EXPLORING THE NEED FOR PLANNED MAINTENANCE IN REPONSE TO LOW PRODUCTIVITY AT A HEAVY STEEL MANUFACTURER

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ABSTRACT

A large steel fabricator observed poor productivity and bottlenecking in their shot-blasting section. This study aimed to identify the causes of low productivity and further identify improvement opportunities. The shot-blasting section was found to add value only 19% of the time. Production records revealed that downtime accounted for 61% of machine non-availability, whilst time study data further revealed that idle time accounted for 11%, rework 9% and yield 21%; all of which contributed to low productivity levels. These factors were further analysed using fish bone diagrams, 5-Why analyses, and interviews to determine root causes of low productivity in shot-blasting. It was concluded that the chief cause of downtime is a lack of planned preventative maintenance (PPM), with downtime, low yield and rework being attributable to a lack of PPM. Implementing PPM would significantly improve throughput at shot-blasting and significantly reduce downtime costs.

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1 INTRODUCTION

The company under investigation specialises in heavy steel fabrication, structural detailing, procurement and heavy machining on very large and time sensitive projects. This means that the company works with large orders and varying demand throughout the year. Reliable lead times are both contractually and organisationally important. Increasing global competition is driving the organisation to streamline fabrication processes to reduce costs, material and time wastage.

A generic steel fabrication process has five stages: 1.Preparation, 2.Assembly, 3.Welding, 4.Fettling and 5.Shot blasting and painting when required. The shot blasting section (5) was identified as the bottleneck to throughput. The shot blasting section comprises three shot blasting machines, hereinafter referred to as Wheelabrators.

Shot blasting is a method used to clean, strengthen (peen) or polish metal. Shot blasting is used in most metal industries, including aerospace, automotive, construction, foundry, shipbuilding, rail, and many others. There are two technologies used: wheel blasting or air blasting.

Wheel blasting uses a rotating turbine wheel to accelerate abrasive particles. The capacity per wheel ranges from 60 kg up to 1200kg per minute. Because wheel blast machines can move such large volumes of grit, they are used for large parts or large areas that require rust-removal, descaling, deburring, or another form of cleaning.

Total productive maintenance (TPM) is the development of a robust, stable value stream by maximising Overall Equipment Effectiveness (OEE). Key elements of TPM includes: preventive maintenance, predictive maintenance, breakdown maintenance, corrective maintenance, and maintenance prevention [1].

This project aimed to understand the flow of material in the Wheel blasting section of the plant by evaluating it as a bottleneck. The study further aimed to evaluate the implications of machine downtime, operational practice and operational efficiencies on the plant as a whole.

Value adding for the Wheelabrator is defined as all time that the machines spend performing shot blasting. A company's main purpose is to make profits [2], and reblasting and idle time, only add to costs. Therefore, failure demand or rework are considered not value adding.

1.1 Objectives

1. Investigate the location and causes for the bottleneck
2. Identify the effects of bottlenecks on the plant
3. Identify opportunities for improvement
4. Recommend plausible solutions for bottlenecks

2 METHOD

This study used both primary and secondary data sources for information. A quantitative approach has been used for the time studies with a qualitative approach used for conducting interviews with informants [3]. Data was collected in the form of a Q&A session. The results were tabulated in an excel spreadsheet and tallied up. All responses were recorded and the most common responses were extracted for the report.

Figure 1: Methodology

Time studies [4] were conducted for 9 days on each of the three Wheelabrators. The studies attempted to identify the utilisation, effectiveness and reliability of the each machine. The time studies provided data on downtime, idle time, yield, rework and non-value adding activities. This data was enriched by looking at historical downtime data from the production monitoring system.

The company implemented a new maintenance logging system in April 2012. Data from this system was used to determine the downtime of each Wheelabrator over 15 month period. The records were first adjusted to account for lunch and tea breaks as downtime giving 7 hour shifts and 14 hour working days[†]. All hours logged as downtime outside normal working hours were rejected.

The convention of idle time has been used, which is any time that the Wheelabrator is available to be used but is not in use for any particular reason. Idle time does not include downtime [5].

To understand why breakdowns and downtime were so high the maintenance procedure was investigated and interviews with various stakeholders were conducted.

3 RESULTS

This section shows the time-study and downtime-history results. It should be noted that Wheelabrator 2 was non-operational for the full duration of the study and was recorded as down time.

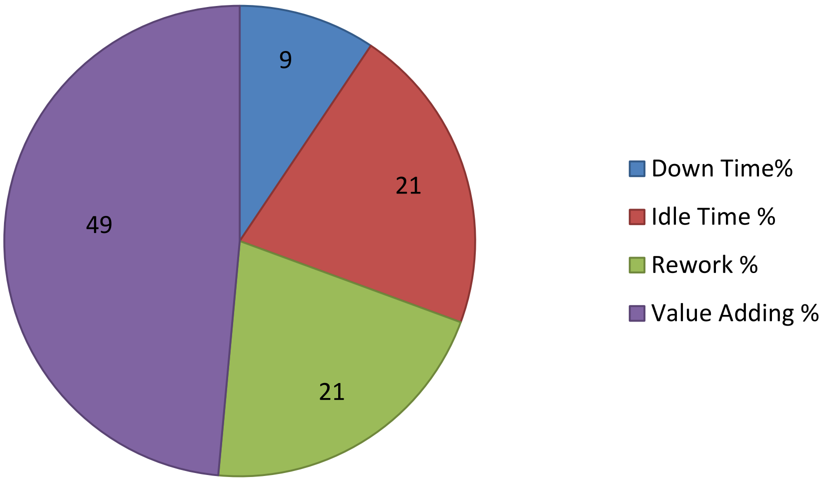

Figure 1: Wheelabrator 1 time study results

[†] Two 8 hour shifts accounting for 30 minute lunch breaks for each shift and 30 minutes for each shift change over. Hence each shift has 7 available working hours and there are two shifts in a day making 14 hours

Figure 2 shows that Wheelabrator 1 displayed 9% downtime, 21% idle time and 21% rework. Value adding time accounts for 49% and the rest, 51 % can be considered waste.

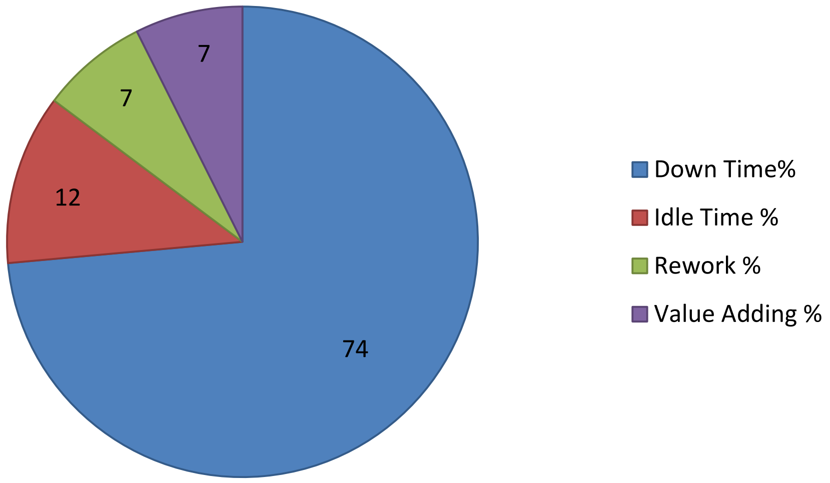

Figure 3: Wheelabrator 3 time study results

Figure 3 shows that Wheelabrator 1, displayed 74% downtime, 12% idle time and 7% rework. Value adding time accounts for only 7% and the rest, 93 % can be considered waste.

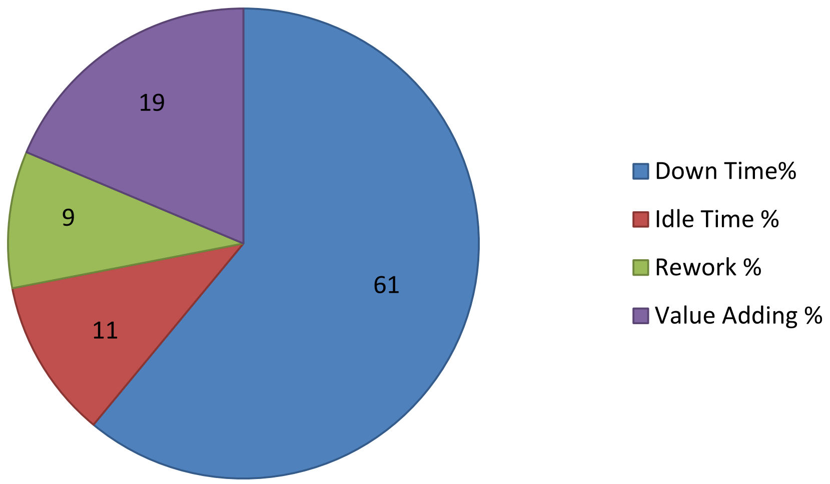

Figure 4: Wheelabrator section averages

Figure 4 shows that the Wheelabrator section displayed 61% downtime, 11% idle time and 9% rework. Value adding time accounts for 19% and the rest, 81 % can be considered waste.

3.1 Downtime

From the data Wheelabrator 1 experienced an average of 8% downtime, Wheelabrator 2 experienced an average of 19% downtime and Wheelabrator 3 experienced an average of 13% downtime. The average downtime from the Wheelabrator section was 14%.

The results led into a root cause analysis (Figure 5) which explored downtime, rework, idle time and general low production at the Wheelabrator section.

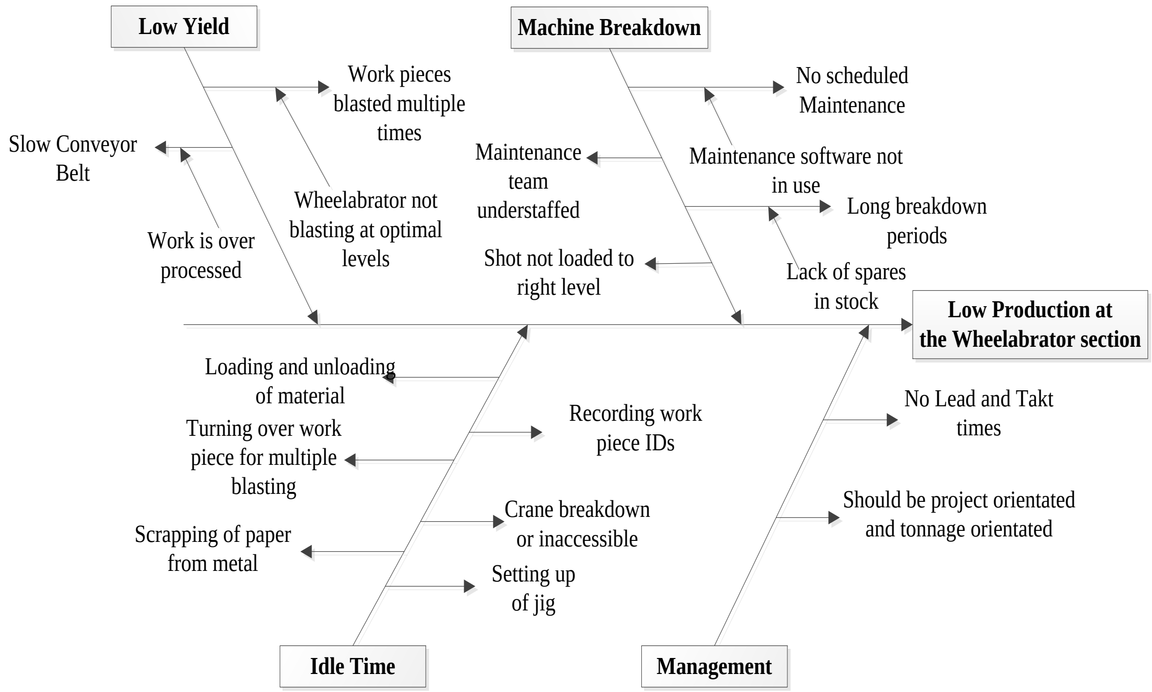

Figure 5: Fishbone diagram for low production at the Wheelabrator section

It is evident that downtime is the most important issue and has the highest impact on production.

3.2 Qualitative analysis of the maintenance department

It was observed that insufficient spare parts are kept in stock and had to be ordered when needed. Interviews in the maintenance department revealed that long lead times occasionally create downtime as long as four weeks. The procurement process requires senior management authorisation, stretching the waiting time even further.

Figure 6, shows the maintenance procedure and identified improvement areas. Key amongst these is the back and forth between the top management that could be eliminated to reduce the time between machine breakdown and spare parts arrivals. Improvement areas are highlighted in yellow.

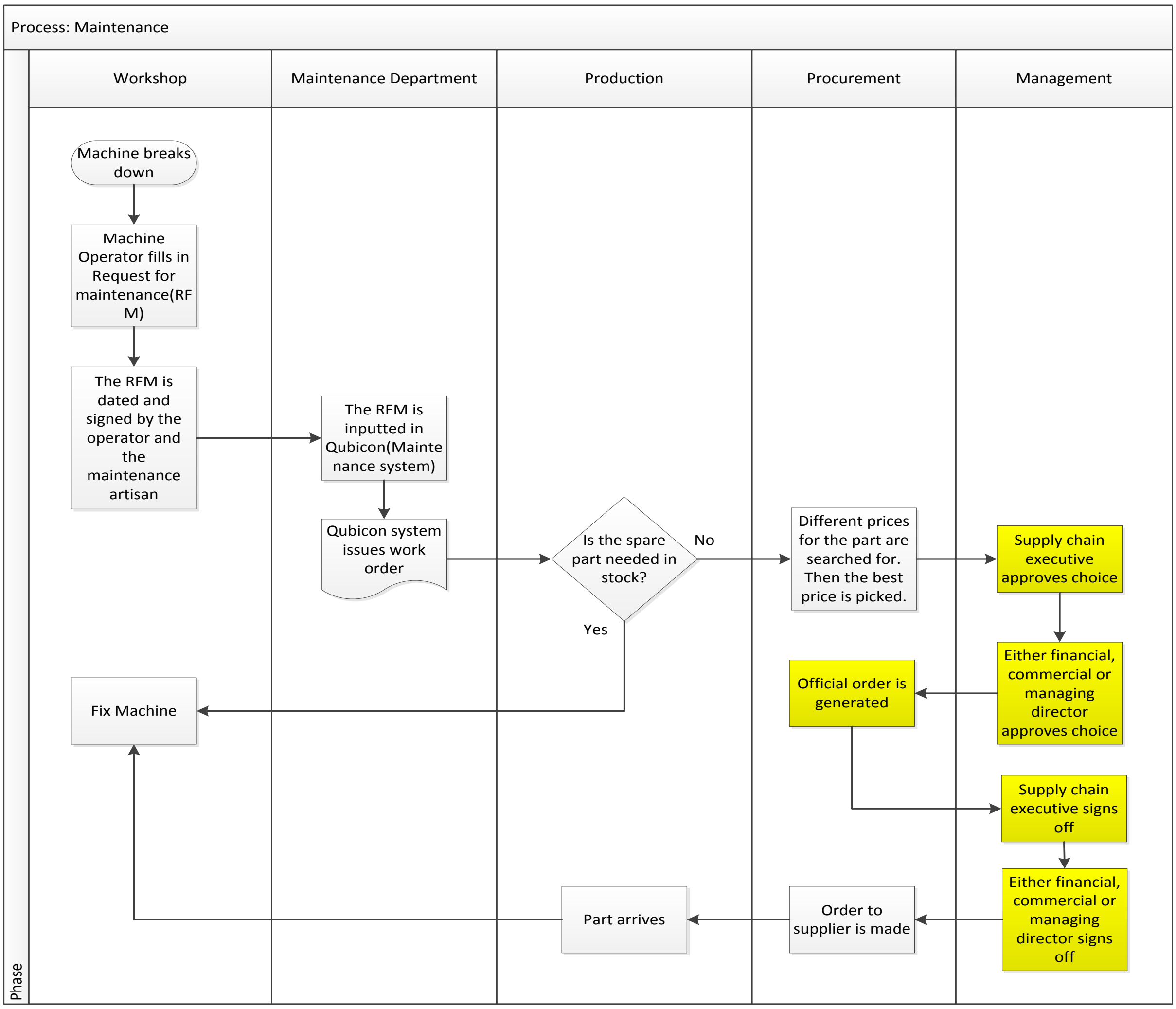

Figure 6: Maintenance procedure

Interviews with the maintenance team revealed a perception of understaffing. There is no scheduled maintenance for the Wheelabrators and the maintenance team is inexperienced in handling the machines.

The reasons given for a lack of scheduled maintenance by the shop floor employees is that the project managers and superiors are not willing to lose the production time to scheduled maintenance. They are concerned with their own production and project deadlines which are approaching soon or are behind schedule and therefore not willing to lose time to scheduled maintenance. This has later been proved as untrue through meetings with the paint department, which contends that there is no planned maintenance system in the organisation.

The interviews also revealed that most employees considered the maintenance team to be inexperienced. This meant most of the issues which occur with the Wheelabrators could be solved in a shorter space of time, if the maintenance team were adequately trained. According to the employees the company previously contracted to repair and service the Wheelabrators was more efficient and competent than in-house artisans. This company manufactured the Wheelabrator, and thus have extensive knowledge of the machines and are able to repair the machines much faster[‡].

Staff also mentioned that the Wheelabrator operators are not adequately trained in the operation of the machines. Thus the machines are run with insufficient shot which strains the machines and may damage them.

3.3 Frequency of breakdowns

Using the historical downtime records an investigation into the frequency of breakdowns was done. The goal was to identify the most common type of breakdowns.

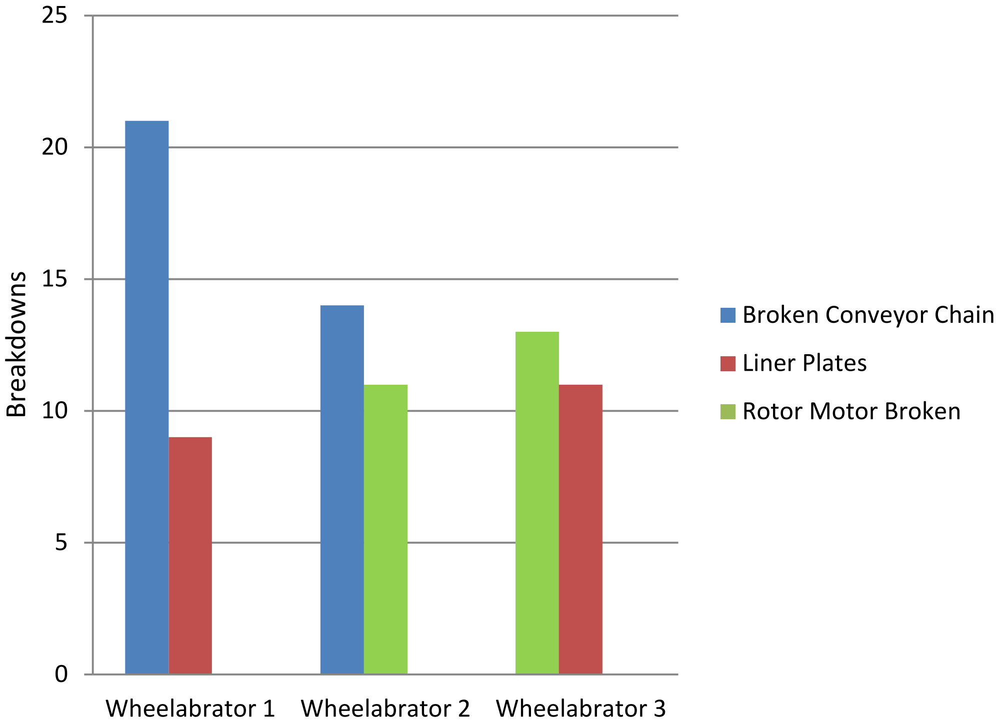

Figure 7: Most Common Breakdowns

From the results shown in Figure 7, the most common types of breakdowns are related to the rotor motors, liner plates and conveyor chain.

The rotor motor is responsible for running the mechanism that physically sprays the shots in the shot blasting process. This was an issue that was addressed through the implementation of IP65 insulation. IP65 is the total protection from dust and external bodies through the use of enclosures.[6]Liner plates are responsible for protecting the interior of the machine from being shot blasted. The liner plates are run to failure. This leads to issues such as holes in the machines that cause shot to leak compounding the pressure on the maintenance team. Most of the issues highlighted in the Historical Downtime Records and Frequency of Breakdowns such as the rotor motors, liner plates and conveyor chain are caused by wear and tear due to a lack of regular maintenance.

Table 1 below shows the number of scheduled maintenance inspections over the past 15 months.

[‡] The outsourcing contract was discontinued for cost reasons.

Table 1: Monthly inspections

Machine	Monthly inspections
Wheelabrator 1	2
Wheelabrator 2	3
Wheelabrator 3	1

3.4 Non value adding activities

From the time studies it is clear that the biggest problem affecting production is downtime. Keeping in mind the theory of constraints which states that the organisation is only as strong as its weakest link[7] and the lean philosophy which states that all wasteful steps must be removed[8], it is important to identify the other issues that are contributing to the bottleneck to remove all waste in the organisation and increase productivity.

3.4.1 Idle time

From the time studies, idle time was caused by:

- Loading and unloading material on the conveyor belts
- Setting up jig for smaller work pieces
- Turning over work piece for multiple blasting
- Cranes for loading and unloading material breaking down
- Recording work piece ID

Work pieces had to be turned over because the machine was not blasting optimally. Depending on the size of the work piece a crane had to be used to help turn it over. Due to every work piece being blasted at least twice they had to be turned over at least once. Wheelabrator 3 blasted up to 40 small items. These 40 small items were individually turned over manually. Wheelabrator 1 blasted large and heavy work pieces that could only be turned over by the use of a crane. Company safety rules stipulate that no employee may lift an object heavier than 25kg. This means that all work pieces blasted in Wheelabrator 1 are turned using cranes and any work pieces blasted in Wheelabrator 3 above that weight are also turned using cranes. From the time studies some work pieces were turned 5 times due to being blasted six times. This results in low yield, high cost of rework and loss of valuable production time.

The crane for offloading and unloading material for Wheelabrator 3 was experiencing downtime for the entire duration of the time studies. This meant that cranes had to be shared and any loading and offloading was done subject to the availability of substitute cranes.

Every blasted work piece has to be recorded which took a considerable amount of time. The manual recording results in time wasted because every item must be recorded before moving to the next production step.

3.4.2 Low Yield and Rework

For this research project a unit was defined as the amount of material that was put through the Wheelabrator once and came out blasted to spec without needing rework or re-blasting. Due to the large variety of parts that are blasted in the Wheelabrator, a unit was considered as any job that was placed on the conveyor belt to be blasted. Hence, a unit that it placed on the conveyor belt and put through the machine for blasting and exits the machine without needing re-blasting would count as 100% yield. If the job had to be blasted twice before being passed as acceptable then the yield would be 50% etc. There is a cost of quality that is incurred due to the low yield and high rework.

Table 2 below shows the yield, as a percentage, for each Wheelabrators and the average determined through time studies.

Table 2: Wheelabrator section yield

Machine	**Yield**
Wheelabrator 1	50%
Wheelabrator 2	0%
Wheelabrator 3	11.9%
Average	**21%**

The time studies showed that yield for the Wheelabrator section is 21%. An attempt should be made to do everything perfectly [9]. There is a high cost associated with poor quality. The lower a company's sigma level is, the higher the chance of cost saving through the increase in sigma levels.[10] The cost savings diminish as the sigma levels increase. A yield of 21% is indicative of a 1 sigma operation. Therefore there is a large opportunity for cost reduction.

The six main causes of low yield were identified as follows: size of shot not appropriate (shot not homogenous), valves not working, filtration system, motors not working, machine setup not correct and blast area not concentrated on workpieces.

3.5 Cost of downtime

From the time study results, down time was considered as the biggest contributor to low productivity in the Wheelabrator section. As a result this section estimates the costs incurred as a result of downtime. It should be noted that this calculation tends be conservative as it ignores[11]:

- cost of repair, such as cost of operator overtime or bringing in consultants
- daily, seasonal variations in revenue
- indirect costs of outages can be as important as these are more immediate costs
- opportunity costs

Importantly, this calculation also ignores that this section is the bottleneck in the plant, and therefore should be costed at the hourly income of the plant [7].

The cost of downtime is calculated using the following equation [11]:

$$\begin{aligned}&\mathit{Estimated\ Average\ Cost\ of\ downtime\ per\ hour} = \\ &\mathit{Employee\ Costs\ per\ Hour} * \mathit{Fraction\ Employees\ Affected\ by\ Outage} + \\ &\mathit{Average\ Revenue\ per\ Hour} * \mathit{Fraction\ Revenue\ Affected\ by\ Outage}\end{aligned} \qquad (1)$$

Where "Employee Costs per Hour": total salaries and benefits of employees per week divided by the average number of working hours; "Average Revenue per Hour": total revenue per week divided by average number of open hours; "Fraction Employees Affected by Outage" and "Fraction Revenue Affected by Outage" are estimates.

The cost of downtime was calculated as ~R1200 per hour. With downtime in the Wheelabrator section averaging 61% or 4 of the available 7 working hours in a shift, the cost of downtime per day is: ~R5000 per shift. There are two shifts per day therefore the cost is ~ R10000 per day.

4 DISCUSSION

The frequency of breakdowns was investigated to identify a trend in the type of breakdowns. Historical records were analysed and the results displayed in Figure 7 show that the most common type of breakdowns are related to the conveyor chain, rotor motor and liner plates. These are all breakdowns that can be prevented by having planned maintenance.

It can be seen from Table 1 that there is a lack of planned maintenance in the Wheelabrator section. Since the records were over a period of 15 months and the conveyor chain for instance has a life span of 6 to 8 weeks there should have been more planned maintenance occurring. The conveyor chain is responsible for transporting the metal through the Wheelabrator. This is a cause of breakdowns because there is no maintenance and insufficient periodic replacement. Thus the chains exceed their recommended life span leading to damage and eventual failure. The reason for a lack of planned maintenance can be considered contentious. Interviews with shop floor members put the blame on the project managers for not allowing planned downtime as this would impede the chances of them meeting their own personal deadlines. This was dismissed as untrue through meetings with the maintenance department. The actual reason is that there is not a procedure for planned maintenance in the organization and the maintenance team is understaffed.

From the time studies, yield for the Wheelabrator section was identified to be 21%. From the 5-Whys analysis, six main issues that lead to low yield were identified: size of shot not appropriate, valves not working, filtration system, motors not working, machine setup, blast area not concentrated. All these issues are due to a lack of periodic maintenance and can be traced back the maintenance department.

A low yield leads to failure demand. From the theory of failure demand there is an increase in the use of the machines because work is not being done correctly the first time. This means there is more wear and tear which leads to more breakdowns and the feeling that there are not enough workforces in the maintenance department. Essentially if the yield could be increased it would reduce the number of downtime or maintenance related issues and reduce failure demand, thus relieving pressure on the maintenance department. This is an example of the far reaching consequences of a lack of planned maintenance. A lack of planned preventive maintenance, combined with an ineffective spare parts ordering procedure results in added downtime.

Rework is a result of the low yield. Rework accounts for 22% of the shift time, when the machines are online. This is not acceptable as this is considered a waste, hence an opportunity for improvement. There is also a cost attributed to rework. This cost adds to the overall costs of the company and affects profits.

The reason for using the machine online data is to get a clear picture of the other issues that affect productivity in the Wheelabrator section and to see how much each affects productivity when downtime is not an issue. Hence this can be used to see what the next problem areas to cover when downtime has been addressed will be. From the theory of constraints an organisation is only as strong as its weakest link and once downtime is addressed another weak link will appear.

Idle time is another issue that was identified. Idle time accounts for 28% of the shift time when the machines are online. This should be addressed as idle time is a waste and does not add value to the business. Although some of the steps such as loading and unloading are necessary, idle time should be investigated in order to reduce the amount of idle time as it is production time that is lost.

Some of the problems identified in the Wheelabrator section in this research project such as; low yield, filtration system, maintenance and shot starvation are consistent with those found in previous studies[12]. This shows that the results are reliable.

Calculations were done in order to estimate the cost of Wheelabrator downtime on the machine. The cost was approximately R10000 per day. Although this is an estimate it is conservative and the costs are likely higher due to cost of repair, such as cost of operator overtime or bringing in a consultant, seasonal variations in revenue and indirect costs of outages can be as important as these are more immediate costs. This cost also does not include the cost of quality which will add to the above cost and further reduce profits.

5 CONCLUSION

The main objective of this study was to investigate the causes of the bottleneck at the Wheelabrator section and to identify the effects of the bottleneck on the plant. Based on the research findings;

- The Wheelabrator section is a bottleneck as its performance is limiting the capacity of the entire production system.
- The biggest contributor to the bottleneck is downtime as 61% of the shift is down time.
- The other contributors to low production at the bottleneck are: rework 9%, idle time 11% and yield 21%
- The cost of downtime is ~R10000 per day.
- Maintenance plays a significant role in low productivity as downtime, rework and yield are linked to maintenance.

6 RECOMMENDATION

The plant should implement a structured planned preventative maintenance programme to reduce the Wheelabrator downtime and increase throughput. The ordering process for spare parts needs to be streamlined. There is a lot of opportunity to improving downtime if the order process is streamlined. Maintain stock for parts causing the most frequent breakdowns to reduce amount of downtime.

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