVITIES ON OPERATIONAL LEVEL*. Tallinn, 7th International DAAAM Baltic Conference INDUSTRIAL ENGINEERING.
- Chahal, V. & Narwal, M. S., 2017. An empirical review of lean manufacturing and their strategies. *Management Science Letters*, 7(7), pp. 321-336.
- Chandran, R. B. & Nair, D. S., 2018. Six Sigma Implementation in Ford Company. *International Journal of Latest Engineering and Management Research (IJLEMR)*, 3(1), pp. 38-42.
- Crawford, M., 2016. *5 Lean Principles Every Engineer Should Know*. [Online] Available at: www.asme.org [Accessed 12 June 2018].
- Davis, C. E. & Davis, E. B., 2011. *Managerial Accounting for Strategic Decision Making, Preliminary Edition*. USA: Wiley and Sons.
- Development Team Productivity Press, 2005. *Lean Culture: Collected practices and Cases*. :CRC Press.
- Fabtech, 2016. *Value network mapping an alternative to value stream mapping for implementing lean in a high mix low volume hmlv fabrication facility*. [Online] Available at: <https://www.fabtechexpo.com/blog/2016/08/17/value-network-mapping-an-alternative-to-value-stream-mapping-for-implementing-lean-in-a-high-mix-low-volume-hmlv-fabrication-facility> [Accessed 10 07 2019].
- Fernández-Solís, J. L. & Rybkowski, Z. K., 2012. A Theory of Waste and Value. *International Journal of Construction Project Management*, 4(2), pp. 89-105.
- Ford, 2011. *OpenSourceSixSigma*. USA: An Open Source Six Sigma, LLC Publication.
- George, 2005. *The Lean Six Sigma Pocket Toolbook*.
- Griffith, A. & Hauser, J., 1991. The Voice of the Customer. *Marketing Science*, 02.
- Haider, A., Jahanzaib, M. & Wasim, A., 2015. Lean capacity planning for tool room: An iterative system improvement approach. *Advances in Production Engineering & Management*, Volume 10, pp. 169-184.
- Hines, P. & Rich, N., 1997. The seven value stream mapping tools. *International Journal of Operations and Production Management*, 17(1), pp. 44-46.

- Jeffrey K. Liker, David Meier, 2005. *The Toyota Way Fieldbook*. New York, U.S: McGraw Hill Professional.
- Keller, P., 2011. *Six Sigma Demystified*: McGraw-Hill Education.
- Kobayashi, I., 1995. *20 keys to workplace improvement*. Portland: Productivity Press.
- Koenigsaecker, G., 2016. *Leading the Lean Enterprise Transformation*. s.l.:CRC Press.
- Kootanaee, A. J., Kootanaee, S. G., Solehboni, Z. A. & Kootanaee, J. A., 2013. Just-in-Time manufacturing system, Revolution in Management Accounting From concept to implement. *International Review of Management and Business Research*, 2(1), pp. 133-148.
- Lean Enterprise Institute, 2018. *Principles of Lean*. [Online]
Available at: www.lean.org
[Accessed 5 July 2018].
- Liker, J., 2004. *The Toyota Way: 14 Management Principles from the Worlds Greatest Manufacturer..* USA: CWL Publishing Enterprises.
- Martin, J. W., 2008. *Lean Six Sigma for the Office*. USA: CRC Press.
- Nightingale, J. Srinivasan D., 2011. *Beyond the Lean Revolution: Achieving Successful and Sustainable Enterprise Transformation*. s.l.:AMACOM Div American Management Association.
- Onofrejova, D. & Janekova, J., 2015. Value Stream Mapping and its Significance in the Production Process. *Acta Logistica*, 2(3), pp. 13-16.
- Palsodkar, M. & Pansare, R., 2018. Barriers and Enablers in Agile Manufacturing of Product. *International Journal of Scientific & Engineering Research*, 9(5).
- Peters, R., 2014. *Reliable Maintenance Planning, Estimating, and Scheduling..* Oxford: Gulf Professional Publishing.
- Pieńkowski, M., 2014. Waste Measurement Techniques For Lean Companies. *International Journal of Lean Thinking*, 5(1), pp. 9-24.
- Rampersad, K. El-Homsi, A., 2007. *TPS-Lean Six Sigma: Linking Human Capital to Lean Six Sigma : a New Blueprint for Creating High Performance Companies*. Chicago , U.S.A: Infomation Age Publishing .
- Rawabdeh, I. A., 2005. A model for the assessment of waste in job shop environments. *International Journal of Operations & Production Management*, 25(7/8), pp. 800-822.
- SKhmot, N., 2017. *The 8 Wastes of Lean*. [Online]
Available at: <https://theleanway.net/The-8-Wastes-of-Lean>
[Accessed 07 01 2018].
- Sternberg, H. et al., 2013. Applying a lean approach to identify waste in motor carrier operations. *International Journal of Productivity and Performance Management*, 62(1), pp. 47-65.
- Tatikonda, L. U. & Tatikonda, R. J., 1991. Overhead Cost Control - Through Allocation or Elimination?. *Production and Inventory Management Journal*, 32(1), p. 37.
- Thorn, A., 2018. *Lean and Agile manufacturing Systems*. Swansea: UWTSD.

Wang, T. & Ji, P., 2010. Understanding customer needs through quantitative analysis of kano's model.. *The International Journal of Quality & Reliability Management*, 27(2), pp. 173-184.

Wilson, L., 2009. *How to Implement Lean Manufacturing*.:McGraw Hill Publishing.

Wilson, L., 2015. *How to implement lean manufacturing*. Second ed. New York: Mcgraw-Hill Education.

