

University of Wales Trinity Saint David

School Of Engineering

Evaluating the Effectiveness of Chosen
Maintenance Strategies for Dedicated
Equipment

Plant and Asset Engineering ACMA 6007

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Summary

The report examined the efficiency of an asset and what could be done to reduce the energy requirement for optimum operation. Further study looked at methods of evaluating maintenance requirements from an engineering perspective, the goal being to reduce the amount of waste being produced and increase operation efficiency.

The first task of the report was to present the background of the company involved. Caerbont Automotive Instruments, a manufacturing company specializing in classic car gauges for vehicles such a Porsche 911 to Land Rover series 1.

The asset chosen was a fiberoptic laser cutter which produces various flat components within the assembly process of a car instrument. This laser cutter can produce hundreds of components per day due to its high-speed cutting and precision. It works when optical fiber is pumped using high powered laser diodes, which then stimulates the active medium to generate laser light by the optical fiber. The laser beam fed to the cutting head uses optical fiber which then cuts the material to create the component.

The next task was to review the current laser maintenance method. The evaluation showed that in the maintenance procedure set, there were areas of reactive maintenance being implemented and also breakdowns due to the machine creating defective components.

When gathering data of performance metrics of the laser cutter, it was seen that one area of the laser could be improved to increase the overall effectiveness of the asset. It was through a cause-and-effect analysis that the root cause was identified as being from deterioration of consumables which then caused high number of defects in production.

Through research, total productive maintenance strategy was the ideal suggestion to improve the current performance of the laser cutter. The team identified areas that require workplace organizational methodology and suggested implementation of new storage equipment to assist.

It was suggested that when the machine is returned to its original condition, a record is made of the equipment's overall effectiveness, the intention being of setting a new standard of quality. A further idea was a schedule would be followed, to prevent the deterioration of the laser cutter created. This would assist in training the maintenance and operating team , help in identifying their roles and improve overall quality of products.

Major costs were estimated to implement the previous techniques and illustrated shown through cost-benefit analysis. Areas were highlighted which had the largest impact on cost from labor needed for workplace organization and the initial training of maintenance practices set within the schedule.

In conclusion, the study demonstrated that with correct preventive maintenance methodology and a greater understanding of its impact, this improvement can improve the production process. The evaluation can be a profitable solution for improving the asset quality and life span while producing a lower failure rate in components for gauge manufacturing.

Introduction

The assignment focused on the evaluation of a current piece of equipment used in the workplace and assessed the maintenance required for that asset. It further explored how to study the effect of equipment, its process and how the consumption of energy could be reduced. The study examined what is required from engineering to ensure equipment can operate effectively and enable a reduction in waste.

The company the report focused on is Caerbont Automotive instruments, a manufacturing company that specializes in car instrumentation including gauges such as speedometers, tachometer and time clocks. The organization mainly provides services in the classic car market for brands such as Austin Martin DB5, Porsche 911 and Landover series 1.

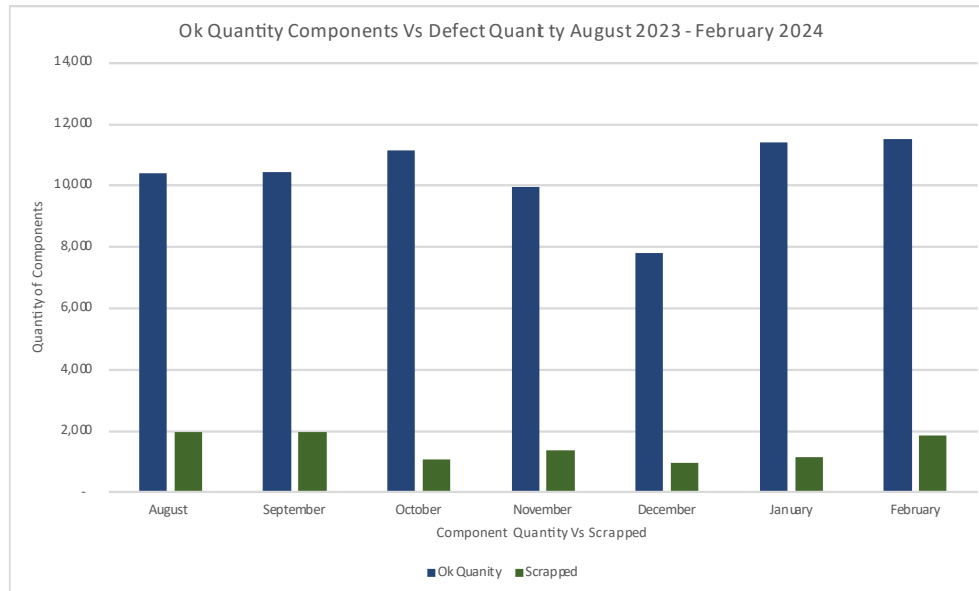
A fiber laser cutter was introduced to create flat metal components used in instrumentation. This investment by the company was to save costs in setting press tooling to create flat components which have multiple operations while the fiber laser has only one and would be considered a less labor-intensive process.

The goal considered is the study is the effects of neglect of certain maintenance requirements of the fiber laser and the lack of resources proving to affect the quality and potentially the longevity of the asset.

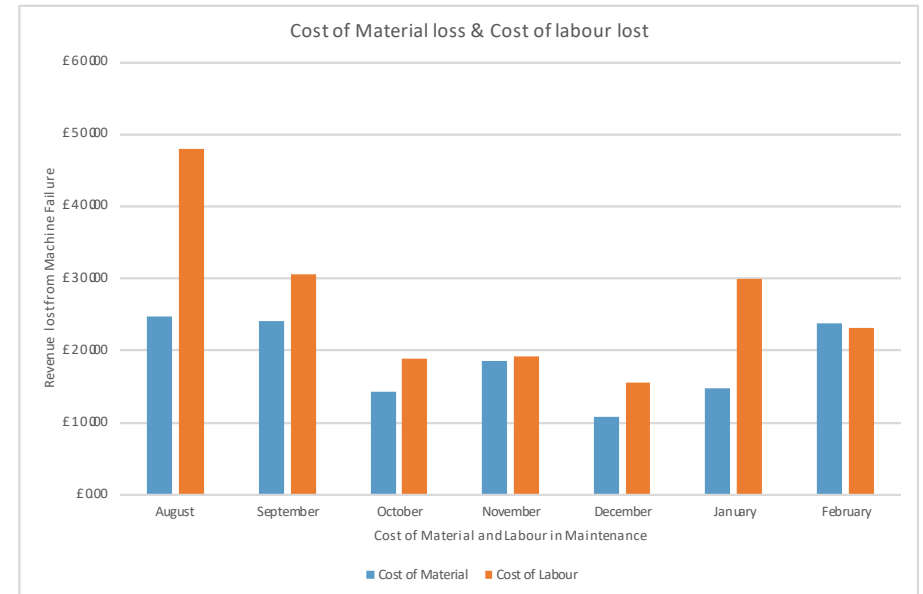
Problem Statement

From August 2023 to January 2024, there has been a recorded loss of over £1,315 in revenue due to waste reported from the laser cutter. This proved to be an increase compared to the six months previous and has causing delays in production and further loss in income for the company. It was further suggested to review the laser asset due to the breakdowns caused by the high defect rate.

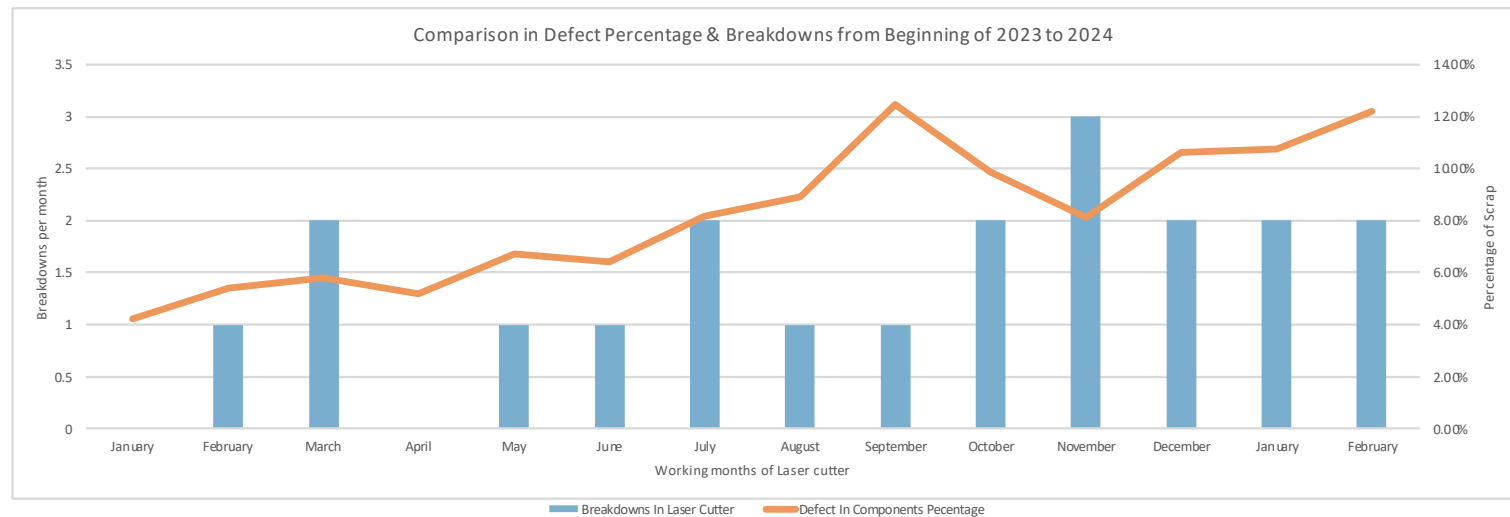
Problem Statement Data



Graph 1 Ok Quantity Components Vs Defected



Graph 2 Cost of Material & Cost of Labour



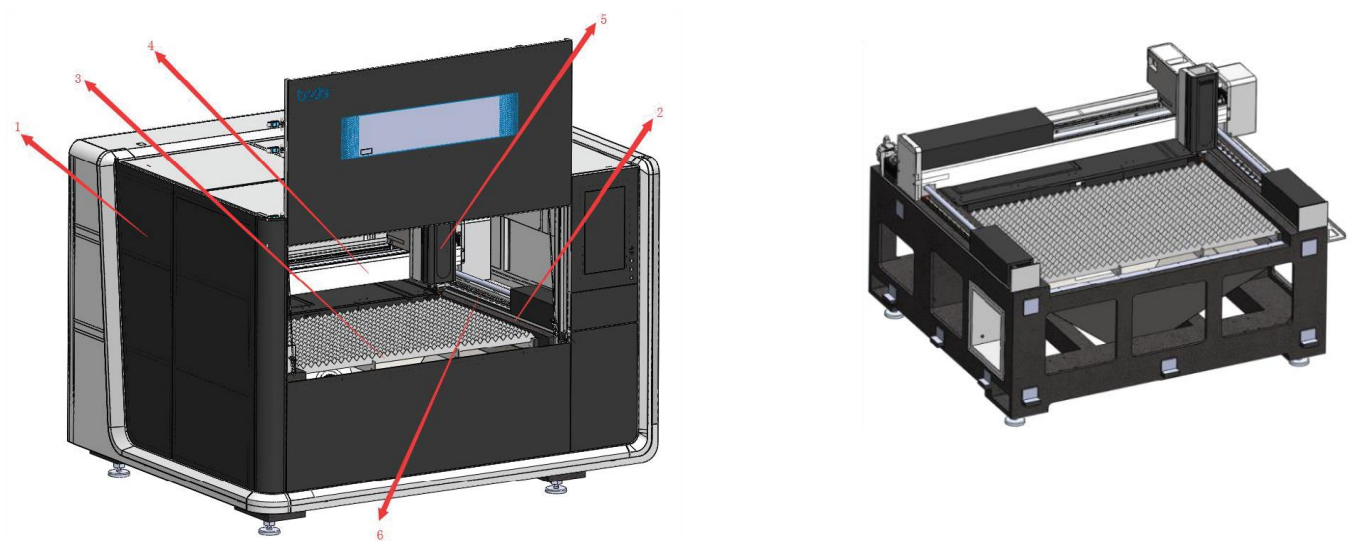
Graph 3 Comparison in Defected & Breakdowns

Reviewing the Asset

Fiber optic laser cutting machines have become the driving force behind sheet metal parts. This has forced manufacturing to move away from more traditional methods of cutting such as cutting press tools or CO2 laser. As described by Dawe, M (2021), the modern fiber laser cutter enables an exceedingly high cutting performance while having the ability to cut singular parts and small or large quantities without having to invest in expensive equipment. Unlike CO2 lasers, the fiber laser consumes less energy and because of the short wavelength can be forced to a smaller diameter resulting in faster cutting speeds.

The process involves optical fiber cables passing through utilizing high powered laser diodes. This stimulates the active medium to generate laser light by optical fiber. Dawe, M (2021) further mentions that when the powerful laser hit the material, the high intensity light is absorbed and converts to heat which then melts the material.

The laser head z axis is controlled by numerical system. The motor drives the ball screws and the laser head is connected to the plate replicate as described by Bodor (2023). For movement around the bed, the X axis and Y axis are driven by ball screws of servo motors.



- 1: Outer Enclosure
- 2: CNC Bed
- 3: Worktable Racking
- 4: Beam Runner
- 5: Laser Z Axis
- 6: Ball Screw Drive

Figure 1 CNC Fiber Laser Cutter by Bodor (2023)

Review of Current Maintenance Strategy

Maintenance history checklists set by the company show the current type of maintenance would be described as mostly preventative or reactive. The preventive maintenance could be mostly based around daily routine tasks that take up a low amount of time and labour to complete. For the laser, this is shown to be around cleaning and checking laser condition.

Unfortunately, there is also reactive maintenance involved within the company's processes. Areas that require reactive maintenance are causing higher labour times due being underprepared and lacking resources to perform some operations. Such maintenance areas such as laser head were somewhat neglected or partially complete which could prove to be impactful on performance and efficiency.

The method of reactive maintenance is described by Mobley, K.R (2014) and used for the laser cutter because of the short-term cost savings as repairs are only performed when required. The company is only replacing resources when they break or run out therefore only paying for what they use. This also means there is no stock of replacement parts or stock control on site for the laser cutter resulting in a possible higher level of risk in performance.

Reviewing Performance in Manufacturing

Historical data in the performance of the laser cutter was collected to get to the root cause of the problem. To assess the current condition, the key performance indicator suggested by Peterson, D (2021) was the overall equipment effectiveness which is a combination of the losses from metrics, availability, quality, and performance. The problem statement suggests that the laser lacks efficiency due to the reject rate, meaning using OEE will help gain insight to where improvements to the failure rate can save the company money long term.

The data gathered also shows the amount of rejects being produced by the laser cutter and the overall percentage of failure.

Maintenance task is partially done

Figure 2 Maintenance Data Showing the Cost & Efficiency

Laser Cutter Performance Data

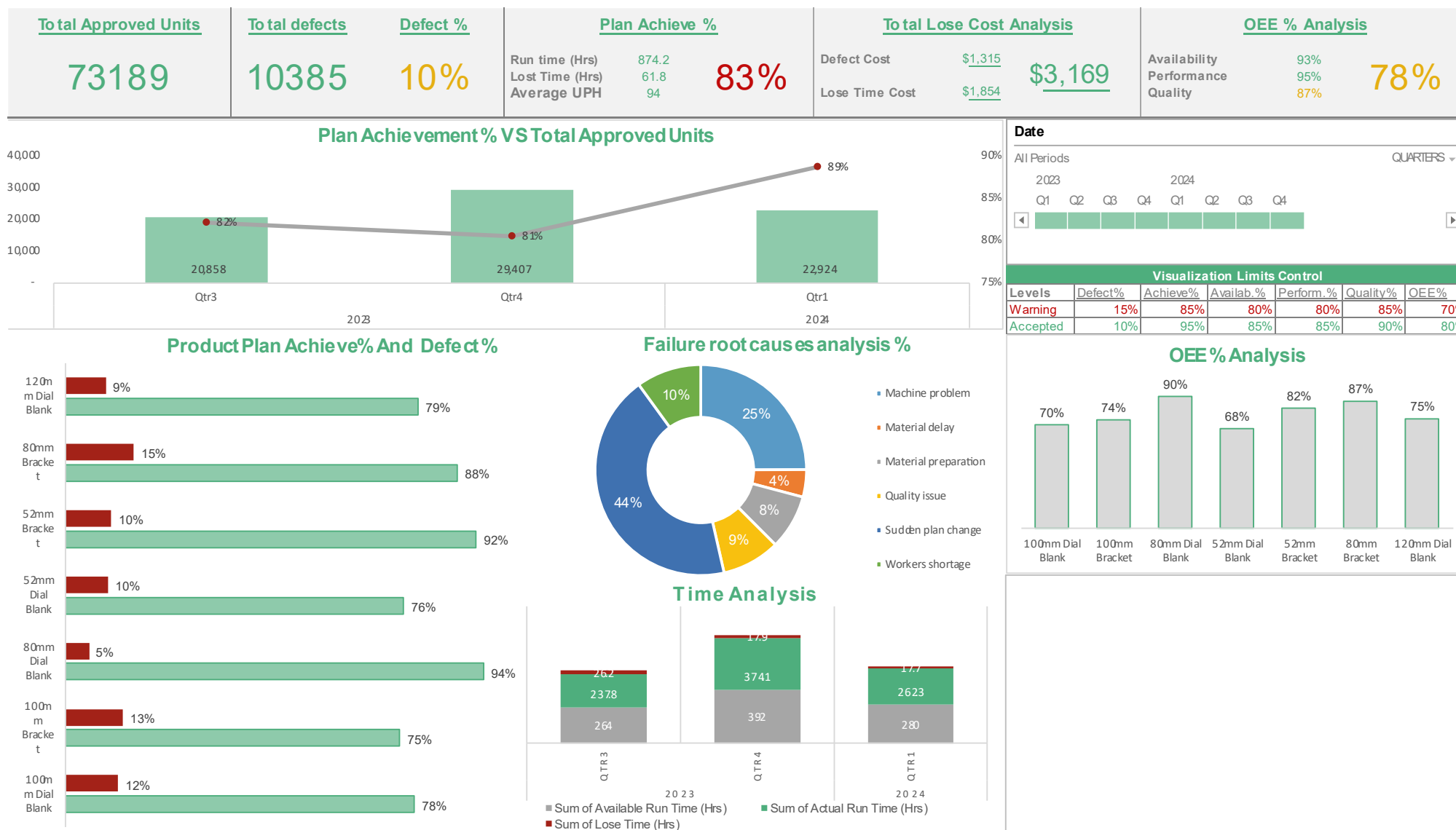


Figure 3 Historical Data of Laser Cutter Performance & Efficiency

Risk Management & Root Cause

The next step was to gather information regarding the current condition with the goal of understanding what the potential causes affecting performance are. Collecting data on current condition or abnormality is also known as fuguai and is suggested by Hasrulnizzam, W (2021) to be any disturbance in the process that is not normal. This further involved inspecting the laser equipment, noting any abnormalities, and then recording them onto a log worksheet where they were graded on their level of risk to performance. The company assessed the risks involved and possible future problems. After reviewing the performance of the laser and current maintenance in the workplace, they were able to recommend practices to minimize risk as reasonably as possible - discussed by Cambell, D.J (2010).

Failure modes also should be identified after inspection of the machinery to detect problems associated with the process. This is regarded as one of the elements in reliability centered maintenance as described by Mobley, K (2015) in The maintenance engineering handbook. The key advantage of this technique is by systemically evaluating each failure mode, the team can quantify and devise precise correction actions.

With the data collected both historical and current, the team could determine what is the cause of the problem by using a cause-and-effect analysis. This would help identify different underlying causes so that the appropriate action is taken to correct the issue. This can be grouped with a 5 whys method to find the real cause and not a symptom.

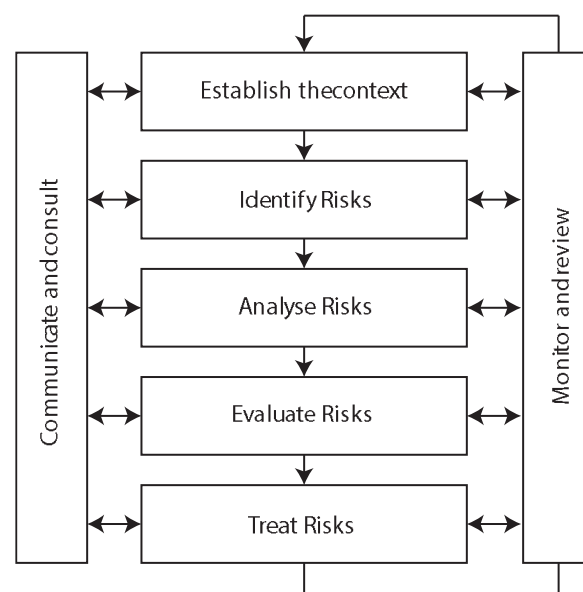


Figure 4 Managing Risk by Cambell, D.J (2010)

Risk Analysis

Risk Analysis Fiber laser Cutter 25/03/2024PAGE 1											PAGE 2											
F TAG ID	Risk Description	Caused by	Consequenc es	Risk Owner	Probabi lity	Impac t	Risk Rating	Sug gested Control	Control Owner	Image Photo	F TAG ID	Risk Description	Caused by	Consequenc es	Risk Owner	Proba bility	Impac t	Risk Rating	Sug gested Control	Control Owner	Image Photo	
R1	Automatic lubrication for x and y rails low.	Lack of care when monitoring auto lubricating system	Cause damage to rail ing which will prove costly	Andy Marks,, Lewis Nekrews, Josh Griffiths	Medium	Mediu m	Moderate	Check and clean up the slag and dust from X/Y- directional dustcloth.	Andy Marks (Machinist), Josh Griffiths		R5	Compressor unit showing error (Maintained Required)	Missed survive to compres sor, creating error message	Breakdown could occur due to neglect	Christine Rodgers, Dave Belton, Jan Healy	High	Mediu m	Severe	Request full maintained of compressor & service plan to avoid being overdue of servicing	Christine Rodgers (production manager),Jan n Healy (Sales)		
R2	Gas cannisters are not stored correctly	Lack of safety procedures put in place	Cannisters could fall and risk getting damaged	Lee Poiner, Kevin Richards	Low	Mediu m	Moderate	Check the pneumatic elements and pipeline in the pneumatic system	Christine Rodgers(Prod uction Manger),Dave Belton (Engineering Manager)		R7	Ventilation system's filters blocked full of dust	Can be a health hazard to employees with lack of ventilation.	Breathing in dust partial can cause lung damage	Christine Rodger, Mathew Rodgers	Mediu m	High	Severe	Support Employees and offer other benefits apart from money	Christine Rodgers		
R3	Chill er cooling system close to low level	Chill er fluid not replenished or is leaking	Can cause overheating and damage to laser head & further halting production processes	Kevin Richards, Lloyd Battrick	Medium	Mediu m	Moderate	Completely discharge cooling water in the filter, and then add new cooling water	Christine Rodgers(Prod uction Manger), Dave Belton (Enginee ring Manager)		R8	Laser nozzle wearing	Wear caused by incorrect parameter s inputted into machine or from overdue of machinery	Poor quality product from laser cutter or clean cutting	Dave Belton, Christine Rodgers, Gavin Roberts	Low	Very High	Critical	Offer other work or job within company	Dave Belton, Christine Rodgers, Gavin Roberts		Potensial Root Cause

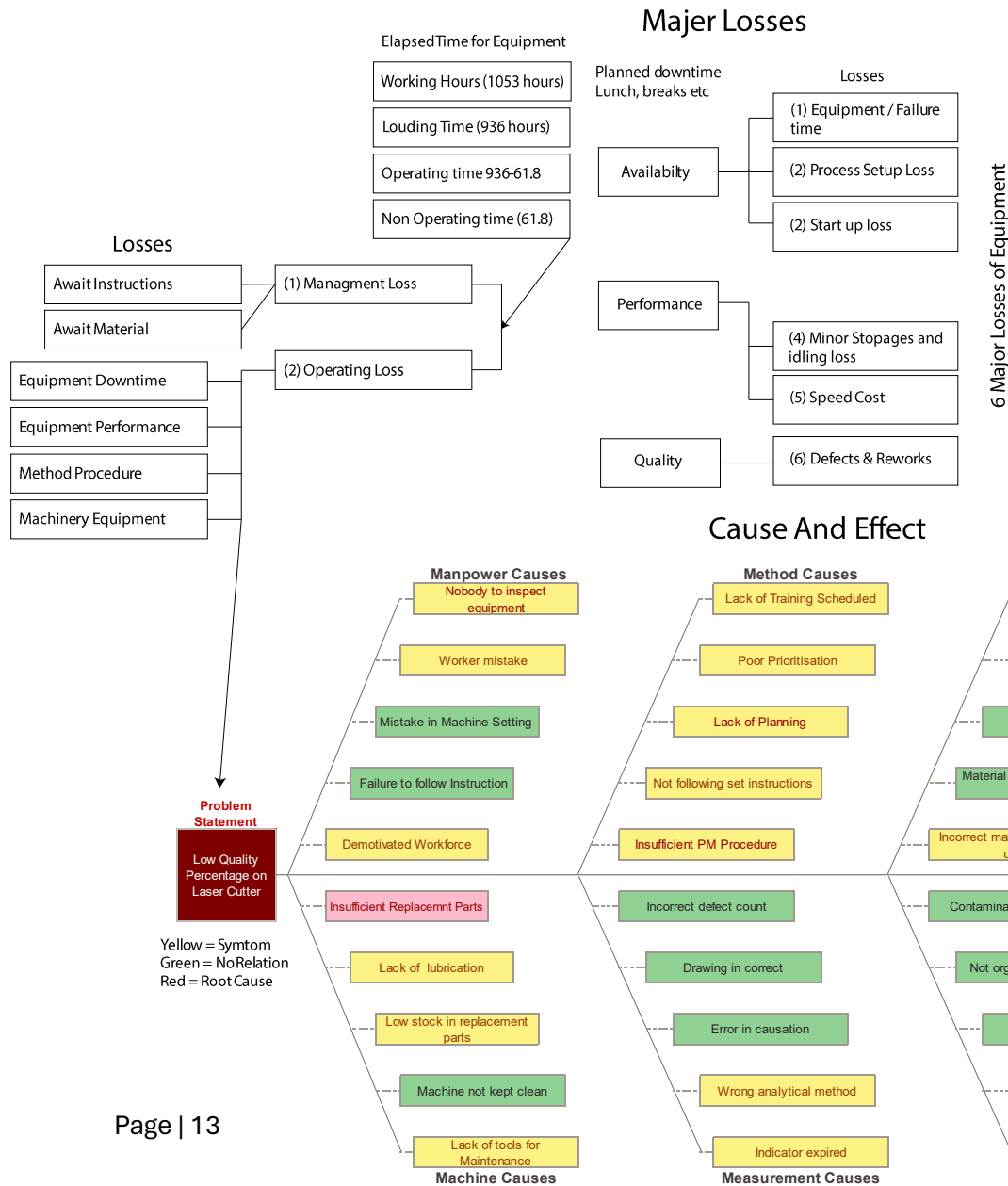
Figure 5 Risk Analysis of Laser Asset & Potential Root Cause

Item:	Fiber Laser Cutter	Responsibility:	Gavin Roberts	FMEA number:	FLC Issue 1
Model:	Bodor I5	Prepared by:	Lewis Nekreus	Page :	1 of 1
Core Team:	Kevin Richards, Lewis Nekreus, Joshua Griffiths, Ethan Merrick, Lee Poiner			FMEA Date (Orig):	16/03/2024 Rev: 1

Function	Potential Failure Mode	Potential Effect(s) of Failure	S e v	Potential Cause(s)/ Mechanism(s) of Failure	O c c	Current Process Controls	D e t	R P N	Recommended Action(s)	Responsibility and Target Completion Date	Potential Action Results				
											Potential Actions Taken	S e v	O c c	D e t	R P N
Component Manufacturing from sheet metal	Cutting components out of tolerance	Scrapped material	8	Calibration of Z axis not set correctly	3	Training given to correctly calibrator before operating laser	5	120	Check on programmed quality of calibration before cutting metal	Kevin Richards (Laser Operator)	Parts checked on calibrated measuring tool	5	4	1	20
		Late Deadline	9	Laser nozzle loose or not correctly fitted	3	Nozzle checked by operator before use	6	162	Nozzle removed at end of shift to forces daily check on condition	Lee Poiner (Maintenance team)	Check daily on nozzle condition for damage	2	2	1	4
			3	Lense damage	2	none	1	6	Lense to be inspected for damage or replaced	Lee Poiner (Maintenance team)	Check laser Lense quality for damage or dust	5	2	1	10
			2	Incorrect parameters	5	Correct training given to operator on setting laser	10	100	Improve computer processing..	Gail Jones (IT Team)	New advanced computer purchased	7	5	2	70
	Laser alarm triggered causing operations to stop	Missed production deadline	10	Inference within cutting area	4	Laser bed is cleared and operation continued	10	400	Check area is clear before operation commences	Kevin Richards (Laser Operator)	Area cleared daily before production usage	3	7	1	21
			10	Insufficient cooling	6	Coolant checked after alarm is set	5	300	Coolant level checked daily	Kevin Richards (Laser Operator)	Fill cooling system every 6 months	1	5	2	10
	Wearing on guide rails	Out of calibration x & y making machine inoperable	8	Insufficient lubrication of rails	5	Checked Automatic lubrication pump and rail condition	3	120	Daily check on rails condition	Lee Poiner (Maintenance team)	Lubrication on rails to be checked weekly	2	3	2	12
	Laser over heating	Damaged laser head	10	Water chiller frozen or insufficient coolant	7	Alarm on laser to trigger when coolant failure occurs	7	490	Daily check on coolant temperature and level	Lee Poiner (Maintenance team)	Chiller to be checked every month or replenished when needed	9	2	2	36
	Oxygen fuel leak	Potential fire hazard or explosion	8	Damaged valve from cylinder	7	none	8	448	Valve main inspected before use	Lee Poiner (Maintenance team)	Secure canisters to prevent from falling Canisters should be in cages	4	5	1	20
			8	Damaged fuel feeding	6	Inspected fuel feed regular	8	384	Feeding tube to be weekly checked on condition	Lee Poiner (Maintenance team)					
	Laser door jammed	Health and safety risk	9	Pulley motor failure	4	none	5	180	Pulley motor checked and PAT tested	Martin Davies (Maintenance team)	Pulley to be checked for slack	2	3	2	12
	High sparking from operations	Wrong nozzle fitted	7	Lack of understanding or training when operating	2	Nozzle and parameters are instruct	10	140	Marked laser nozzles for correct operation	Kevin Richards (Laser Operator)	Training to be given to staff operating laser	1	7	2	14
		Incorrect parameters	7		1	none	10	70	Parameters added to instruction	Martin Davies (Maintenance team)					
	Bed support racking wear	Insufficient support to hold sheet metal in position	8	Wearing from laser cutting	10	none	2	160	Change racking support when required	Kevin Richards (Laser Operator)	Replace racks when needed	5	3	2	30

Figure 6 FMEA Laser Cutting Components out of Sheet Metal

Root Cause & Summary of Data Calculated



Data Summary

$$\text{Overall Equipment Effectiveness} = \text{Availabilty} \times \text{Performance} \times \text{Quality}$$

$$78\% = 93\% \times 95\% \times 88\%$$

$$\text{Availability} = \frac{\text{Total Run Time} - \text{breakdown time} - \text{changeover time}}{\text{Total Run Time}}$$

$$\text{Availability} = \frac{936 \text{ hour} - 61.8 \text{ hours downtime}}{936 \text{ hours}} = 93\%$$

$$\text{Performance} = \frac{\text{Total Number of Parts Produced}}{\text{Operating time}}$$

$$\text{Performance} = \frac{83571 \text{ Parts produced}}{874.2 \text{ run hours}} = 95\%$$

$$\text{Quality} = \frac{\text{Number of Good Parts Produced}}{\text{Total Number of parts produced}}$$

$$\text{Quality} = \frac{73189}{73189 + 10385} = 88\%$$

$$\text{MTBF} = \frac{\text{Total time all items on test regardless of whether they failed}}{\text{Total number of failures}}$$

$$\text{MTBF} = \frac{874.2}{12} = 72.85 \text{ hours}$$

Equation 1 OEE Calculations and MTBF

5 Whys

Insufficient replacement parts	Why ?
No stock for consumables	Why ?
Parts are only purchased when needed	Why ?
Company uses reactive maintenance methods	Why ?
Company is unaware of cost impacted in repair	Why ?

Figure 7 Cause & Effect Analysis, 5 whys also Included

How to improve Current Maintenance

For the company to improve current maintenance strategies and performance of the laser cutter research was made and solutions sought through total productive maintenance techniques. This is a method to reduce equipment losses while maximizing the effectiveness of the production system. TPM is a set of practices, methods and tools that enables organizations to maximize effectiveness of production systems as defined by Suzuki, T (2017).

Initially, TPM would be explained and introduced to the company in relation to being implemented with laser cutter production. When conducting TPM the members involved must communicate clearly and frequently on methodologies introduced. For this study the focus was on only a few techniques used as one piece of equipment was being monitored. TPM is a long-term solution with the goal of zero defects and breakdowns, which is why this was an ideal tool for the laser cutter.

The next step is to return the laser cutter back to its original condition. Borris, S (2006) stated - basic condition as being a method of returning to original specification. Consumables such as purified water, oil lubrication and laser head nozzle needed to be either replenished or replaced to be able to achieve this condition. The method is also based around 5-S system and autonomous maintenance, which involve cleanliness, standardization and sustainability, As mentioned by Trout, J (2023). He also explained the need for continuous improvement to keep equipment in its original condition.

Once the baseline state of the laser cutter is established, autonomous maintenance could be introduced to give a more detailed examination of the equipment. This involved the equipment operators performing a set of basic daily maintenance activities on their equipment. This can be implemented to support smooth and effective asset operations, which is done by detecting and correcting equipment problems early. Also included can be marking areas that were identified in the root cause, such as parts that are prone to wearing.

The last section will be the schedule, which is based on more preventative maintenance methodology. The procedure means that the necessary tasks will be completed fully and at the set date to prevent the deterioration of the asset. Such tasks including consumable replacement and lubrication are major steps to solving the performance issues identified. This schedule is based on methods suggested by Mobley, K (2004) who further suggested that discipline is the major problem in organization and that control procedure's must be established for the success.

Checklist & Examples Taken from Place of Work

5S	#	Check Item	Description	Score				
				0	1	2	3	4
1S: Sort	1	Materials or parts	Are there any unneeded materials or parts around?					
	2	Machines or other equipment	Are there any unused machines or other equipment around?					
	3	Tools, Supplies, Parts	Nothing on the floor except Legs, Wheels, or Pallets?					
	4	Frequency	Have items been sorted by everyday use vs. those used occasionally?					
	5	Written standards	Has establishing the 5S's left behind any useless standards?					
Sub Total:								
2S STORE (Set Locations & Units)	1	Location indicators	Are shelves and other storage areas marked with location indicators and addresses?					
	2	Item indicators	Does everything <u>HAVE</u> a place? Is everything <u>IN</u> its place?					
	3	Quantity indicators	Are the maximum and minimum allowable quantities indicated (Kanban)?					
	4	Marking of walkways and storage areas	Are lines or markers use to clearly indicate walkways and storage areas?					
	5	Tools	Are tools arranged functionally to facilitate picking them and returning them?					
<i>Note: A Kanban is a self-sustaining inventory system. (It has a Min, Max, Re-order Point, and Re-order Quantity)</i> Sub Total:								
3S: Shine & Sweep	1	Floors	Are floors kept shiny and clean and free of waste, water, dust and/or oil?					
	2	Machine	Are the machine wiped clean often; kept free of waste, dust, and/or oil?					
	3	Cleaning and checking	Is there a cleaning checklist being followed that is effective?					
	4	Cleaning responsibilities	Is it clear (understood and communicated) who is responsible for cleaning?					
	5	Habitual cleanliness	Do workers habitually clean their workstation without being told (sweep floors, wipe equipment, desk, etc)?					
Sub Total:								
4S: Standardize	1	Improvement Audits	Was the 5S audit completed for this area last month? Month before?					
	2	Improvement ideas	Were the improvement ideas from the last audit acted upon?					
	3	Key procedures	Are standards procedures written, clear and actively used?					
	4	OPLs	Are One Point Lessons used to communicate key activities / procedures?					
	5	The First 3 S's	Are the first three S's (Sort, Set Locations and Shine) being maintained?					
Sub Total:								
5S: Sustain	1	Training	Is everybody adequately trained in standard procedures?					
	2	Tools and parts	Are tools and parts being stored correctly?					
	3	Stock controls	Are stock controls being adhered to (Kanban)?					
	4	Procedures	Are procedures updated (within last year) and regularly reviewed?					
	5	Activity boards	Are activity boards used? Are they updated and regularly reviewed?					
Sub Total:								

Item	Total "S"	Type	Criteria
0	0	Serious	activities not conducted at all
1	5	Major	activities implemented between 0– 30%, danger of process going down
2	10	Minor	activities implemented between 31- 60%, if not attention paid could become a Major
3	15	Trivial	Activities conducted in a systematic way but could improve, 61-90%
4	20	Excellent	Activities implemented and used in a systematic way, 91-100%. Focused Improvement

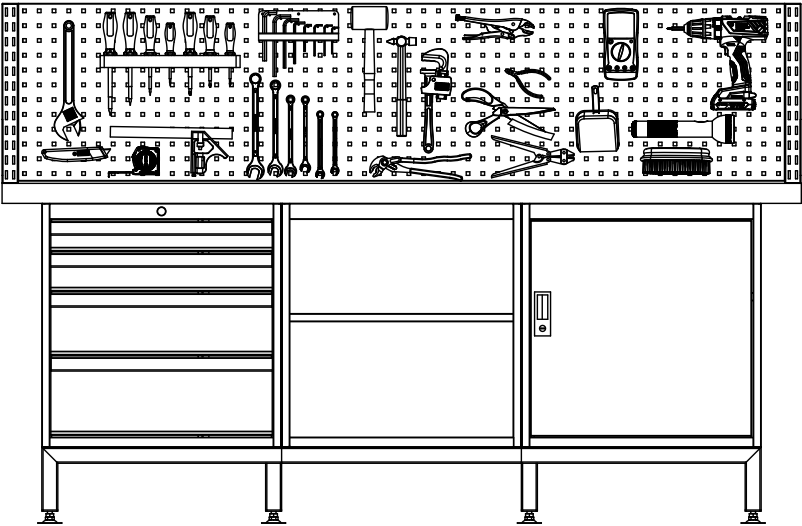
Example of Findings

Item #	Description and Corrective Action	Picture Available	Finding Type*		
			D	P	R
R1	Storage of consumables incorrect, proper storage required				
R2	Tooling for maintenance not correctly stored				
W1	Oil not stored Correctly				

Figure 8 5s Checklist with Examples From Site

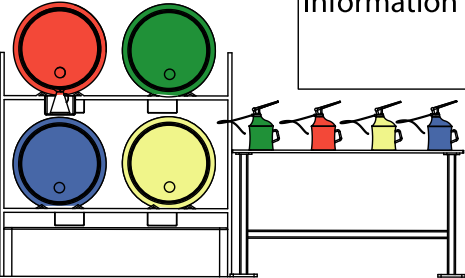
5s Implementation Examples

Item: R2

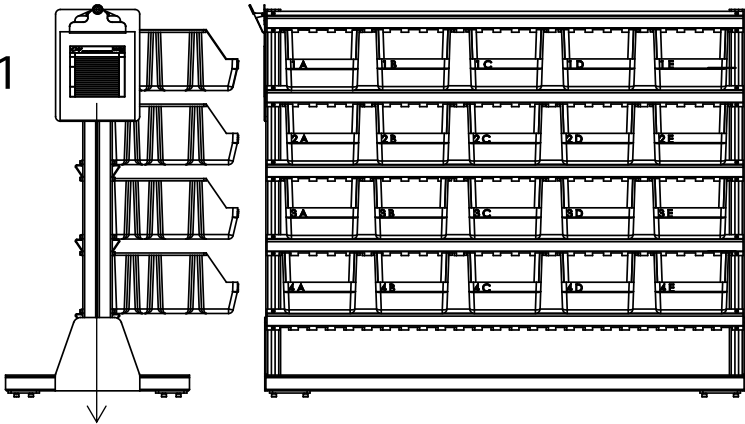


Red
Code: 4140
Brand: Shell
Viscosity: 36
Application: X & Y Rail
Additional Information

Item: W1



Item: R1



Inventory List Bodor Fiber Laser Consumables						
Ca. bodor laser						
Name	Description	Supplier Part Number	Location	Quantity Recorded	Re order at	Date of Recorded
Nozzle	Single layer nozzleBD-01B-S-D5.0	30205000169	1A	3	2	02/01/2024
	Single layer nozzleBD-01B-S-D3.0	30205000166	1B	4	3	
	Double layer nozzleBD-01B-D-D5.0	30205000178	1C	3	3	
	Double layer nozzleBD-01B-D-D2.0	30205000172	1D	2	2	
	Single layer nozzleBD-01B-S-D4.0	30205000167	1E	1	1	
Ceramic Lockrings	Diameter32mm BD-01A-0-32	31299000028	2A	1	1	
	Diameter-28mm BD-01A-1-28	31220000002	2B	2	2	
	Diameter20.6mm BD-01A-0-20.6C	31220000006	2C	4	5	
	Diameter31mm PRLCI-003113	31299000050	2D	1	2	
	Diameter31mm/BD-01-1-31	31205000517	2E	2	3	
Lenses	D38.1×1.6-PW-6KW-01	31205000148	3A	3	4	
	D30×2-PW-12KW-01	31205000158	3B	2	2	
	D27.9×4.1-PW-6KW-01	31205000288	3C	1	1	
	D21.5×2-PW-12KW-01	31209117001	3D	3	2	
	D24.9×1.5-PW-6KW-01	31205000287	3E	5	3	
Gaskets	VB-D 43.6-33-2.1A11	31229000099	4A	2	2	
	V01B3-40.2-33-2.5-A07/301-01	30829000006	4B	1	1	
	41.5×34.3×3.4-02	30805000116	4C	2	1	
	34.5×26.6×3.4-02	30805000115	4D	2	1	
	32×24×3.8-02	30805000124	4E	2	2	

Figure 9 5s illustrations with Examples of 5s Solutions

Signature: Lewis nekrews

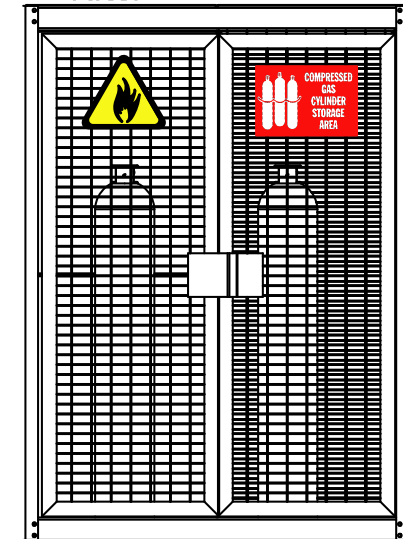
Further Checks in Autonomous Maintenance Stage

Step No.	Check Item	Description	Score					Total
			0	1	2	3	4	
0 (Safety)		1 Proper PPE available and worn properly						
		2 LOTO procedures developed and posted on/near equipment						
		3 LOTO Authorized Personnel properly trained						
		4 Chemicals properly labeled and stored						
		5 LOTO and SOE are mapped out						
		6 Necessary warning signs posted						
		7 Hoses/piping/equipment parts labeled						
		8 Principle of operation of machine understood by the team						
		9 OPL's generated related to SOE and LOTOTO						
1 (Sort)	Are there unneeded items around the workplace ?	# Are there unneeded items such as tools, packaging / process materials ?						
	Is Red - Tag area have been established?	# Are all unnecessary items placed in Red - Tag Area?						
	Are unneeded items clearly identifiable?	# Are unneeded equipment, forms, procedures, tools etc easy to spot?						
	Have rules been established regarding unneeded items?	# Have regulations for disposal of unneeded items been set? Does segregation of waste take place?						
	Are activity board well organized?	# Are activity boards kept clean and displayed neatly? Is it up to date?						
2 (Set)	Are storage units marked? Items properly stored?	# Are cabinets and supplies marked with location indicators?						
	Do documents and equipment have their owner's names on them?	# Are such items marked with names or color coding to make identification easy? Standardize?						
	Are documents and tools easy to use?	# Are documents and tools arranged so they are easy to pick up and put back?						
	Items easy to see, use and return?	# Markings / Visual controls effective? Limits (Min / Max) stated?						
	Demarcation exist?	# Are walkways, seating, inspection areas etc. clean and well defined?						
3 (Shine)	Are there wastes or paper scraps on floor?	# Are floors and equipment kept clean?						
	Are items clean?	# Is equipment regularly cleaned e.g. keyboard, mouse, screen, desk, workbenches and area?						
	Have specific cleaning tasks been assigned?	# Is there a person responsible for overseeing cleaning operations?						
	Are waste bins allowed to overflow?	# Do waste bin always get emptied before they overflow?						
	Has cleanliness become a habit?	# Do workers habitually sweep floors and wipe up dirt without being told?						
4 (Standardize)	3S Conditions maintained?	# 5S Map posted in area? Cleaning schedule posted in zone? Cleaning tasks described in SOP or OPLs?						
	Are site / PPE clothes Ok and Clean	# Are workers wearing dirty work clothes? Is PPE available for individuals?						
	Is there a proper lighting?	# Is the angle and intensity of the lighting adequate for the work being done?						
	Does the area give the impression of shining cleanliness at first sight?	# Do lighting, colour, design and ventilation give a good atmosphere to the environment?						
	Have rules been established for maintaining the first three 5S?	# Are the first three 5S (Sort, Set, Shine) being maintained?						
5 (Sustain)	Are audits taking place as planned?	# 5S audits routine and posted in area? Are results improving each time and displayed on Activity Board?						
	Are agreed actions for continuous improvement taking place?	# Team involvement (all members = 4)? Are the teams being recognised for their strenuous effort?						
	Are shift hand - overs professional and effective?	# Do people discuss issues and activities from the previous shift? ?						
	Members demonstrate maintaining 5S conditions?	# Safety and GMP rules being followed?						
	Do people follow Team rules, regulations and agreements?	# Does worker take rules, regulations and agreements seriously?						

Before

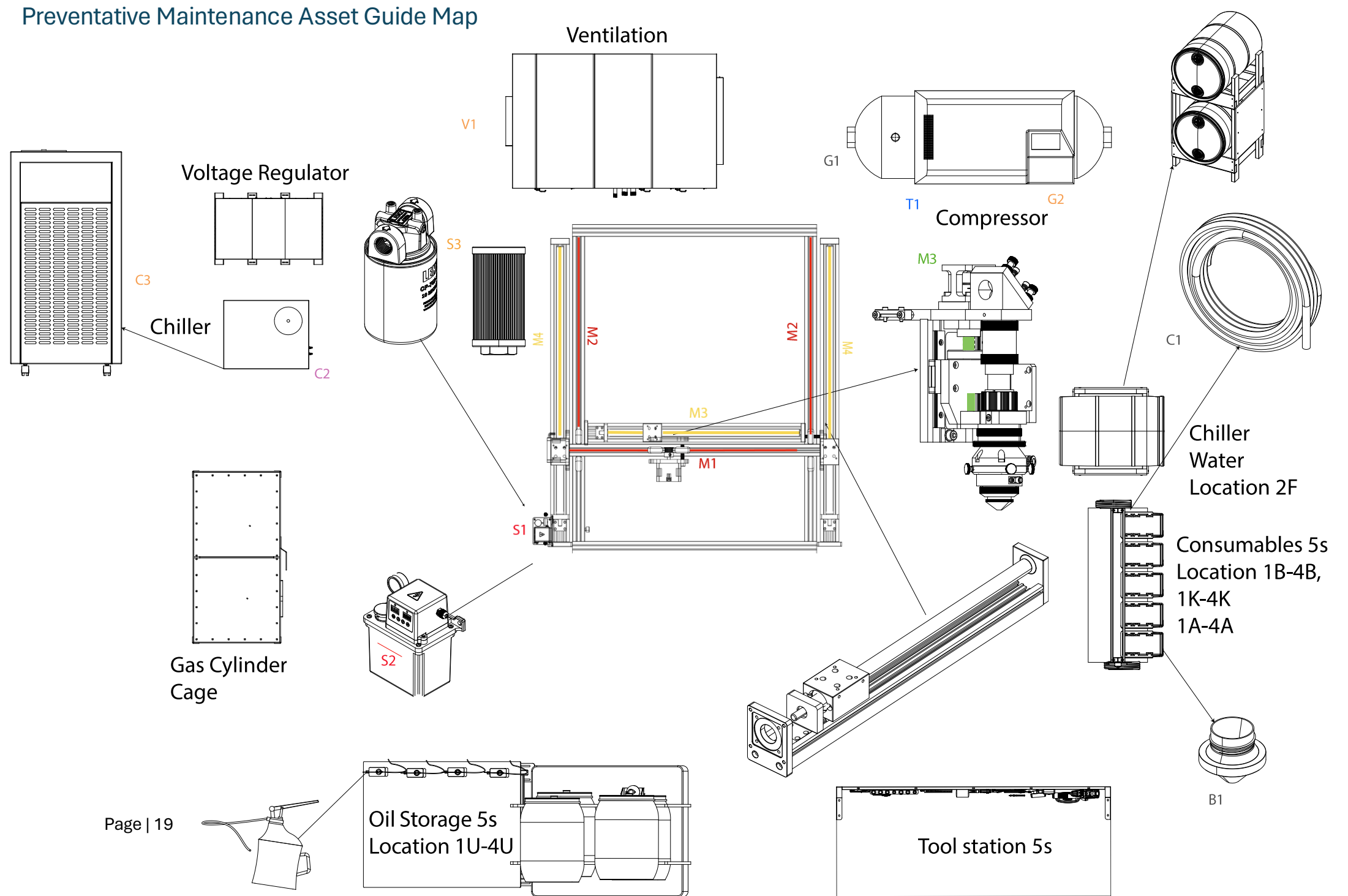


After



[illegible]

Preventative Maintenance Asset Guide Map



Cost Implementation

One impact of the discussed maintenance improvement would be the company having to invest more resources in time and people to implement the change. Many of the costs involved could be not readily identified during the process development.

Communication with stakeholders can be considered one of the costs involved as it may be necessary to promote the change and illustrate the benefits. Abbas, T(2022) suggests engaging with members of the maintenance team on the new plan would also be an essential step for successful change.

New stationary equipment would be identified as a branding cost. This type of cost could involve the instruction of items such as the storage of consumable equipment for the laser. Budget restrictions would impact on purchasing such items like storage units and containers.

Training on the new schedule, with associated resource, would be required with the associated maintenance engineers and operators. The suggested preventive maintenance techniques would be considered a culture change from current methods of reactive procedures. The map previous illustrated aids in this, as it will assist in explaining what the leader of the project is trying to achieve.

The time needed to implement this change and the disruption that it would cause will be one of the greater factors of cost. Production would be impacted, and it would be essential that the project manager acknowledge this factor to create allowances, as mentioned by Jorden, A (2022)

A cost- benefit analysis would show the actual cost of the change to the laser procedure, and attempt to achieve better quality components. This method, stated by (Campbell and Brown, 2022) ,helps the team identify, measure and compare the benefits and cost of an investment.

Cost-Benefit Analysis

Costs						
Costs	Year 1	Year 2	Year 3	Year 4	Year 5	Total
	2024	2025	2026	2027	2028	2024 - 2028
Non-Recurring Costs (one time)	£5,764.00	£0.00	£0.00	£0.00	£0.00	£5,764.00
Recurring Costs (annual)	£4,709.00	£329.00	£4,709.00	£329.00	£0.00	£10,076.00
Total Costs	£10,473.00	£329.00	£4,709.00	£329.00	£0.00	£15,840.00
Total Costs (Present Value)	£10,473.00	£329.00	£4,709.00	£329.00	£0.00	£15,840.00
Total Costs (Present Value) to Year r	£10,473.00	£10,802.00	£15,511.00	£15,840.00	£15,840.00	

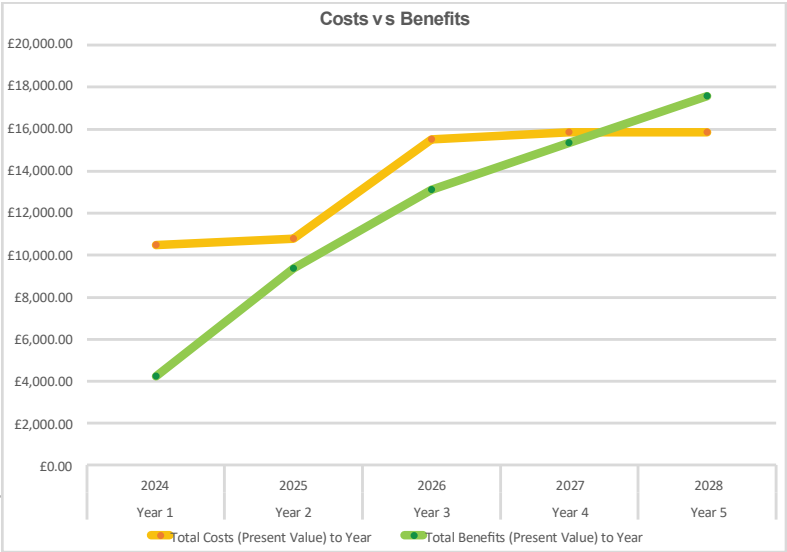
Benefits						
Benefits	Year 1	Year 2	Year 3	Year 4	Year 5	Total
	2024	2025	2026	2027	2028	2024 - 2028
Unplanned Maintenance	£625.00	£740.00	£740.00	£740.00	£740.00	£3,585.00
Component Defects	£1,200.00	£2,000.00	£1,500.00	£1,000.00	£1,000.00	£6,700.00
Unplanned Downtime	£2,400.00	£2,400.00	£1,500.00	£500.00	£500.00	£7,300.00
Total Benefits	£4,225.00	£5,140.00	£3,740.00	£2,240.00	£2,240.00	£17,585.00
Total Benefits (Present Value)	£4,225.00	£5,140.00	£3,740.00	£2,240.00	£2,240.00	£17,585.00
Total Benefits (Present Value) to Year r	£4,225.00	£9,365.00	£13,105.00	£15,345.00	£17,585.00	

Benefit or Cost per Year r	-£6,248.00	£4,811.00	-£969.00	£1,911.00	£2,240.00	£1,745.00
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Benefit or Cost (Present Value)	-£6,248.00	£4,811.00	-£969.00	£1,911.00	£2,240.00	£1,745.00
Benefit or Cost (Present Value) to Year r	-£6,248.00	-£1,437.00	-£2,406.00	-£495.00	£1,745.00	

Benefits Cost Ratio [BRC]	1.11
Return of Investment [ROI]	11%

Payback Period	4.22 years
Net Present Value [NPV]	£1,745.00



Costs					
Non-Recurring Costs (one time)	Year 1	Year 2	Year 3	Year 4	Year 5
	2024	2025	2026	2027	2028
Project Initiation Meeting (1 Hour)	£78.00				
Planned Downtime (36) Hours	£850.00				
Restore Laser Condrtion (5 Hours)	£130.00				
5s Labour Implementation	£2,808.00				
5s Oil Storage Dispencers	£756.00				
5s Oil Storage Racking	£222.00				
Compressed air tubing (30m)	£72.00				
Gas tubing Oxygen (50m)	£81.00				
Gas tubing Nitrogen (50m)	£81.00				
Gas tubing Nitrogen (50m)	£65.00				
New Scheulde Training	£156.00				
5s Tool Table	£350.00				
Storage unit (Consumables)	£115.00				
Total Non-Recurring Costs:	£5,764.00	\$ -	\$ -	\$ -	\$ -
Recurring Costs (annual)	Year 1	Year 2	Year 3	Year 4	Year 5
	2024	2025	2026	2027	2028
5s Oil 32 Viscoty	£1,200.00		£1,200.00		
5s Oil 46 Viscoty	£1,200.00		£1,200.00		
5s Oil 68 Viscoty	£1,200.00		£1,200.00		
5s Oil iso 22 Viscoty	£780.00		£780.00		
Brass nozzle Single layer 1.5	£25.00	£25.00	£25.00	£25.00	
Brass nozzle Single layer 1.0	£25.00	£25.00	£25.00	£25.00	
Brass nozzle Single layer 2.0	£25.00	£25.00	£25.00	£25.00	
Brass nozzle Double layer 2.0	£28.00	£28.00	£28.00	£28.00	
Oil pump Filters	£44.00	£44.00	£44.00	£44.00	
Purified Water	£120.00	£120.00	£120.00	£120.00	
Chiller filters	£20.00	£20.00	£20.00	£20.00	
Lenses	£20.00	£20.00	£20.00	£20.00	
Compressor oil filter	£22.00	£22.00	£22.00	£22.00	
Total Recurring Costs:	£4,709.00	£329.00	£4,709.00	£329.00	£0.00
Total Costs:	£10,473.00	£329.00	£4,709.00	£500.00	£7,000.00

Figure 12 Cost-Benefit Analysis of Suggested Improvement Method

Conclusion

The report focuses on the study of a single piece of equipment in the production process and evaluates what can be done to improve the current maintenance approach with an alternative maintenance strategy that could prove beneficial for the company and improve overall process.

Reviewing current maintenance practices showed that reactive maintenance is introduced when more defects occur in production. Some areas in maintenance are either only practice complete or prove to be reactive maintenance. This type of maintenance strategy was chosen to reduce the cost needed to be able to complete operations while maintaining the asset enough for it to prove effective.

The data gathered showed that the overall quality of the laser cutter was impacting negatively on the performance of the laser cutter. The root cause analysis suggested that the wearing of certain laser components has impeded the production of lasered components.

To improve the current maintenance strategies, it was researched to use methods based on total productive maintenance because this technique has the similar goal of having minimum defects in production processes. Scheduling a new preventative maintenance plan could assist the company in understanding the proposed changes and to get stakeholders on board by predicting future benefits.

The value in the reports study was that it shows that preventive maintenance can potentially improve the quality of components when produced from the laser cutter. This could then result in less rework, faster production of car instruments and then increase customer satisfaction. Convincing the company to have a preventive mindset while using correct techniques to lower the risk of costly repairs could also save the company revenue in the long term.

Further work

For further work, one area that could be investigated is the actual implementation of total productive maintenance and studying the results from the new overall effectiveness of performance after base condition is established. The task was to evaluate what could be done to improve maintenance procedures, however piloting the new schedule suggested and monitoring the results could prove beneficial in providing evidence in the improved preventive strategy.

Another area which could be improved would be based around the laser compressor. Principles of servicing the compressor were introduced into the new schedule, however the compressor could be suggested as another project entity considering the amount of attention is needed according to Bloch, H.P (2024) -who mentioned that in order to achieve high reliability and availability of a compressor asset depends on operating philosophy, maintenance strategy employed and the extent of predictive and production instrumentation deployed to indicate the health of the compressor.

References

- Abbas, T (2022) How to Establish Cost of Change Management [Online]
<https://changemanagementinsight.com/how-to-estimate-cost-of-change-management/>
Accessed 2024, April, 05th
- Agustiady, T. and Cudney, E. (2023) Total Productive Maintenance. Second Edition. CRC Press.
Boca Raton
- Bloch, H. (2006) A Practical Guide to Compressor Technology. 2nd Edition Wiley, New Jersey
- Bodor (2024), Fiber Laser Cutting Machine – Bodor , [Online] <https://www.bodor.com/en/>
Accessed 2024, March, 02th
- Borris, S (2006) Total Productive Maintenance – Proven Strategies and Techniques to Keep
Equipment Running at Peak Efficiency, Mcgraw-Hill Company, New York
- Campell, J.D (2011) Asset Management Excellence - Optimizing Equipment Life Cycle
Decisions, Second Editon, CRC Press, Boca Raton
- Dawe, G. (2021), Fiber Laser Cutting Everything You need to Know, [Online]
<https://kanyanaengineering.com.au/fiber-laser-cutting/#:~:text=Fiber%20laser%20technology%20generates%20a%20focused%2C%20high-powered%20laser,and%20converted%20into%20heat%2C%20which%20melts%20the%20surface> Accessed 2024, March, 05th
- Fredrickson, B. (2011), 5 Commonly Overlooked Laser Maintenance Areas, [Online]
<https://www.thefabricator.com/thefabricator/article/lasercutting/5-commonly-overlooked-laser-maintenance-areas>, March, 15th
- Hasrulnizzam, W (2021), Fuguai Mapping: Useful method for problem solving, [Online]
http://eprints.utem.edu.my/id/eprint/11199/1/Fuguai_Mapping_The_Useful_Method_For_Problem_Solving.pdf Accessed 2024, March, 05th
- Mobley, K.R (2004) Maintenance Fundamentals, Second Edition, Elsevier Butterworth, Oxford
- Mobley, K.R (2014) Maintenance Engineering Handbook, Eighth Edition, Mcgraw-Hill Company,
New York
- Ortiz, C. (2016) The TPM Playbook. Taylor and Francis, London

Peterson, D (2021) How To Calculate Overall Equipment Effectiveness [Online]
<https://control.com/technical-articles/what-is-overall-equipment-effectiveness-oeef/> Accessed 2024,
March, 28th

Srivastava, N.K (2015), Predictive maintenance using modified FMECA method, [Online]
<https://www.inderscience.com/offers.php?id=71521>, Accessed 2024, March, 20th

Stephens, M. (2022) Productivity and Reliability-Based Maintenance Management, Second Edition.
2nd Edition Purdue University Press, West Lafayette

Suzuki, T.(2017) TPM in Process Industries, Taylor & Francis, London

Trout, J (2021), Fiber Laser Cutting Everything You need to Know, [Online]
<https://kanyanaengineering.com.au/fiber-laser-cutting/#:~:text=Fiber%20laser%20technology%20generates%20a%20focused%2C%20high-powered%20laser,and%20converted%20into%20heat%2C%20which%20melts%20the%20surface>
Accessed 2024, March, 05th

Trout, J (2023) Total Productive Maintenance: An Overview – What is it and how it can improve you
OEE, [Online] <https://www.reliableplant.com/Read/26210/tpm-lean-implement> March, 27

