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Visualizing the Effects of Chronic Versus Sporadic Losses in Manufacturing Industries – A Case Study

Marcus BENGTSSON [a, b, 1], Peter ALM [b] and Bo TJULIN [b]
[a] *School of Innovation, Design and Engineering, Mälardalen University*
[b] *Operations, Volvo Construction Equipment, Sweden*

Abstract. Measuring overall equipment effectiveness can be rather difficult. Particularly to capture all chronic losses, those losses that occur frequently, often on a daily basis, and often with a rather quick and easy fix without involvement of other support functions. Sporadic losses, on the other hand, such as breakdowns, lack of material or manpower is quite easily logged as it gets noticed. This issue is clearly a bigger one when discussing manual or semi-automatic OEE measurement systems. As a complement to this and as a way of visualizing effects of chronic versus sporadic losses a tool has been developed and tested in a case study in an industrial setting.

Keywords. Chronic losses, sporadic losses, minor stoppages, breakdowns, overall equipment effectiveness

1. Introduction

Overall equipment effectiveness (OEE) was introduced by Nakajima [1] as a performance indicator within the total productive maintenance (TPM) concept. The objective of the indicator was to maximize equipment effectiveness by reducing six big losses: equipment failure, set-up and adjustments, idling and minor stoppages, reduced speed, process defects, and reduced yield [1].

OEE is a commonly used and accepted performance indicator to increase the effectiveness of equipment by reducing losses [2] and, further, it has been pointed out as a key measure for both total productive maintenance and lean maintenance [3, 4]. OEE is not without flaws though. There are pitfalls [4], misconceptions [5], and misuses [6, 7] in both measuring and using OEE. OEE measurements itself, give no long-term improvements – it gives information and statistics on where there is possible improvement potential in reducing losses [8]. It is not until the employees and managers in an organization roll up their sleeves and start to work on and implement counteractions to these losses when actual improvements can be achieved in processes.

One issue with improvement work related to the use of OEE measurements can be found in varying loss types. The disturbances or losses captured by OEE can roughly be divided into two types of losses, namely chronic and sporadic [9, 10, 11, 12]. The chronic losses are usually more complicated, often hidden and considered small [12]. Due to the

[1] Corresponding Author, E-mail: marcus.bengtsson@mdh.se.

fact that they often have more than one cause, they tend to persist even after improvements have been implemented [9]. Sporadic loss tends to be more obvious since they often occur quickly and cause large deviations from normal state [9, 12]. Sporadic losses are often seen as a serious problem, but it is often the chronic losses that accounts for low utilization and large costs [12]. This was illustrated in, for instance, a case study on preconceived beliefs on the results of OEE measurements, where managers in a production facility greatly undervalued the (chronic) loss of "tool change and quality control" in comparison to the (sporadic) loss "lack of material" [13]. In the study, 80% of the respondents believed that "lack of material" was a logged as a bigger loss than "tool change and quality control" when in fact, "tool change and quality control" had been logged as a loss almost four times as many hours as "lack of material" [13]. Further, additional studies on OEE measurements [14, 15] illustrate that losses in performance are larger than losses occurring in availability. The losses of performance are in this case related to cycle time losses/reduced speed and idling and minor stoppages [14] and speed rate and utilization due to blocking or idle state [15] which are more likely to be of a chronic nature than sporadic.

Therefore, improvement initiatives must include not only how to reduce sporadic losses but also how to reduce, for instance: minor stoppages, reduced speed, and quality issues. It is quite common that companies work in a structured way to reduce sporadic losses while leaving the chronic losses unresolved [16]. Also, Ljungberg [14] reports that the minor chronic losses in OEE reporting often are regarded as something normal and that the awareness of its impact on production output is low. Quite often the chronic losses become habitual losses, i.e., they become a part of the daily routine and is therefore not experienced as a loss at all [17].

Another issue with improvement work related to the use of OEE measurement can be found in the fact that it can be difficult to log some of the chronic losses and by such these losses are not even visualized. Particularly if the OEE data-collection is manual or semi-automatic. For instance, Ylipää et al. [15] state that it is difficult to measure minor stoppages. This can be visualized by OEE studies that have presented performance rates on 100% [18] and even beyond 100% [14, 15] indicating that the process is run in faster cycle times than the stipulated cycle time and that chronic losses, such as idling and minor stoppages and reduced speed, are probably not logged to the extent of their true existence.

The purpose of this paper is to present the development and the test of a tool to visualize the impact of sporadic losses (machine breakdowns) and chronic losses (minor stoppages) based on approximations from machine operator experience and/or other production- and maintenance follow-up systems. The objective of the tool is to depict that even very short stops, in ranges of seconds to a few minutes, overtime will evolve to hours and even days. The goal of the tool is threefold. First, to stress that it is often equally important to work with improvements on both sporadic and chronic losses and that the logging of chronic losses is highly important for the success of an OEE-program. Second, to complement and compare the chronic losses logged in an OEE-system with machine operators experience of chronic losses (minor stoppages). The tool can also be used to quantify operators and other personnel's experience if other quantitative follow-up systems, such as OEE, are not used within a facility.

2. Theory

2.1. Overall Equipment Effectiveness

OEE was originally defined to log the six big losses containing: equipment failure, set-up and adjustments, idling and minor stoppages, reduced speed, process defects, and reduced yield [1]. However, as mentioned by, for instance, Ljungberg [14] additional factors need to be added in order to measure what truly affects the capacity utilization. Some of these include planned downtime, lack of material, and lack of labor. Depending on, for instance, approach to loss definitions, the intended implementation area, and specific characteristics on an industry there are differences in OEE definitions [19].

Regardless of loss definition the losses logged in OEE can roughly be divided into either sporadic or chronic in nature [9-12, 16, 17], see Figure 1.

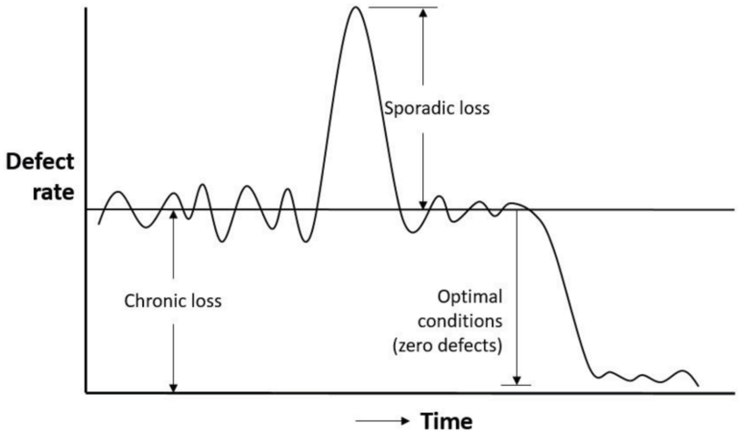


Figure 1. Sporadic and chronic losses [16, p.39].

2.1.1. Sporadic Losses

Sporadic loss tends to be obvious since they often occur quickly and cause large deviations from normal state [9, 12]. Sporadic losses are often seen as a serious problem by employees and management [12]. Depending on loss definition, examples of sporadic losses within OEE can be breakdowns, lack of material, lack of personnel, quality problems etc. Breakdowns are, by Shirose [9], pointed out as the root of all problems due to when they occur, they do not only stop production but also delay deliveries and create product defects. Sporadic losses usually stop production, and they are as such easy to notice. According to Nakajima [16] sporadic losses can be characterized as: "…infrequent or unusual events that cause a sudden breakdown or obvious loss of quality." (p.39). Further, Nakajima [16] states that the remedy for sporadic losses is restoration. Nakajima [16] means that the sporadic losses are triggered by changes in condition, such as: equipment, jigs and tools, work methods, and operating conditions, which can be restored to normal levels.

2.1.2. Chronic Losses

Chronic losses are usually more complicated, often hidden and considered small [12]. Due to the fact that they often have more than one cause, they tend to persist even after improvements have been implemented [9]. It is often the chronic losses that accounts for low utilization and large costs [12]. Even if a single sporadic loss can be very costly compared to a single chronic loss the frequency of the chronic losses cumulates to considerable losses and costs [16]. Quite often the chronic losses become habitual losses, i.e., they become a part of the daily routine and is therefore not experienced as a loss [17]. Depending on loss definitions, example of chronic losses within OEE can be obstructed product flow, component jams, misfeeds, sensors blocked, lubricant top-up, delivery blocked, cleaning/checking [20] as well as other minor stoppages, speed loss setup/adjustment loss, startup losses [16] etc. According, also to Ljungberg [14], the minor, chronic losses are often perceived as something normal, therefore the impact on production output is therefore also often unclear. According to Nakajima [16], chronic problems are usually latent, they often result in negligible loss per incident, they occur frequently, they can easily be restored by operators, they rarely come to the attention of supervisors, they are difficult to quantify, and they must be detected through comparison with optimal conditions. Also, Ylipää et al. [15] state that it is difficult to measure minor stoppages. Muchiri and Pintelon [21] also state that when using manual data collection, the accuracy is very low due to the fact that minor stoppages and downtime can often be forgotten. Further, Muchiri and Pintelon [21] state that manual data collection, while being low in cost, has low data accuracy; contrarily, automatic data collection is high in cost, but its data accuracy is higher and the data-collection process is simplified.

3. Tool Development

The tool is developed using MS Excel. The objective with the tool is to visualize that also shorter stops, if occurring frequently, amounts to a lot of hours over a longer period of time. In order to visualize this, we have in the tool calculated the losses to lost number of full shifts during one production year. The tool is quite straightforward with basic arithmetic, the point of the tool is in its visualization and comparison of the loss types. The input to the tool can be both quantitative data from computerized systems as well as domain experts experience depending on what data sources are available as well as the quality of the data sources. For instance, quantitative data can be collected from computerized maintenance management system (CMMS), OEE-measurements, or other production follow-up systems. If these data do not exist or if the data is not trusted or if one simply wants to compare this data to other sources one may also input approximations from domain experts. The domain experts can, for instance, be operators, team leaders, production managers, repairmen, or maintenance technicians/engineers working close to the specific machine or machines being analyzed. As previously stated, if a machine is not connected to an automatic follow-up system it can be difficult to log all minor stoppages and disturbances in a manual or semi-automatic system.

3.1. Assumptions and Limitations in the Tool

Below are some assumptions and limitations of the tool described.

- Production can either be staffed in daytime, two-shifts, or three-shifts
- The maintenance department are always staffed in three shifts
- No work is performed during weekends by neither maintenance nor production
- A shift includes eight working hours

- One production week includes five working days
- One production year includes 46 working weeks
- It is only possible to input five different types of breakdowns (with same or similar mean downtimes) and five different types of minor stoppages (with same or similar mean downtimes)
- If a breakdown occurs when operating on a daytime- or a two shift-strategy a maintenance department will work to fix it on a three shift-strategy
- A breakdown can occur anytime during a shift, e.g., when running daytime, a breakdown with mean downtime (MDT) of 8 hours can occur in the middle of the shift causing a four-hour stop since a maintenance department uses the other shifts to repair the breakdown
- Representatives from a maintenance department need to be involved in the repair of a breakdown
- Representatives from a maintenance department need not to be involve in the short-term remedy concerning minor stoppages, operators can handle those issues. In solving the issues concerning minor stoppages on a long-term basis, representatives from a maintenance department might need to be involved, this is however out of the scope of this tool
- The downtime cost is the same for breakdowns as for minor stoppages

3.2. Equations

The equations are created in MS Excel. If one is looking to compare sporadic and chronic losses, the required input to the tool is N_{BD}, N_{MS}, S, MDT_{BD}, and MDT_{MS} in order to calculate and visualize the end product $LS_{TOT, BD}$ and $LS_{TOT, MS}$. It is also possible to input an approximated downtime cost per hour, then a second end product will also be $C_{TOT, BD}$ and $C_{TOT, MS}$. All acronyms and equations, Eq. (1) to Eq. (10) are presented below.

- N_{BD} No. of breakdowns per year per breakdown type
- N_{MS} No. of minor stoppages per shift (average) per minor stop type
- S No. of shifts production is operating
- MDT_{BD} Mean Down Time per breakdown type (h)
- MDT_{MS} Mean Down Time per minor stop type (min)
- $T_{TOT, BD}$ No. of hours of downtime due to breakdown type per year
- $T_{TOT, MS}$ No. of hours of downtime due to minor stop type per year
- LS_{BD} No. of lost shifts due to breakdown type per year
- LS_{MS} No. of lost shift due to minor stop type per year
- $LS_{TOT, BD}$ No. of lost shifts per year due to breakdowns
- $LS_{TOT, MS}$ No. of lost shifts per year due to minor stoppages
- C Downtime cost per hour
- C_{BD} Downtime cost per breakdown type
- C_{MS} Downtime cost per minor stop type
- $C_{TOT, BD}$ Total cost of downtime due to breakdowns per year
- $C_{TOT, MS}$ Total cost of downtime due to minor stoppages per year

$$T_{TOT,BD} = N_{BD} \cdot MDT_{BD} \tag{1}$$

$$T_{TOT,MS} = \frac{(N_{MS} \cdot MDT_{MS} \cdot S \cdot 5 \cdot 46)}{60} \tag{2}$$

$$LS_{BD} = (T_{TOT,BD}/24) \cdot S \quad (3)$$

$$LS_{MS} = \frac{T_{TOT,MS}}{8} \quad (4)$$

$$LS_{TOT,BD} = \sum LS_{BD} \quad (5)$$

$$LS_{TOT,MS} = \sum LS_{MS} \quad (6)$$

$$C_{BD} = T_{TOT,BD} \cdot C \quad (7)$$

$$C_{MS} = T_{TOT,MS} \cdot C \quad (8)$$

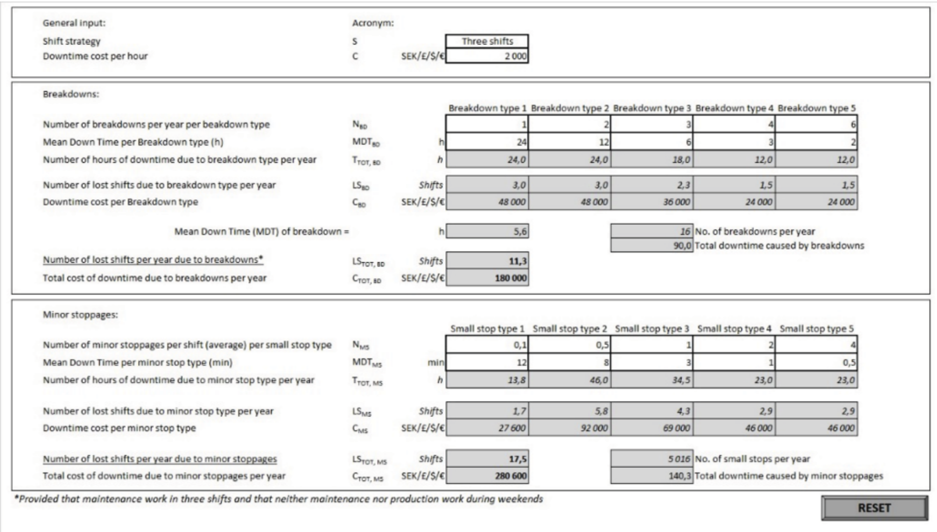
$$C_{TOT,BD} = \sum C_{BD} \quad (9)$$

$$C_{TOT,MS} = \sum C_{MS} \quad (10)$$

3.3. Theoretical Example

In the made-up, theoretical, example in Figure 2, 16 breakdowns have occurred in the past 12 months in an equipment that is being operated on a three-shift strategy. One breakdown had a downtime of 24 hours, two of them had a mean down time of 12 hours, three of them had a mean down time of 6 hours, four of them had a mean down time of 3 hours, and finally six of them had a mean down time of 2 hours. This equals a total down time of 90 hours, which in number of shifts, if the shift length is 8 hours, equal 11.25 shifts of lost production due to breakdowns. These breakdowns are assumed to be taken care of by the maintenance department. In the same equipment there exist a number of minor stoppages that are assumed to be taken care of by operators. The first minor stop type occurs once every 10th shift and last for 12 minutes. One of the minor stop type takes place once every two shifts and last for about 8 minutes. Another minor stop type takes place every shift and last for about 3 minutes. A fourth of the minor stop type takes place twice per shift and last for about a minute. One last minor stop type occurs four times per shift and lasts about 0.5 minutes. On a yearly count, these minor stoppages account for 140.3 hours of lost production which equals 17.5 shifts of lost production. There is a possibility to insert a downtime cost per hour which will visualize the downtime in hours in financial terms instead. In this made-up, theoretical, example the downtime cost per hour is set to 2000 SEK.

What seems small in time and seems easily fixed, which becomes almost natural during a day's work, quickly adds-up and becomes a big loss if summed-up for a whole year. Surely, longer stops such as the 24 hours stop in the example brings other types of disturbances such as disturbing production downstream in the value chain. However, the long-term performance of a machine is surely affected by the minor stoppages.



General input:	Acronym:		
Shift strategy	S		Three shifts
Downtime cost per hour	C	SEK/£/$/€	2 000

Breakdowns:			Breakdown type 1	Breakdown type 2	Breakdown type 3	Breakdown type 4	Breakdown type 5
Number of breakdowns per year per beakdown type	N_{BD}		1	2	3	4	6
Mean Down Time per Breakdown type (h)	MDT_{BD}	h	24	12	6	3	2
Number of hours of downtime due to breakdown type per year	$T_{TOT, BD}$	h	24,0	24,0	18,0	12,0	12,0
Number of lost shifts due to breakdown type per year	LS_{BD}	Shifts	3,0	3,0	2,3	1,5	1,5
Downtime cost per Breakdown type	C_{BD}	SEK/£/$/€	48 000	48 000	36 000	24 000	24 000
Mean Down Time (MDT) of breakdown =		h	5,6		16	No. of breakdowns per year	
					90,0	Total downtime caused by breakdowns	
Number of lost shifts per year due to breakdowns*	$LS_{TOT, BD}$	Shifts	11,3				
Total cost of downtime due to breakdowns per year	$C_{TOT, BD}$	SEK/£/$/€	180 000				

Minor stoppages:			Small stop type 1	Small stop type 2	Small stop type 3	Small stop type 4	Small stop type 5
Number of minor stoppages per shift (average) per small stop type	N_{MS}		0,1	0,5	1	2	4
Mean Down Time per minor stop type (min)	MDT_{MS}	min	12	8	3	1	0,5
Number of hours of downtime due to minor stop type per year	$T_{TOT, MS}$	h	13,8	46,0	34,5	23,0	23,0
Number of lost shifts due to minor stop type per year	LS_{MS}	Shifts	1,7	5,8	4,3	2,9	2,9
Downtime cost per minor stop type	C_{MS}	SEK/£/$/€	27 600	92 000	69 000	46 000	46 000
Number of lost shifts per year due to minor stoppages	$LS_{TOT, MS}$	Shifts	17,5		5 016	No. of small stops per year	
Total cost of downtime due to minor stoppages per year	$C_{TOT, MS}$	SEK/£/$/€	280 600		140,3	Total downtime caused by minor stoppages	

*Provided that maintenance work in three shifts and that neither maintenance nor production work during weekends

RESET

Figure 2. A screen shot of the Excel-tool with the example as input.

4. Case Study Methodology

4.1. Case Company Introduction

The case company is a discrete item manufacturing company supplying internal customers with components for the automotive industry. During the first six months of 2021 the plant had roughly 750 employees. The plant is divided into various production cells based on product families. The manufacturing machines used in the machining-related production cells differ significantly in their type, set-up, material being manufactured, and age. In total, about 400 manufacturing machines exists within the plant. Some machines are stand-alone, whereas others are situated in a value stream with material handling systems, such as material handling robots, conveyors, and gantry cranes, and others are situated in a storage crane set-up. Material comprises cast and forged materials as well as, to a smaller extent, aluminum.

In the company, OEE has been measured since more than ten years ago when lean production through a company specific lean production system was implemented. The current OEE-system and loss definition has been in place since 2014. The system is manual, and operators log their losses either by pen and paper (and later enter it to a system) or directly into a system.

The current computerized maintenance management system (CMMS) has been in place since 1999. In the system, all maintenance actions are logged with both quantitative data such as repair time and when (in time) a specific work order was created, when it was started, and when it was finished. Also, work orders are reported by free-text fields and there is a connection to what spare parts has been used.

4.2. Selection of Case

In parallel to an initiative of improvement work carried out by the maintenance department to increase the OEE-level of the manufacturing machines in one production cell of the company the production manager of that cell was asked if it was possible for us to test the developed tool in a case study, which was accepted.

The production cell manufactures several different variants of a particular type of gear from forged material and contains several manufacturing machines such as: turning machine, gear hobbing machine, gear shaving machine, broaching machine, deburring machine, and washing machine, as well as some logistics equipment, in the form of conveyors and robots. The production cell has been operating on a four-shift strategy the last year.

4.3. Data Collection

Two team leaders and two operators in the production cell were introduced to the tool and its purpose. Based on the introduction one machine in the production cell was chosen to test the tool on. The machine is to a large extent the bottleneck in the production cell but when producing certain variants, it is not always the case. The machine is a turning machine and was installed in 2007. The team were interviewed on the minor stoppages that had occurred the past year and possibly was still occurring. They were asked to have in mind to bring up all minor stoppages and disturbances that if the machines would be working without problems would not have happened, i.e., the theoretical or optimal level.

After the domain expert data collection, quantitative data from the company manual OEE-measurement system was downloaded for the last year (fourth quarter of 2020 and the first three quarters of 2021) of the specific machine. Also, quantitative data from the computerized maintenance management system (CMMS) was downloaded of the specific machine (same interval as OEE-measurement). In the CMMS, focus was on Breakdowns (larger sporadic failures). In the OEE-measurements, data logs for the loss categories "Breakdowns, long stops" and "Disturbance in equipment and tools" was of special interest. The OEE loss category "Breakdowns, long stops" were compared to the breakdowns logged in the CMMS. The OEE loss category "Disturbance in equipment and tools" were compared to the approximation of the domain experts. The sporadic breakdowns and chronic disturbances were of course compared to each other also.

5. Case Study Results

5.1. Results from Approximations of the Domain Experts

During the interview, eight chronic losses with approximated frequency and downtime were communicated by the domain experts, see Table 1. Since the developed tool only allows for five entries of minor stoppages, similarly to breakdowns, some of the minor stoppages were bundled and average values on frequency and downtime were calculated, see Table 1. Where approximations of frequency and downtime were made in an interval, the lower approximations were chosen as input to the tool. For instance, if the downtime were approximated to 5-10 minutes, 5 minutes were used as input to the tool. This data was compared to the quantitative data, see Section 5.2, and entered into the tool, see Section 5.3.

Table 1. Results from the approximations of the domain experts.

Bundle	Chronic loss	Frequency of occurrence	Frequency of occurrence (times per shift)	Downtime (minutes)	Downtime (low average per bundle)
1	Door does not close on first attempt	4-5 occ. per shift	4-5 occ. per shift	0.166	0.166
2	Turning station, chips and dirt on sensor	1 occ. per shift	1 occ. per shift	10-15	8.33
2	Outbound conveyor (inside machine), lacks signal	1 occ. per shift	1 occ. per shift	10	8.33
2	Outbound conveyor (outside machine), lacks signal	1 occ. per shift	1 occ. per shift	5	8.33
3	Abutment control, problems with chips	5-10 occ. per week	0.33-0.66 occ. per shift	2	2
3	Clamping jaws gets stuck in chuck	1 occ. per day	0.33 occ. per shift	2-10	2
4	Inbound conveyor, chips and dirt on sensor	2 occ. per week	0.133 occ. per shift	5-10	5
5	Operator panel screen freezes (needs restart)	2-3 occ. per month	0.03-0.05 occ. per shift	3-4	3

5.2. Quantitative Results

In the CMMS, 46 breakdowns were found. The work orders for these had been open for an average of 11 hours, this totaled 506 down time hours due to breakdowns. This data was entered into the tool. In the OEE-system 355.2 hours were logged on the loss category “Breakdown, long stops”, respectively, 106.2 hours were logged on the loss category “Disturbance in equipment and tools”, see Figure 3.

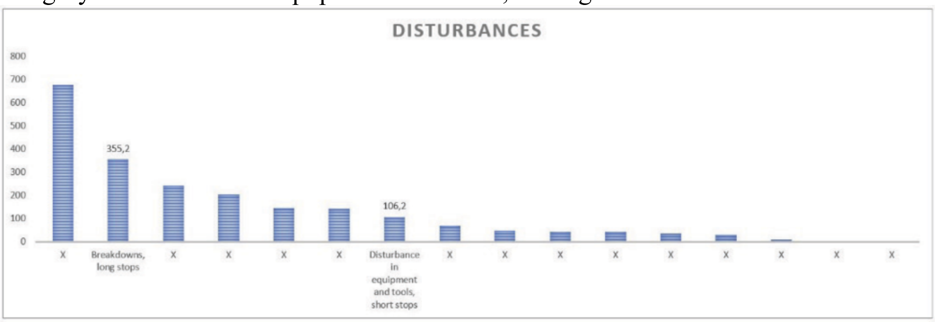


Figure 3. Bar chart of OEE losses of the machine.

5.3. Comparisons and Overall Results

When the data from the domain experts were entered into the tool and it was visualized that the approximated minor stoppages accounted for 319.4 hours and almost 40 lost shifts for one year, see Figure 4, the domain experts themselves (both the operators and the team leaders) were surprised.

That the approximation of minor stoppages does not match what is logged in the OEE-system is perhaps not that surprising. What might be surprising, though, is the amount that is un-matched. More than 200 hours are lacking in the OEE-system in comparison to the domain expert approximation. Firstly, as stated in the theoretical part, logging minor stoppages is difficult, specifically when logging through a manual system. Also, some of the stops are probably not even seen as a loss as it has become so natural with ordinary day-to-day production. Secondly, this particular production cell produces several different variants of gears, depending on variant, different machines in the cell becomes the bottleneck. The OEE is though always logged on the same machine, independent of current bottleneck. As such, losses in the machine are not logged if it is not the current bottleneck while at the same time losses in the downstream value flow are logged.

That the logged loss category “Breakdown, long stops” in the OEE-systems does not match the data from the CMMS is perhaps also not that surprising. In this particular CMMS, work orders might be open longer than the actual stop as, e.g., repairmen might wait to close it during testing. Also, a work order might be open when there is no production planned and as such no OEE is measured.

In this case, a rather problem filled machine was chosen, at least when comparing to other machines within the production cell. This can be seen by the fact that a rather high number of breakdowns with a rather long mean down time had been reported in the CMMS. By judging on the domain experts’ approximation there are also minor stoppages that needs the attention in order to increase effectiveness of the machine. Also, only two loss categories are highlighted in the OEE-measurement, as can be seen in Figure 3, additional losses might need attention too.

Had there, in the tool, been a possibility to choose four-shifts, which the production cell had been producing in the past year, the total minor stoppages had increased. Also, if not using the lower approximations of frequency and downtime of the minor stoppages the total minor stoppages had increased even more.

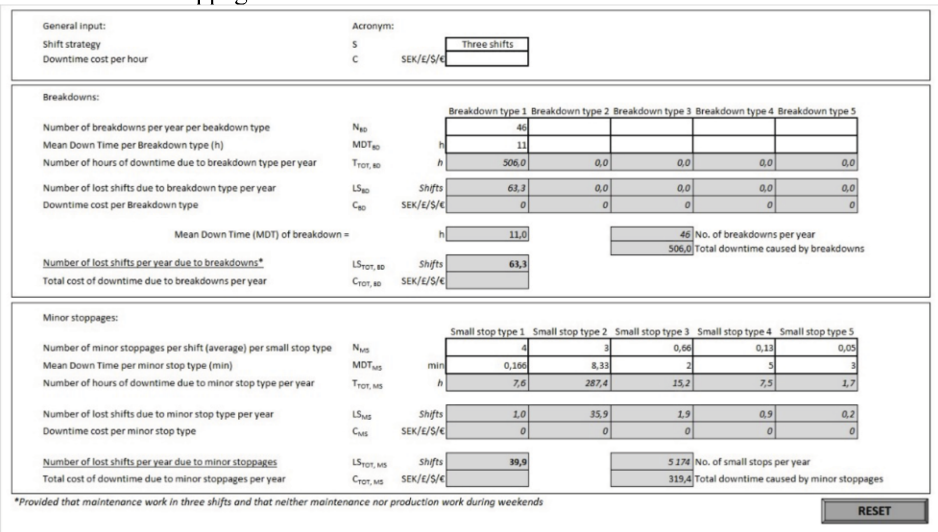


Figure 4. Screen shot of the results of the tool.

6. Discussions and Conclusions

Measuring performance indicators is an important step in achieving a successful improvement work. Sometimes though, depending on how measures are taken, errors in the measurements can be introduced. Several researchers [15, 16, 21] express that it can be difficult to measure minor stoppages and chronic losses. Where possible, it can be wise to complement quantitative measures with domain expert approximation as well as to compare similar quantitative measures from different systems in order to get the most information to prioritize and plan for improvements. The developed tool, presented in this paper, can help in this task so that data accuracy can be improved, particularly if a company is utilizing manual data collection as expressed by Muchiri and Pintelon [21]. The tool might also help to visualize to operators, management, and support functions how much minor stoppages actually disturb production and that it is important that these does not go unnoticed in OEE-measurements.

A limitation with the tool is that it is only possible to choose daytime, two-, and three-shift strategies. Developing the tool so that it can also calculate losses in four- and five-shifts will enhance the usability. The number of possible inputs to breakdowns and minor stoppages can also be increased. Currently there is only a possibility to input five breakdowns and minor stoppages with similar frequency and downtime.

Another limitation with the tool is that it, so far, only compares the sporadic loss of breakdowns with the chronic losses of minor stoppages. Clearly, other sporadic losses than breakdowns exist, and in some cases, breakdowns can even be chronic in nature. Similarly, other chronic losses exist also, such as in, reduced speed and in quality losses.

A third limitation with the tool is that it does not take into consideration unknown chronic losses. As stated in the theoretical section, chronic losses are something that is often perceived as something normal [17] and therefore it might be difficult to find all by interviewing domain experts. In order to find all chronic losses, it is necessary to compare operations to theoretical or optimal levels and possibly to do this by connecting machines to a follow-up system. Connecting the machines and log/track minor stoppages in OEE- or ERP-systems and also to automatically log cycle times is a solution. However, it is wise to first debug the loss collection process and work with the losses we know before we automatize/digitize the measurements or else there is a risk in digitizing waste [22]. Even if a machine is connected and signals that detect losses can be logged a lot of the losses need to be categorized by an operator so that the root-cause of the loss gets known. A good point is made in Jones et al. [23], where it is stated that ". . .technology can assure the availability of data but not guarantee that the data is accurate." (p.128)

A fourth limitation with the tool and the paper is that it only deals with the recognizing and observing and to some extent logging the losses. It deals in no way on improvement work or prioritization of improvements on either sporadic or chronic losses. This is by several authors [9, 16] discussed as also being something difficult. The notoriousness of the chronic losses can thus be expressed as both being difficult in recognizing and observing but also difficult in improving. How to reduce chronic losses should also be considered as a suggestion to future studies.

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