ŠKODA AUTO VYSOKÁ ŠKOLA, O.P.S.

Programme of Study: B6208 Economics and Management
Specialisation: Business Administration and Operations

Analysis of TPM on the EA 211 engine processing line

Bc. Robert Turinsky

Thesis supervisor:
Ing. Petr Novotný, Ph.D .

Extract this sheet and replace it with the assignment of the Master´s Thesis

Unless otherwise indicated in the text or references, or acknowledged below, this thesis is entirely the product of my own scholarly work.

Any inaccuracies of fact or faults in reasoning are my own. Accordingly I take full responsibility. This thesis has not been submitted either in whole or part for a degree at this or any other university or institution.

I hereby declare that I have mentioned all used sources and that I have cited them correctly according to copyright of the Act no. 121/2000 Coll., on Copyright and Related Rights.

This is to certify that the printed version is equivalent to the submitted electronic one.

Mladá Boleslav, 07.01.2016

Hereby I would like to thank Ing. Petr Novotný, Ph.D. for his helpful comments and valuable contribution, when supervising my Master´s Thesis.

Table of Contents

Acronyms

CZK	Czech Crown
JIPM	Japan Institute of Plant maintenance
PDCA	Plan Do Check Act (method for improving processes)
OEE	Overall Equipment Effectiveness
SMED	Single minute exchange of dies

Introduction

With production sites becoming more and more efficient, there are various trends in production such as automation or using more robots. But with this the problem of finding the right maintenance strategy occurs, as robots are not able to maintain themselves. The worldwide competition is getting bigger and bigger with globalisation. The cost for machinery is also increasing as the human factor is decreasing within western countries. The problem which needs to be faced is the right handling of machinery. People tend to think that machinery, once installed will work forever. But it needs also be maintained on a regular basis. It is not enough to lubricate the machines at a certain interval. As the machinery is getting more complex also complex maintenance is being needed. Further the maintenance is generating a significant amount of costs which need to be evaluated. Here is the model of TPM of which this thesis will come to bear.

The focus will be on the EA 211 engine process line, which is processing engines for most gasoline engines of Škoda Auto as well as for the whole Volkswagen group. Precision is very important within this process; therefore quality issues based on a lack of maintenance cannot be accepted. Further the EA211 are fitted into most of the Škoda cars, and especially for the model range from Citigo up to the Octavia inevitable. Therefore the stable supply of the vehicle assembly line is important.

The theoretical part of this thesis is presenting the history and development of TPM, then showing the process of implementation and appropriate methods which need to be applied. Also the way of measuring the effectivity will be described.

The practical of this thesis starts with the implementation of TPM at Škoda Auto and then analyses factors that influence the effect of TPM. On one hand the losses on the production line is analysed. This will be done by measuring the data within a timeframe and applying a trend model to show the development. On the other hand the opinion of the personnel is being evaluated with a survey provided measuring the success of TPM and also the disadvantages. Furthermore an 8 hour TPM shift each week was implemented at the production line and it will be clarified if this shift has a right to exist, as it reduces the capacity of the production line.

1 Beginnings and implementation of TPM

The origin of TPM began after the Second World War with Dr. W. Edward Deming's work for various Japanese companies. He was a statistician and used applied statistical methods on production. The preventive maintenance was widespread but not adopted to the machinery's needs as it tends to need investment more than it is necessary. This leads to an increase of cost which could be avoided.

But the beginning of Total productive maintenance started in Japan in the 1960's with Nippon Denso a producer of automotive electrical parts (which belongs to Toyota Group), implemented preventive maintenance, which means that the machinery is maintained before failing. The problem that Nippon Denso had was the increase in automation on production lines, as a consequence maintenance increased and the preventive maintenance was insufficient. So they started to give regular maintaining tasks for maintenance to the machine operators. So when the production line is standing still, they have the possibility to clean the machinery and the maintenance person has time to solve other issues. This is called autonomous maintenance. Another part is that Nippon Denso was starting to plan the machinery regarding the needs of maintenance in order to reduce the problem within the working time of the machine (McCarthy, Rich, 2004).

Furthermore Nippon Denso involved all employees within the process of implementation and running the TPM system. One of the persons who worked at Nippon Denso was Seiichi Nakajima, he is called the founder and implementer of modern TPM in hundreds of companies. He also was one of the founders of the Japan Institute of Plant Maintenance (JIPM).

The critical success factors according to the JIPM for TPM (Willmott, Mc Carthy, 2001) were:

- Maximum utilization of equipment.
- Development plan and system for maintenance of machinery for their whole life span.

- Involvement of all departments who are dealing with maintenance, this is not only the maintenance department, but also the production and tooling department and suppliers of the machinery.
- The whole company needs to be involved from top management down to the production workers, to show that this concept is supported by the whole company.
- Make TPM popular within the company with internal communication and workshops.

All these actions as a whole create the system of total productive maintenance. In the western companies first attempt to implement TPM was in the 1990’s, but it quickly abated. The problem was the lack of expertise so it clashed fast. But more so, the tasks of cutting down costs and improving quality TPM became a big topic again in the 2000’s.

The basic for TPM is 5S. This is also a Japanese system. It has the following factors(Willmott, Mc Carthy, 2001):

- Seri (sort) means that unnecessary tools or things should be removed from the workplace. This has also something to do with preventing accidents as obstacles should be also removed.
- Seiton (set in order) apply the system for giving each tool a defined place where it can be found. It saves time for searching tools and makes checking easier.
- Seiso (Shine) it means to clean the workplace completely in order to improve safety and broken things. It also helps to identify problems better e.g. if a machine is leaking oil and it was cleaned before it can be seen well.
- Seiketsu (Standardize) create standard processes and they should be written down and should be made accessible to all employees in order to give them the possibility to get in touch with the standards.
- Shitsuke (Sustain) it means to keep the achieved standard and check it regularly. This should be done with audits and periodical trainings of workers.

1.1 The six big sources for losses

In order to increase the OEE, losses need to be minimized. For this reason TPM defines six sources for losses (Willmott, Mc Carthy, 2001):

- Machinery down time

This is due to a defect in the machine during operation time. These losses can be short but can have a big effect in total. It must be distinguished between failures which depend on machinery or if it is machinery independent.

- Changes of product and tooling

This loss occurs when the production line switches the tools for producing another product. The time is counted when the last piece of the former product is produced until the new product is being produced, but in an adequate quality. This time duration is measured within the Single minute Exchange of Die (SMED) philosophy. The aim of the SMED method is to reduce this time for tooling and therefore to increase the efficiency.

- Still standings or short stops

This can happen if a work-piece is jamming the conveyor belt. This fault does not need to be for long and probably can be solved within seconds or minutes. But if this happens frequently then it can threaten the production time.

- Losses from lower takt time

This loss occurs when the production line is not working within the set takt time and is working with a lower speed. These problems can be based on quality or machinery issues.

- Losses through starting issues

It can happen that the machines need some time to start (e.g. heating) or until the full line speed is reached. This problem only happens when the machinery is completely shut down.

- Quality losses

This can happen if the production department is producing without being in the tolerance for production. Rework will be necessary and parts need to run the production line for several times.

The reasons for these losses are:

- Bad condition of machinery.
- Lack of maintaining / human failures.
- Lower knowledge of how to achieve a better situation.

The goal of course is to achieve zero defects within production. This can only be managed by eliminating the reasons for losses. Defects within the machinery can, with good monitoring, be found with 85% reliability (Mc Carthy, Rich, 2004). After implementing a monitoring system, a maintenance plan should be worked out in order to prevent failures. But on the other hand some failures can also result from a lack of knowledge or over lubricating. This can lead to failures or even to a shorter life span of the machinery.

It is also common that with the implementation of TPM new machinery is bought as it is identified as weakness. But the problem is if the maintenance workers had issues or breakdowns with the old equipment then purchases for this reason of new machinery is the wrong approach. Because if there has been a lack of knowledge in the equipment, new equipment does not solve the problem. As it is grounded on lack of knowledge, what is the reason for new technology to be better? So therefore, a restoration of machinery should be taken into consideration. According to the motto: ”restore before improve” (Mc Carthy, Rich, 2004, p. 35). Restoring is improving the current equipment so workers do not need to get used to new machinery. Furthermore the knowledge of machinery in the maintenance department should be deepened and in the end costs can be broken down as restoring is cheaper than new equipment.

1.2 Overall equipment effectiveness (OEE)

To explain the OEE, first a look at the parts of which it is combined needs to be explained. The three factors are: availability, performance and quality. Each of these factors measures an important part of the production. The division is making the identification of sources of low OEE easier (Al-Radhi, 2002).

Taking a closer look at the Availability it can be seen that it is counted by the real operating time divided by the planned production time – see (1). It means that the planned stops of the production line for example for planned maintenance or breaks are not included within this time as they are predicted. The real operating time measures the effective time the machines are working. The real operating time is mainly influenced by unplanned failures and breakdowns. Also the time for waiting for the parts or changes for tooling is counted as breakdown and reduces the real operating time (Košturiak, et al., 2006).

1 $$Availability = \frac{real\ operating\ time}{planned\ production\ time} \tag{1}$$

The performance factor is dealing with speed loss. It takes into account how much could have been produced and how much was produced in reality. The ideal cycle time is telling how much time the process takes to produce one piece. It is important to mention that all pieces are counted regardless their quality as the performance indicator is not considering quality aspects. This time is multiplied by the total pieces produced within one day or one shift. This is up to the author.

Then, this result is divided by the net operating time, which is already taking into account all the planned stops – see (2).

$$2 \quad Performance = \frac{ideal\ cycle\ time \times total\ pieces}{net\ operating\ time} \qquad (2)$$

The quality is the last part of the OEE (Košturiak, et al., 2006). It measures the ratio between quality pieces, which went through quality testing and the total number of produced pieces –see (3). It is important to mention that also the pieces that are reworked counted as total pieces and not as quality pieces. The first reason is that according to the Japanese philosophy the part should be in adequate quality for the first time and rework should not be needed. This quality index can help to make the amount of rework visible and therefore reduce the losses. The second reason is that often reworked parts need to be sent to the production line again in order to check their quality. This leads to a reduction of the total capacity of the line, as the machinery is working two times on the same piece instead of working on two pieces within the same time.

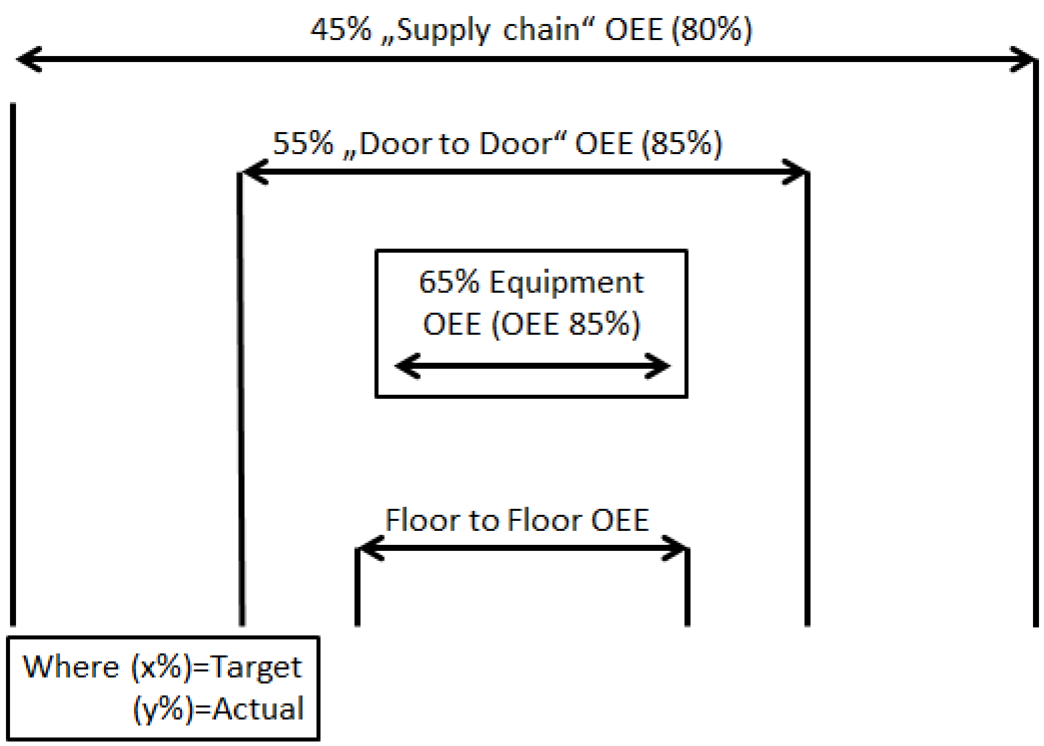
$$3 \quad Quality = \frac{good\ pieces}{total\ production\ of\ pieces} \qquad (3)$$

The OEE is a combination of all three factors. These are multiplied by each other – see (4). The result is the overall effectiveness. World-class companies should achieve an OEE of 85% at minimum (Mc Carthy, Rich, 2004). But it counts only of the internal equipment effectiveness within the production.

$$4 \quad OEE = Availability \times Performance \times Quality \qquad (4)$$

OEE can be measured within a much wider scope, as there are plenty of sources for reducing the efficiency not only of production but within the whole company and supply chain. These cases are shown in Fig. 1, which divided the OEE into different layers from the complete supply chain to the equipment effectiveness. For example production has a bad OEE because the supply of raw material is inadequate so a frequent change of tooling is necessary or even the production line is forced to run on lower takt time and the raw material is limited.

The OEE can be divided into "Equipment" OEE, which is measuring the six big losses and is only measuring the production line. The target for this OEE should be 90%. The next is the "Door to Door" OEE. This is taking into consideration the supply chain within the factory. This means logistics from and to the production line and other internal processes. The target OEE for this case should be 85%. But this "door to door" OEE is only measured within the plant or factory. The complete supply chain from supplier up to the end customer is called Supply Chain OEE, including OEE's mentioned before. The target percentage is 80% according to McCarthy. So it needs to be considered that is fine when the Equipment OEE is 85% so at maximum, but if the Door to Door processes are adjusted wrong it can lead to a smaller OEE in total. This can be for example wrong logistical management or wrong prioritizing.



Source: Lean TPM A blueprint for change, page 21

Fig.1 Layers of measurements for OEE

1.3 Implementation of TPM

The methodology of TPM should be implemented in within 7 steps (Al-Radhi, 2002); it is close combined with the 5S method, which was previously described.

1.3.1 Step 1 Initial clean up and discovering faults

First of all a ground clean-up must take place in order to find the weak places and identify problems. The reasons for this clean-up are that the personnel gets in physical contact with the machines and gains a different perspective of their equipment. Further, with clean machinery, there are no difficulties such as leaks or abnormal concentration of dirt. This dirt can also lead to failures so it is important to identify and to take action in order to reduce the amount of impurity. It is also the first step to get an idea about the machinery and as it will be explained later about creating a maintenance plan. Because the initial clean up should remark a new standard it should not be considered as a unique action.

1.3.2 Step 2 Identification and elimination of sources for uncleanliness

The root causes for the uncleanliness, which was identified in step 1, need to be investigated. Possible root causes can be:

- Over lubricating the machinery.
- Wrong set up of machinery.
- Leaks within the oil leading systems.
- Wrong layout of equipment.

The aim should be to find the sources for contamination and reduce their after effects to a minimum or in best case down to zero. It is also necessary when providing an audit, it will be more described in further steps, to emphasize these sources as they are regularly checked.

1.3.3 Step 3 Autonomous maintenance and lubrication standards

The first aim is to adapt a system for autonomous maintenance; this includes making a schedule for each maintenance task which can be done on a regular basis. The interval between the maintenance shifts should be short as the level of knowledge is relatively low and frequent control of the machinery is being advised. Further auditing would also help to increase the level of maintenance. For audits it should be considered to create a schedule, but not on a regular interval, some of the maintenance tasks which will be checked, should be switched between each other. The intention is to check the maintenance performance under normal conditions. Otherwise it can happen that the maintenance is only done just before the audit.

The second aim of this step includes and set the following tasks:

- Standards for lubrication (intervals for checking, how to refill).
- Type of lubricants being used.
- Places of lubrication.

In addition a timing plan for providing the lubrication and checking its level needs to be included. Also the responsibilities need to be clarified, which tasks will be checked by production and which ones by maintenance. The tasks should be showed by the maintenance personnel to the production personnel in order to increase the knowledge of “their” machine.

1.3.4 Step 4 training of operators in technical skills

The aim of this step is to make the operator familiar with the technical specifications of their machinery. This training can be provided by the technical personnel who developed the machines and also by the maintenance department as they should be also aware of the technical specifications. Further, the maintenance department can give advice on which parts of the machinery are key indicators, in order to locate abnormalities as early as possible. It should show some basic specifications such as lubrication, pneumatic and hydraulic circuits. Further which parts are wearing most quickly and need to be focused on. Also the correct description of the parts of the machinery is recommended, that in the case of failure the communication is being improved and production and maintenance understand each other. As these departments will get in closer contact with this training the inter-departmental communication will benefit from it.

1.3.5 Step 5 providing autonomous inspection of machinery

The aim of this step is to hand over the task of inspection to the operator. Therefore the standards for autonomous inspection need to specified and clearly stated. The basic columns are:

- Which machine is meant (an internal number is being recommend) and where is it located?
- Who is responsible for providing the autonomous inspection?
- When should the maintenance happen?
- How should it be provided?
- Which factors should be measured and checked?
- Who should be contacted in case of troubleshooting?

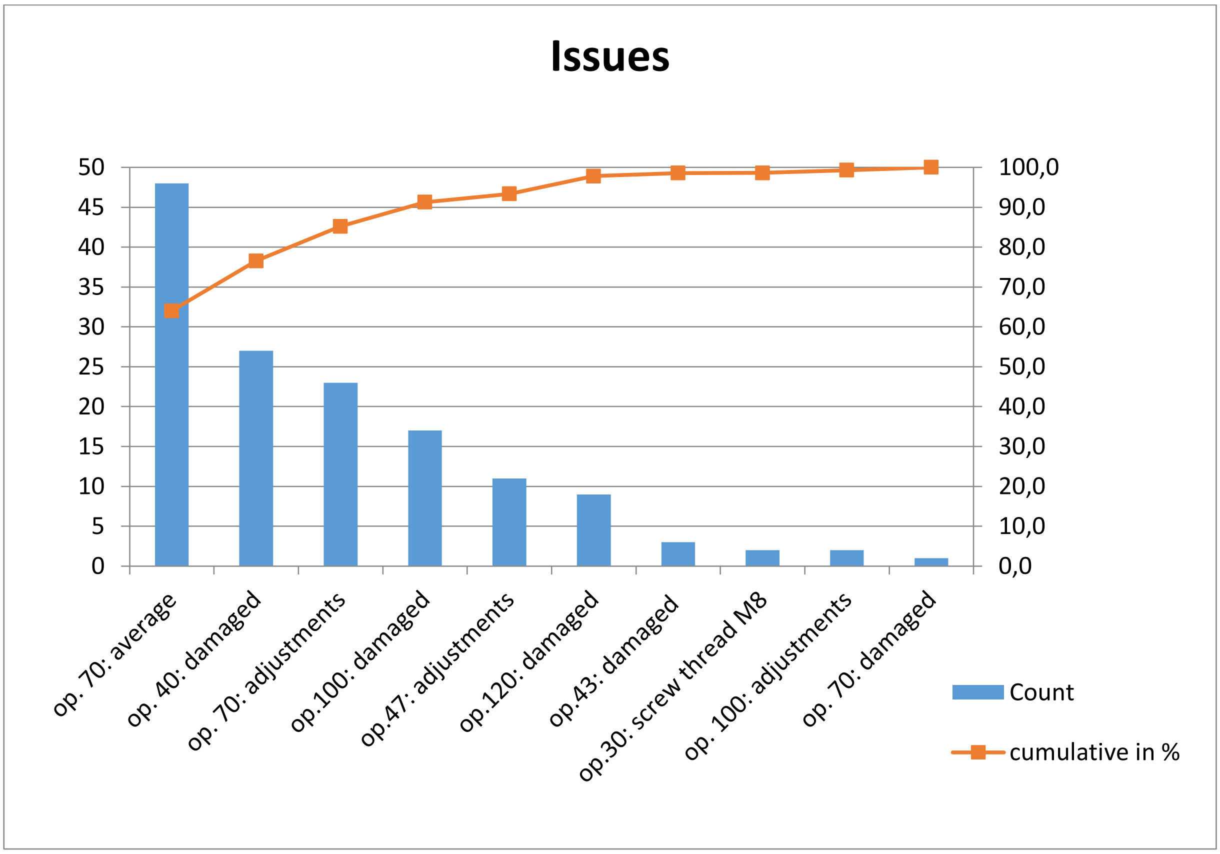
Another important part is the implementation of measurement systems for issues and maintaining. These can be visual signals e.g. lights that are indicating the status of the machine. Further the level of lubricants in the machine should be marked with maximum and minimum. Or that the position of bolts and nuts should be marked to register abnormalities immediately.

At the end of step 5 the outcomes should be:

- Increase efficiency of machinery.
- Reduce the frequency of abnormalities.
- Set the right standard for autonomous maintenance.

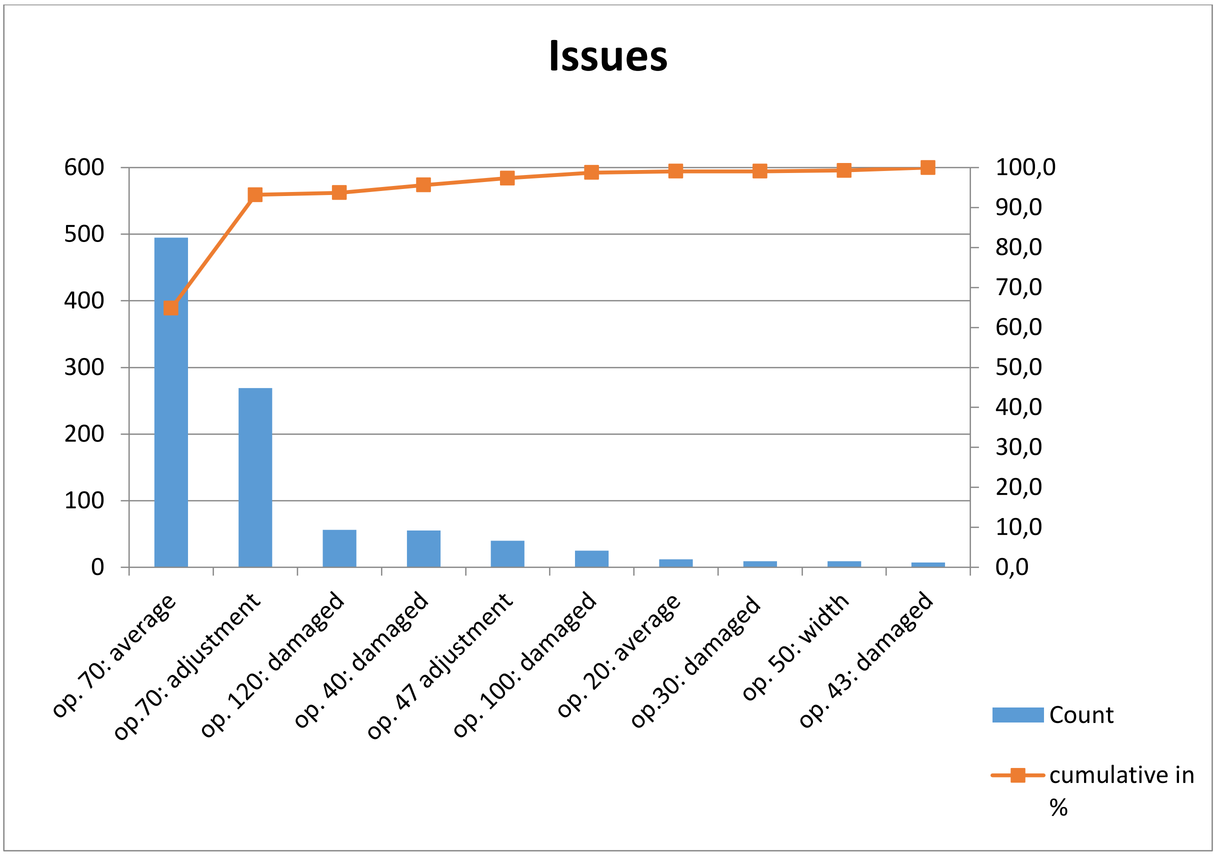
1.3.6 Step 6 standardize procedures and increase efficiency

In this step, the standards which were set need to be reviewed and maybe changed. The methods of providing and the influence of autonomous maintenance need to be measured. The aim is to improve the efficiency of maintenance and then to improve the machinery effectiveness. For identifying the important issues, a Pareto diagram for the issues is being recommended. It states how often the issues are occurring and how important they are to the process. The bar charts count how often one problem occurs (Fig. 2a, 2b). The line chart counts the cumulative count. If the two parts of the diagram are compared it can be seen that the first line chart (Fig. 2a) is increasing slowly, whereas the increase in the second graph (Fig. 2b) is significant between the first and second issue. This means that the two problems make 75% of all issues in Fig. 2a, in comparison with Fig. 2b where the first two problems make over 90% of all issues. So the Pareto analysis shows the weight of the problems. This can be helpful for evaluating the issues. To conclude the example the Pareto analysis showed that in the first case (Fig. 2a) the issues are spread and have more or less the same influence on the production. But when taking the second diagram (Fig. 2b) the first two issues are causing more than 90% of the problems, so it needs to concentrate on them.



Source: internal material Škoda Auto

Fig. 2a Pareto Analysis at Škoda Auto



Source: internal material Škoda Auto

Fig. 2b Pareto Analysis at Škoda Auto

1.3.7 Step 7 improving the maintenance (KAIZEN)

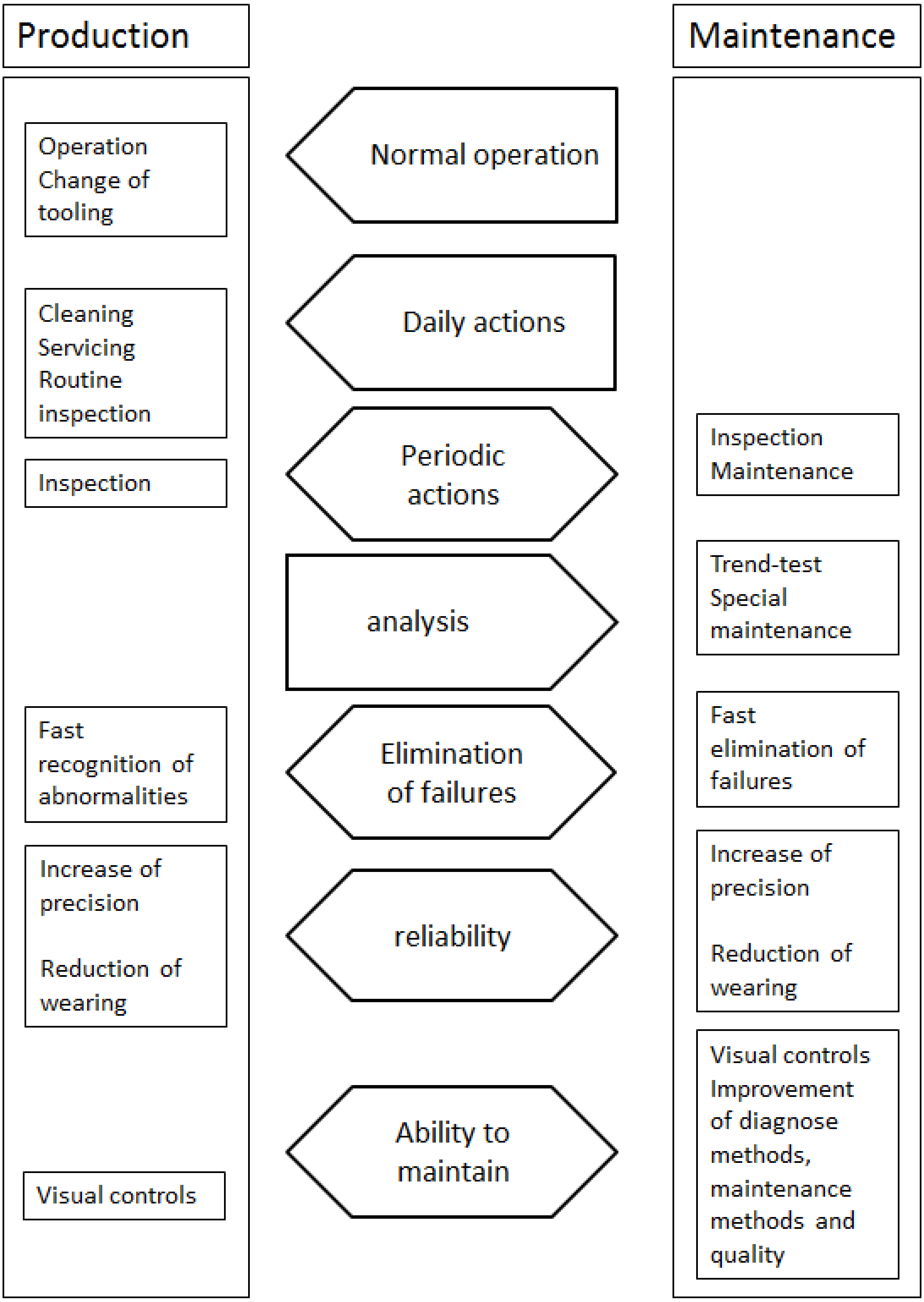
The implementation of TPM should not be considered a steady method which will be applied one time with no change further necessary. Here the idea of Kaizen which means continuous improvement needs to be considered. It states that everything can be done better and if a problem occurs it is subject to investigation so that it does not happen again. This kaizen thinking is an inevitable part of the success of every improvement which is made in the company. It is one of the core values of Japanese manufacturing (Košturiak, et al., 2006).

So one of the keys to improve the situation is the correct evaluation of data, which should have been collected in step 6. But also the employees need to understand the meaning of Kaizen. The aim is that the maintenance department is making improvement on the machinery and complicated tasks during the breakdown. The level of knowledge at the production department needs to be increased to a higher level in order to handle minor failures on their own. It is mandatory that there is a good communication between the maintenance and production department. Both of them are part of the team which is running the machines.

The increase in autonomous maintenance should lead to less unplanned breakdowns and it should not happen anymore that the employees are aware of a problem but do not solve it until the machine breaks down.

The most important point is that the condition of machinery should improve and therefore also their lifetime should be prolonged. The non-planned failures should be reduced to a minimum and therefore the OEE should be increasing.

How the tasks between production and maintenance department should be divided if the 7 step approach is provided correctly, can be seen in Fig. 3. It states that the daily checks should be provided by the production department, whereas the periodical maintenance will be done by both departments. The operators can show the long term problems, which are not interfering production but can be improved. The maintenance department should then provide a deep analysis of this issue. Further it can be seen that most of the tasks are split between these two departments in order to guarantee good cross departmental work and to solve issues earlier.



Source: own processing according to Erfolgreich Produzieren mit TPM, page 35

Fig. 3 Distribution of tasks between maintenance and production department

1.4 Methods of communication

For a successful implementation of TPM the right communication is inevitable. A good method is to use a TPM board, on which are all the tasks, responsibilities and possible problems summed up. It should be used as the linking part between the maintenance and production department. An example of a TPM board can be seen in Fig. 4. This board is used to put on all the failures which were found within the TPM system. It offers an overview for all the employees so the cross departmental communication can be improved.

Source: Škoda Auto internal material

Fig. 4 TPM board at Škoda Auto

Further the introduction of TPM cards is strongly recommended. These cards are filled in by operators and will be then put on the TPM-board that the maintainer can pick up the tasks.At Škoda Auto there are currently two cards in use. The first one is the red card, which is for maintenance workers, as it was found by the production employees; still, maintenance is necessary to solve the issue. The TPM cards will be put on the TPM board or into a special TPM box. The aim is for maintenance to organize their work and prioritize each task, so that they are solved quicker. The other type of card is the blue card, which is used by the production people when they find and issue but can repair it on their own. These cards are also collected and evaluated; the aim of the blue cards is to identify repeated repairs in order to solve them. Sometimes production does not know if a problem is repeating because they are all working on different shifts and it seems only to be a small problem to them. An example of this TPM cards can be seen in Fig. 5.

Source: Škoda Auto internal material

Fig. 5 TPM card system

Further it should be taken into consideration to arrange regular meetings for the production and maintenance employees that they can speak about long term issues and minor problems, because during normal production these problem are not mentioned so often. Another method, which should be taken into consideration, is job rotation. The employees can get an idea about the work in the other departments. It can help to develop new ideas and the viewpoint of the participating employees may change.

1.5 PDCA circle

The PDCA circle was promoted by Dr. W. Edward Deming. He was one of the key drivers of modern maintenance as stated already in chapter 1. It states that the improvement of processes needs to be divided into four steps(Al-Radhi, 2002), which are:

- Plan
- Do
- Check
- Act

The Plan stage states that it is necessary to set goals that should be achieved with the change of the standard. Further the methods of measuring need to be defined clearly. Also the way to accomplish the goals needs to be set. Here the question of key processes needs to be raised.

The act stage is the active part in the implementation of the agreed steps. Further the data needs to be collected in order to measure the improvement within the next steps.

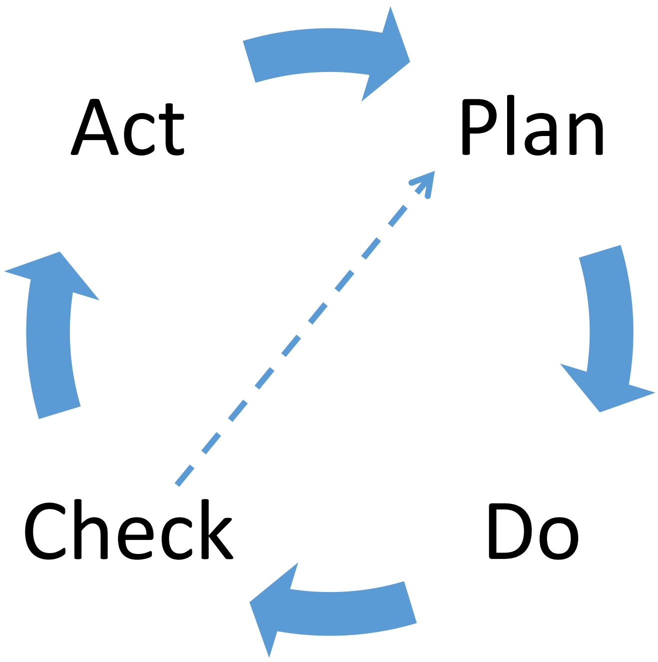
The check stage actually is evaluating the results from the second do-step. The goals need to be compared with the real results which were achieved. If no results were achieved the PDCA should start from the beginning.

The act stage is for assessing the results of the improvements. If the implementation is successful it should be set as a new standard and should be made visible to other departments within the company. The aim is to create a knowledge base and the same standards within the company. If the implementation was not successful, the PDCA circle should start again from the beginning.

Within the six sigma method the PDCA circle is also called DMAIC process (Košturiak, et al., 2006). This process is comparable but gets more into detail as it is divided into:

- Define
- Measure
- Analyse
- Improve
- Control

In Fig.6 the cycle of PDCA can be seen along with the fact that if during the check stage no results were measured then it is necessary to get back to the plan stage.



Source: own processing

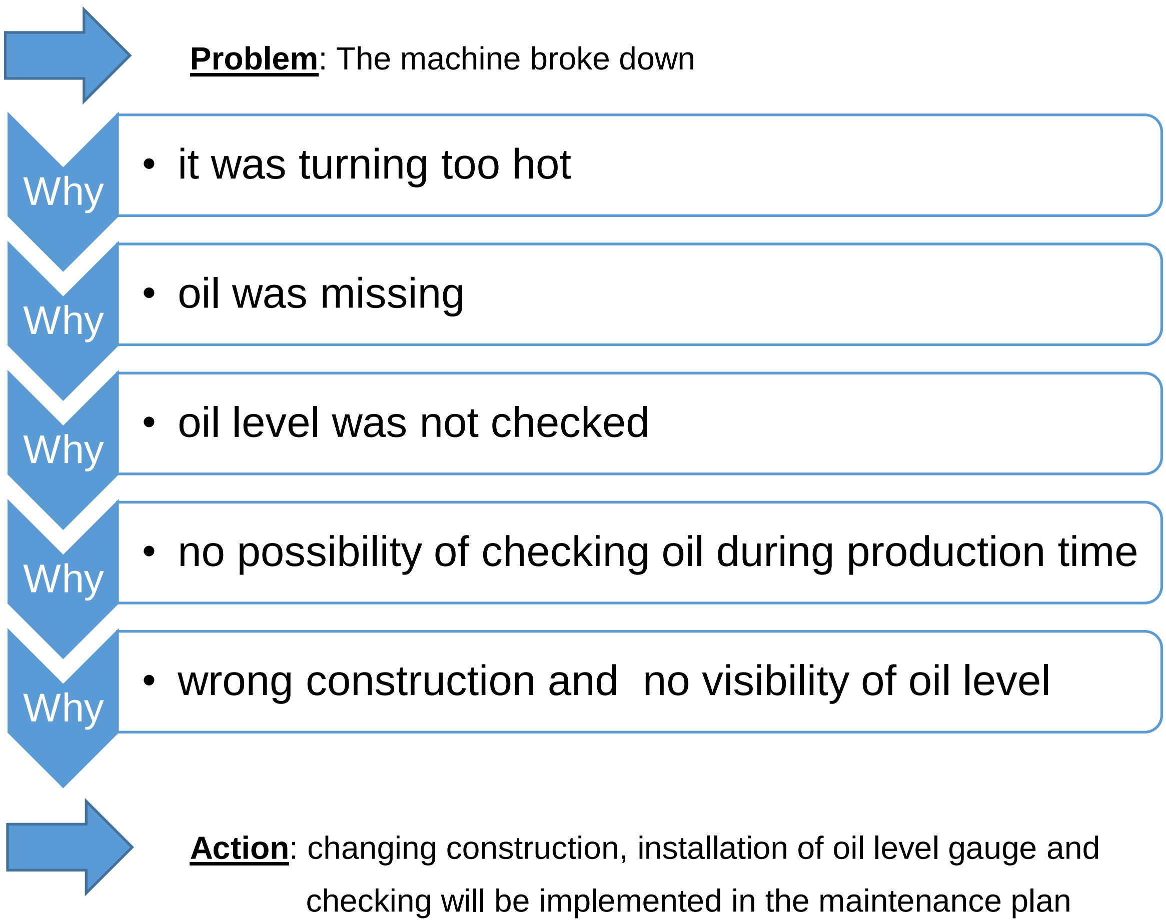
Fig. 6 PDCA cycle with check shortcut

1.6 Procedure of attacking failures and issues

First the sporadic losses need to be challenged, as these lead to unplanned maintenance and breakdowns. These issues can be easily tackled by improving the equipment condition, training the employees, that the concentrate on weak places. With these optimizations 80 percent of the breakdowns can be removed and a zero breakdown environment is possible and achievable(Willmott, McCarthy, 2004). The next step to put focus on chronical losses, here it is inevitable to apply problem solving approaches as it is difficult to identify the root causes and to solve them (McCarthy, Rich, 2004).

1.7 Problem identification method with 5-W approach

For identification of the root causes the 5-W approach can be very helpful. It states that the problem is taken and then 5 times asked "why". The reason is that sometimes the problem seems to be easy and is obvious. But this can be only the view of the assessing person. Moreover the issues can lay down deeper. To clarify an example from daily production will be used in Fig. 7.



Source: own processing according to Škoda Auto internal material

Fig. 7 5-W approach example

As it can be seen in the example the obvious problem was that the oil was missing. But with the 5-W approach, it will be asked several times where the source of the problem is. Because people tend to solve the problems superficially, in this case that oil is missing but not why. Therefore as it can be seen in Fig. 4 the root problem was that there was no lubrication standard set as there was no possibility to check the level of oil within the machine. The 5-W approach should be used when there is a breakdown within the machinery in order to find the root cause of the issue and not to solve only the final outcomes of the issues.

1.8 Visual management

Visual management is necessary for TPM. It should be included within the autonomous maintenance. It means that there is a visual support for the persons who provide the autonomous maintenance. As an example the minimum and maximum level of a lubricating part will be signalized with colours. Further there can be traffic light on the machines pointing to the machine that is having an error to be found easier (Al-Radhi, 2002).

2 Background of TPM at Škoda Auto component production

Škoda Auto has more than 100 years' experience within the engine production. The situation before TPM was that operators had plans of what to clean by the end of their shift. TPM started in 2013 with a 2 hour TPM shift each week. The decision for TPM was made based on the experience that during the engine processing a lot of dirt is produced and it was not cleaned on a regular basis which lead to the issue of breakdowns and increased wear of machinery. Further the operators were forced to stop the machinery during the production time for cleaning. So the overall production was strongly decreasing. The aim of the management was to give the employees the opportunity to identify their machinery and to improve it. Therefore not only a TPM shift was introduced but also the necessary training had been provided. It also contained also training with other members of the Volkswagen Group in order to share the experience. The next step on the engine processing line was the switch to a 8-hour TPM- shift each Friday morning. Within this time frame an external company is hired to provide cleaning within the machinery. Further, all issues which were discovered during the week and not effecting the production urgently are solved at this time. For this purpose either the Škoda maintenance department is called or special trained maintenance personnel mainly from the manufacturer of the machinery is coming. Within this timeframe the complete production is standing still so that maintenance actions are not to be done during normal production time. In addition the maintenance department is present with 2 maintenance engineers. These are also providing the weekly and monthly stated maintenance tasks which are highly specific. The operators have the task to support the maintenance engineers and also to get familiar with the failures and issues in order to repair them, if they are easy tasks, or to avoid them by changes during the operations. They also should help the maintainers to find the sources of the issues if it is a complex problem because they work with the machinery every day and have a profound knowledge of the methods how the machines work.

2.1 Process application of 7 step implementation of TPM

To ensure the identification of the source of failure can be done better, the first step of cleaning the production line was done by external personnel.

After this step the departments worked on identifying the uncleanliness and designed the proper timesheets for cleaning, further improvements on the machinery were provided in order to delete the source of uncleanliness. Also, the visual check was improved with minimum and maximum standards of oil for example, and then the exact type of oil for each machine was stated. Before the implementation of TPM a universal oil for lubrication was used, now the machinery got the oil recommended from the manufacturer.

The 3rd step was done by working out the standards which are put on each machine with critical places which should be checked by the operator.

The 4th step that the operators should be trained by the maintenance staff for, is lacking according to the head of the production line. Because the number of maintainers was cut down in 2014, they are concentrating more on the operational maintenance. The operators claim that there is less time for the training for causes of failures. This point should be improved by getting the maintainers and operators to meet regularly in order to solve the lack of communication.

This lack has also an effect on the 5th point of introduction of TPM which describes that the autonomous inspection should be handed over from the maintenance to the operators. There are currently trials to involve the operators more within the regular inspection. But as there is a lack of communication this process is taking a lot of time.

The 6th step with improving the efficiency is implemented as the OEE is checked in more detail in order to identify probable problems. Further pareto analyses are provided as described in chapter 1.3.6.

The last step which is improving the maintenance is done as the production department is in contact with the maintenance department and discussing new ideas reducing the production. Therefore the employees should be involved in this discussion and always consider new improvements. Within the survey in chapter 2.7.2 the last question is dealing with the ways of TPM improvement.

2.2 Methodology

The data presented in the following part was collected from regular reportings. As the data is varying very strong in some cases, the method of moving the average was used in order to smooth the data. The length of this moving average was adjusted to a 5 interval moving average. As trend model the linear trend model was chosen based on better comparability regarding trend developments.

It was also tried to smoothen the data by a 3 interval by it was shown that the interval was chosen too short as the quality of the model was inadequate and the changes within the various weeks are still too big. Then when an interval of 8 was chosen, there occurred the problem that the timescale was shortened too much. The interval of 5 was chosen to smooth the data on monthly basis. Specifically, the measurement of the spare parts is needed to be at a minimum 5 interval moving average because the collected data for the spare parts is defined as the arrival of the parts at the warehouse and not when it is ordered or when it is built into the machinery.. It influences the data when the ordered parts are not available in an adequate quantity or if they are available but the quality is poor. A factor was used to change the data as the original data is confidential material. The data is analysed per week in order to get the exact models in high detail. Ordering by month was tried but this seemed to be too rough as the timescale which was monitored was too short. Further it was tried to break down the data into days but then two problems occurred. The first one was that sometimes the data in days was not available, which is the case with data from 2014. Therefore it would be necessary to average the available weekly data. The second and more difficult problem was that the variation between several days is high which would be negative for a linear trend model. For the analysis Microsoft Excel with the data analysis added in was used. The timescale from January 2014 to November 2015 was chosen in the background as data from 2013 is only available in 60% of all data. But the methodology was different and it was not possible to make it comparable to the other data. Further the quality of the available data is poor so the validity should be questioned.

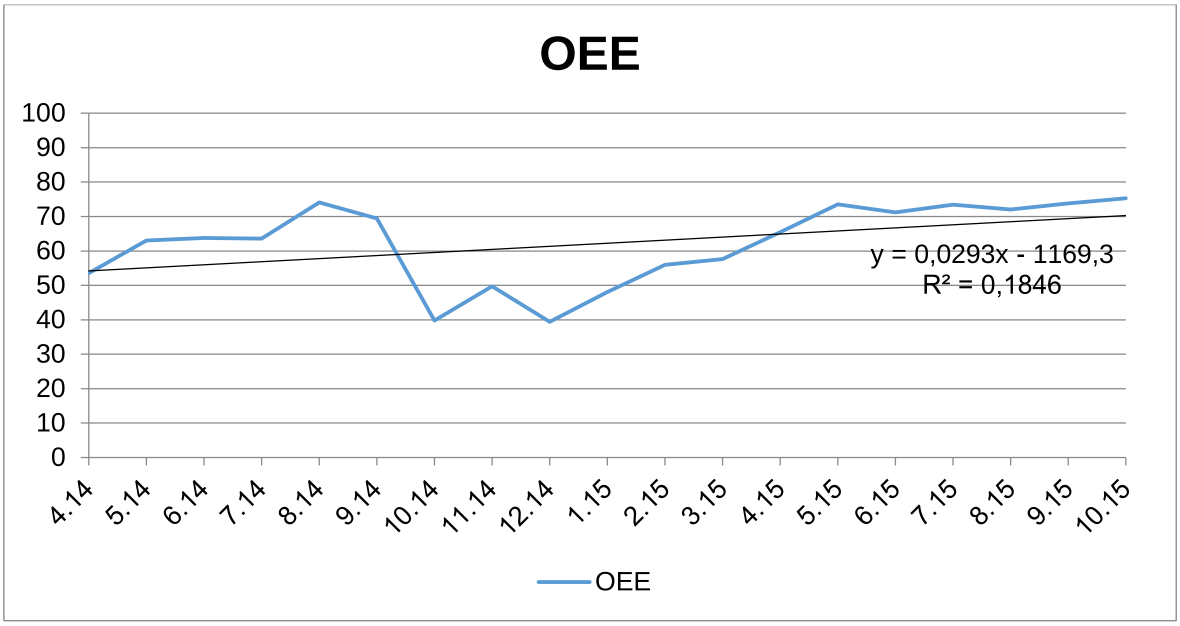
The author also tried to normalize the data, the outcome was that the key indicators and trends did not changed significantly. But to make the final statements clearer it was decided to show the data in the original format. Further, the comprehensibility is better with un-normalized data.

The data from the weeks 32-34 in 2014 and 2015 was removed from the graphs for retooling, technical losses. The reason was that the production floor was without production so the graphs would be at zero level and the mathematical calculation would be considered as values which would affect the final outcomes. The calculation of spare parts is considering this timescale because during these 3 weeks costs are generated so they could not be let out.

Furthermore the OEE was measured here the limitation that in 2014 there was no exact method for measuring the OEE, therefore the data quality is insufficient. With the introduction of more detailed data at 2015 the quality increased. Therefore the meaningfulness of the analysis is reduced.

2.3 OEE measurement

The OEE was started to be measured by April 2014. It was done by months until September 2014 then it was broken down in weeks. But with the increase quality monitoring the deep of the measurement increased steadily in 2015. The development is illustrated in Fig.8. The OEE has a strong decrease from October 2014 to December 2014. This was due to high organisational losses because the production line was waiting for raw material. Further frequent changes of tooling were necessary which also influenced the total performance. In January the OEE increased steady from 45 % up to 73,4 % in May. Then it remained on a constant level. With the implementation individual data collection at each machine in October 2015 the OEE should increase even more, because possible bottlenecks can be identified more easily. The linear trend model is with a confidence level of 18, 46 % a low predictive value. This is due to the decrease in the months October 2014 until December 2014. Further it would be necessary to either break down the date per week, what is due to the data source not possible, or that the monitoring period needs to be prolonged.

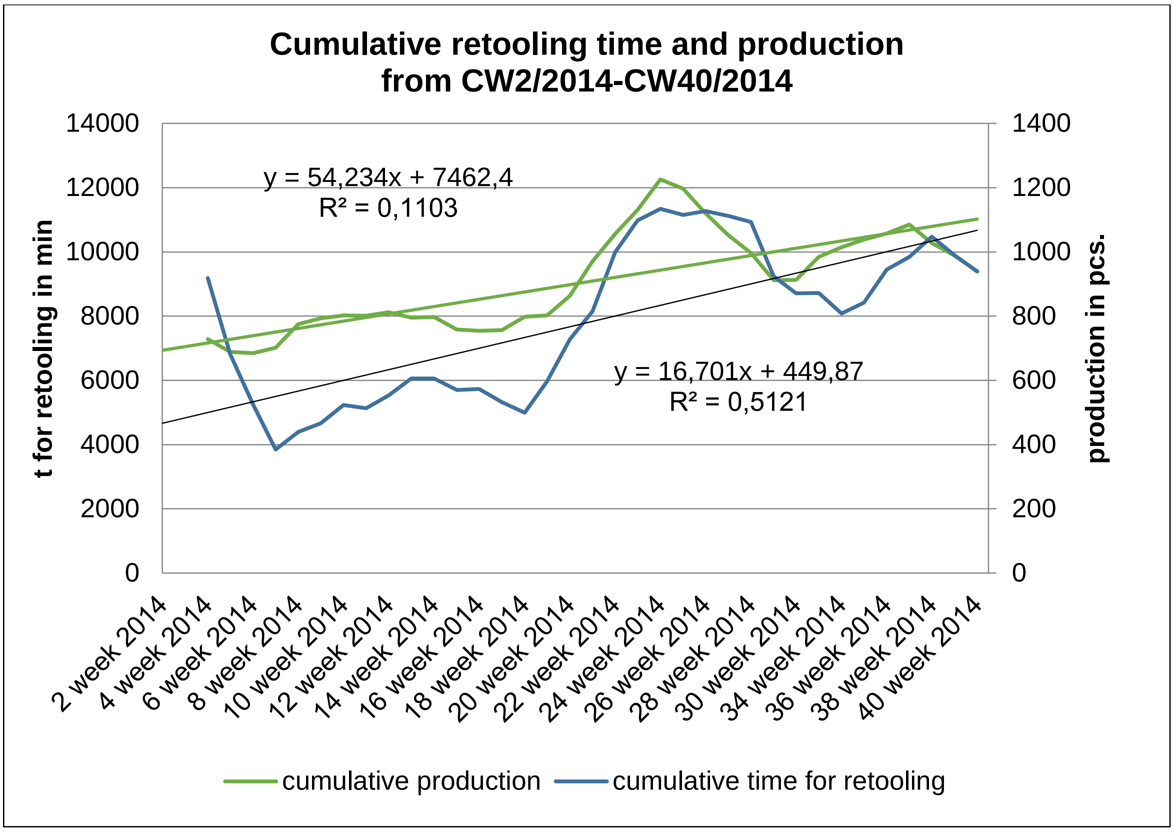


Source: internal data from Škoda Auto production

Fig. 8 OEE development from 04/2014 to 10/2015

2.4 Time for retooling cumulative

The retooling time is connected to TPM as it is one of the six losses described on p. 11, and further it was mentioned that with the operators being part of TPM should get better knowledge of their operating machinery and therefore the retooling time should decrease. The time for retooling was analysed by weeks and in cumulative view. This counts from the moment when the production line is going down for changes until the moment when it starts working again with new tooling.



Source: internal data from Škoda Auto production

Fig. 8 Cumulative retooling time before TPM introduction

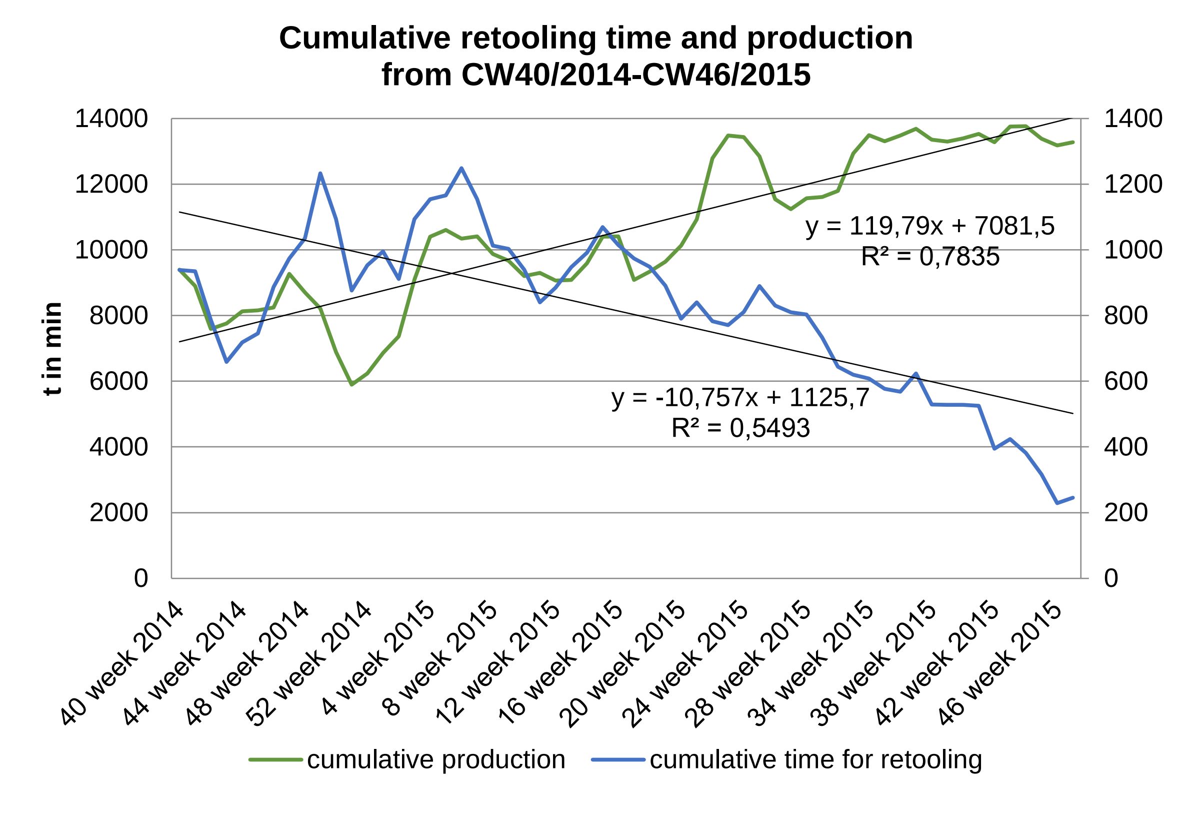
The data in Fig.7 shows that the weekly production and the time for retooling were getting closer until they crossed in week 26 and the retooling time was higher than the production this lasted for 3 weeks until week 29. Further it can be seen that both lines have a similar course, but in this place it needs to be pointed out that both lines are referring to a different scale as in the graphs before and after the introduction of TPM.

Tab. 1 correlation between retooling and production before TPM introduction

	cumulative time for retooling	*cumulative production*
cumulative time for retooling	1	
cumulative production	0,879147311	1

Source: own processing with Microsoft Excel

Another indicator for the thesis is the correlation between production and retooling. With 0,88 it is very high and leads to the suggestion that with the increasing production the time for retooling is increasing with the same percentage points.



Source: internal data from Škoda Auto production

Fig. 9 Cumulative retooling time after TPM introduction

With the implementation of TPM the total time of retooling was on a higher level until it started in the 14th week of 2015, to decrease constantly. The production of engines is increasing which can be seen with the rising linear trend-line. The increase of quality in both models can be explained through the lower level of variation throughout the week and with a longer timescale of observation.

Tab.2 correlation between retooling and production before TPM introduction

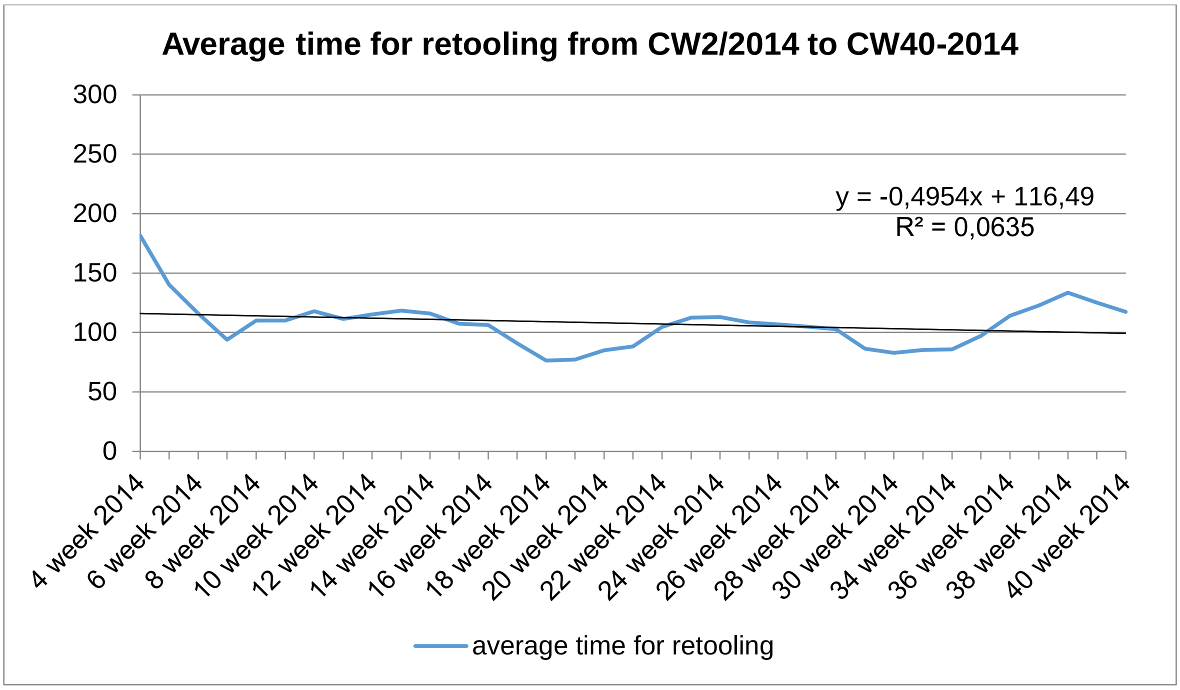
	cumulative time for retooling	*cumulative production*
cumulative time for retooling	1	
cumulative production	-0,595553318	1

Source: own processing with Microsoft Excel

The correlation got to a negative level which strengthened the aspect that the retooling time is decreasing while the production is increasing. This supports the statement from p.32 that retooling time should decline as operators know their machinery better. But considering another method of calculation the average time for retooling will be described in the following part.

2.5 Average time for retooling

As the time for retooling is an important indicator it was measured with another method. This means how much the operators take on average until they can start to produce a new type of product. It basically takes the total minutes per week spent on retooling and divides it by the sum of retoolings done in that week. It was already stated in chapter 2.1 that the weeks 31-34 are excluded. From the beginning with 170 min/retooling (Fig. 10) the values dropped and stabilized around 100min per retooling. In the linear model the average retooling time decreases by -0,4954 which marks a slightly low value. But it needs to be considered that the coefficient of determination of the model is with the value of 0, 0635 at a very low level and so the reliability of the trend model should not be taken as entirely appropriate. It was also tried to apply an exponential trend model, but in order show the change before and after the implementation of TPM this model is appropriate.



Source: internal data from Škoda Auto production

Fig. 10 Average time for retooling before TPM introduction

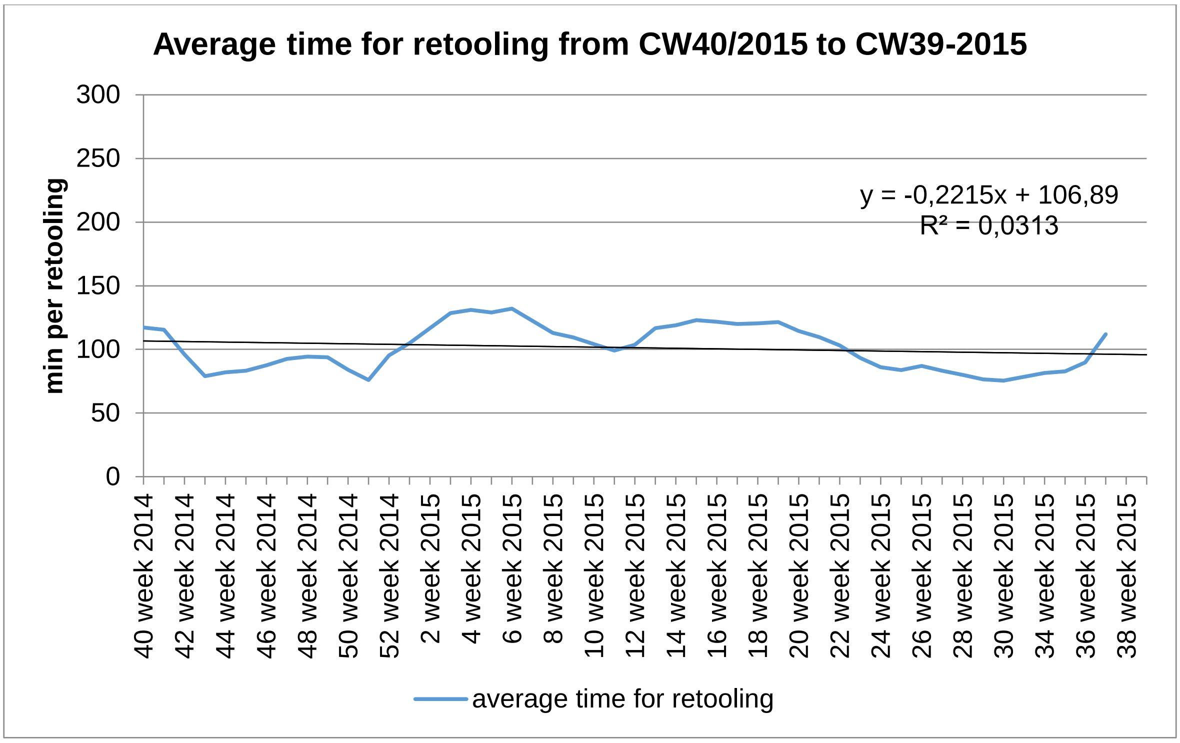
After the implementation of TPM the average tooling time (Fig.11) fluctuates around the value of 100. When taking a look at the linear model the decrease is by -0,2215 lower than before the implementation of TPM. It could be asserted that after the implementation of TPM the decrease of the average retooling time has stagnated. This assertion can be negotiated with revising the data before TPM implementation. Because the retooling time started at a high level with values of 181[1] in week 4 and 140[2] in week 5, this influenced the already weak[3] linear model very strongly, so in fig.12 it can be seen that it tested to start the timeline in week 6 and the value 115[4] this influenced the model so strong that the inclination was in near to zero in a value of 0,0385. With the revised data it could be considered that the average time for retooling after implementation TPM is decreasing according to the linear model.

But as the coefficient of determination is low on all levels and the changes in the inclination are small, a decrease of average time for retooling cannot be proved.

[1] It is the moving average from week 2 until week 6
[2] It is the moving average from week 3 until week 7

[3] It is considered as weak because of the coefficient of determination
[4] This is the moving average from week 4 until week 8

Now there are two contradictive measurements with the decreasing cumulative time for retooling and stagnating average time for retooling. Both measurements are important as the cumulative retooling time affects the OEE directly and the average time is better to measure the speed of the retooling. The decreasing cumulative retooling time can be explained through the reduced number of retools which reduce the total amount of loss. The operators can sometimes need more time for a retooling; this is measured by the average time for retooling. To summarize, it cannot be proven that TPM had a direct effect on the retooling time. The cumulative retooling time is due to logistical processes and planning, which the production does not need to change, so often. Also the stagnating average retooling time can be decreasing because of fluctuation of operators on other production lines. This means that when new operators come to the engine processing line they logically need more time for retooling than an experienced operator.

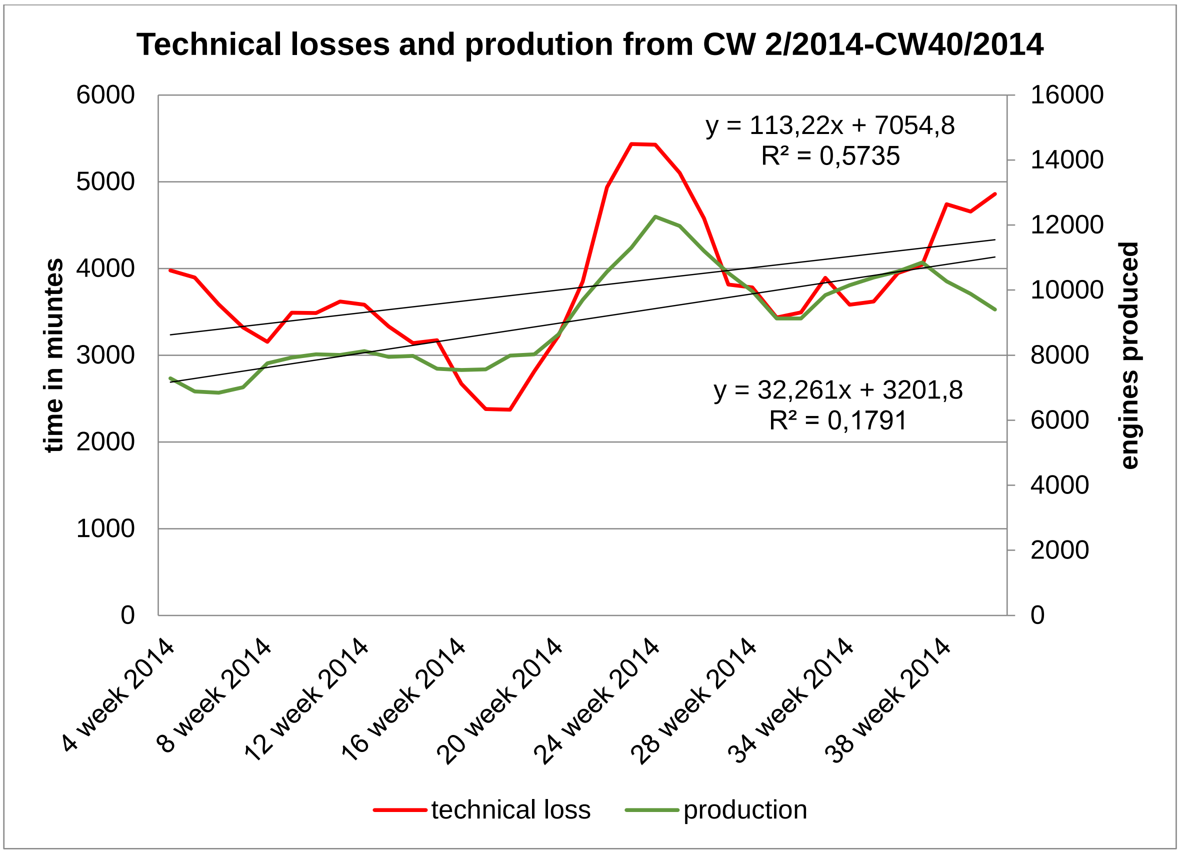


Source: internal data from Škoda Auto production

Fig. 11 Average time for retooling after TPM introduction

2.6 Technical losses

The technical losses belong also to one of the sources of the six big losses described in chapter 1.1. It influences the total time for production. Technical loss means that the machinery is standing still by virtue of an error or a damaged part. By applying TPM the technical losses should be reduced as the machinery is maintained regularly. Further minor problems are solved within the TPM shift, so that these issues are not affecting the available production time. The analysis of the data in Fig. 13 shows that with growing production the technical losses are increasing as well. They are not increasing as strong as the production, because the incline of the technical losses is 32, 261 and the incline of production is 113, 22. It also appears that there is a correlation within this timescale. This claim can be proven by tab.3 with a correlation between the two factors of 0, 73[5]. This means that with increasing production the losses of technical issues grew as well.



Source: internal data from Škoda Auto production

Fig. 12 Technical losses before TPM introduction

[5] The value was rounded from the original 0,729899068

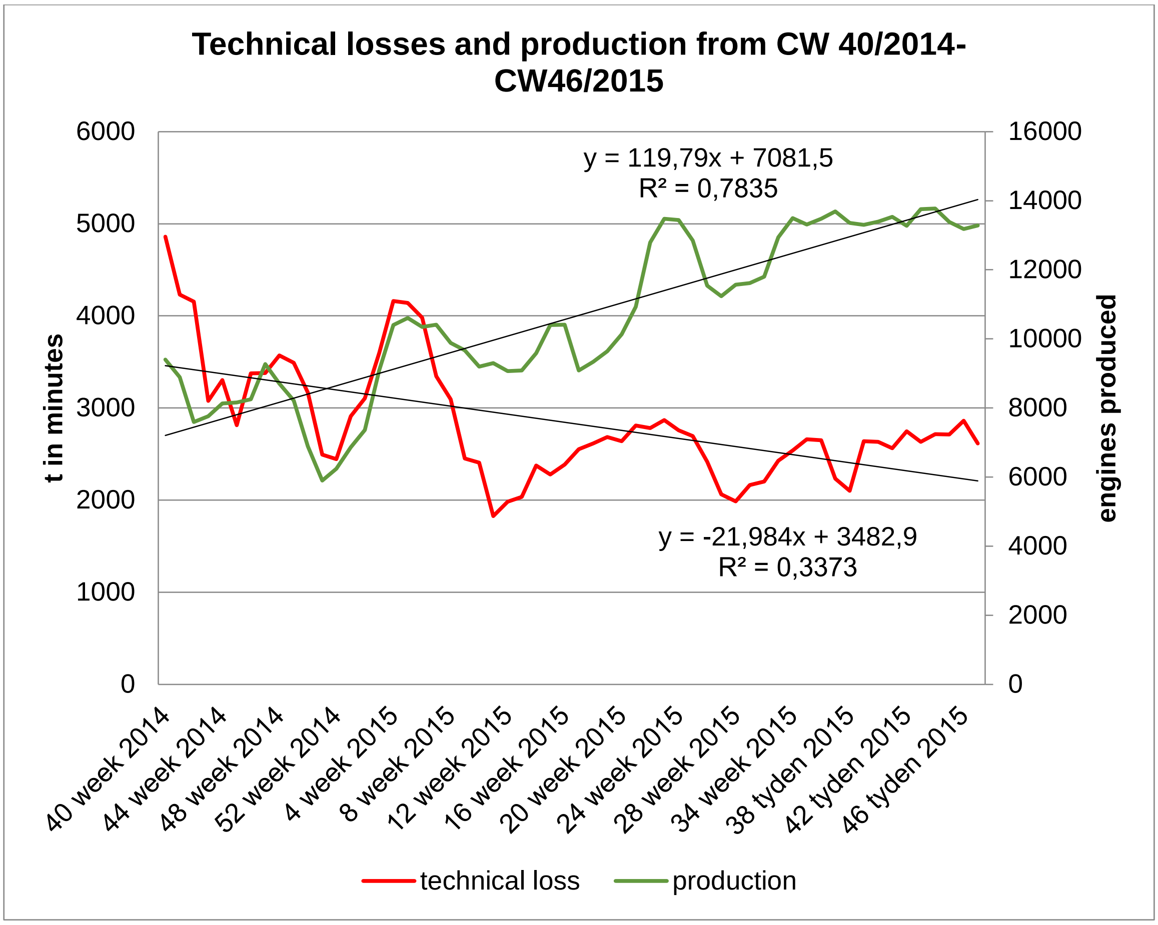
Tab. 3 Correlation between technical losses and production before TPM introduction

	technical losses	*production*
technical losses	1	
production	0,729899068	1

Source: own processing with Microsoft Excel

With the implementation of TPM in CW40 in 2014 the maintenance department together with production tackled the sources for the technical losses and the losses decreased. In Fig.14 the decrease of the total technical loss time can be demonstrated. While the same course between these two factors can be seen until week 4 in 2015, after this moment the lines are not copying each other. Then, a significant decrease in the technical loss time can be seen. Here the effect of TPM and the increase care and maintenance of the machinery can be considered as proven. Another factor was examined in the correlation in Tab.4. The result is that the correlation got a -0,29[6] a negative value. This supports the case that the factors diverge from each other, and further the positive effect of TPM on the technical loss time can be seen.

[6] The value was rounded from the original -0,292039172



Source: internal data from Škoda Auto production

Fig. 13 Technical losses after TPM introduction

Tab. 4 Correlation between technical losses and production after TPM introduction

	technical loss	*production*
technical loss	1	
production	-0,292039172	1

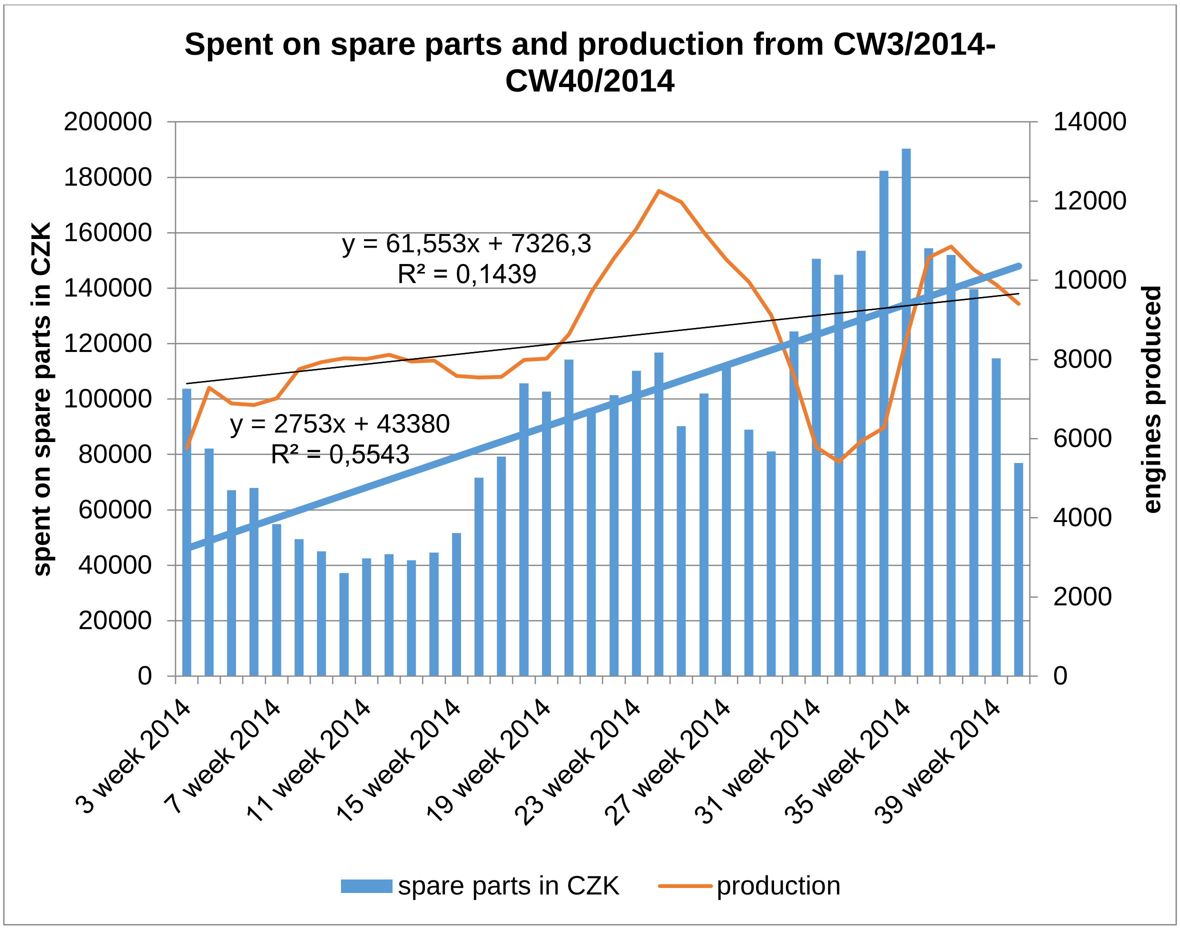
Source: own processing with Microsoft Excel

2.7 Spare parts development

The spending of spare parts is an important factor as is generates a tremendous amount of costs within the production. It should be mentioned that the data from the amount spent on spare parts is collected when the parts are logged into the inventory. There was no reliable data available from the ordering process or when the parts are assembled on the production line. Therefore the data from the spare parts was shifted 2 weeks before the production line, in order to get the ordering date. The inflation rate was not taken into consideration as most of the parts are bought in the European Union and paid in Euro. So the inflation rate balanced with the falling rate of the EUR against the CZK. It needs to be also taken into account that the machinery was established in 2012 so the manufacturing guarantee ended by mid-2014 for most of the machines. This lead to an increase of the spent spare parts. The data was revised from the interrupting data. For instance, extraordinary spent for a spindle which is distorting the dataset. As this spindle cannot be maintained or lubricated better TPM has no influence on this spending. And this data was significantly influencing the evaluation. Another factor which needs to be taken into consideration is the budget. As it can happen that the maintenance department, which is the budget holder for the spare parts spent, has some money left on their account they are ordering parts on stock by December. This leads to an increase of costs in December 2014 and has nothing to do with more broken parts in this timeframe. The author had discussions with the maintenance department and moved the data to the actual data when it was assembled in the production line. In addition the data from weeks 32-33 in 2014 and 2015 stayed in the evaluation, although they are linked in the former statistics. The background is that despite the production not producing there were maintenance actions going on and these generated costs[7].

When taking a look at the evaluation in Fig. 15 it can be seen that the increase of maintenance cost is very strong. From this point it seems that there is no correlation between production and the spent spare parts. This illustrates that the parts were changed when they broke down regardless from the production volume. This can be supported by Tab.5 which shows a correlation between the factors of only 0,08[8].

[7] In chapter 2.1 more details are given
[8] Rounded from original 0,083861



Source: internal data from Škoda Auto production

Fig. 14 Spare parts before TPM introduction

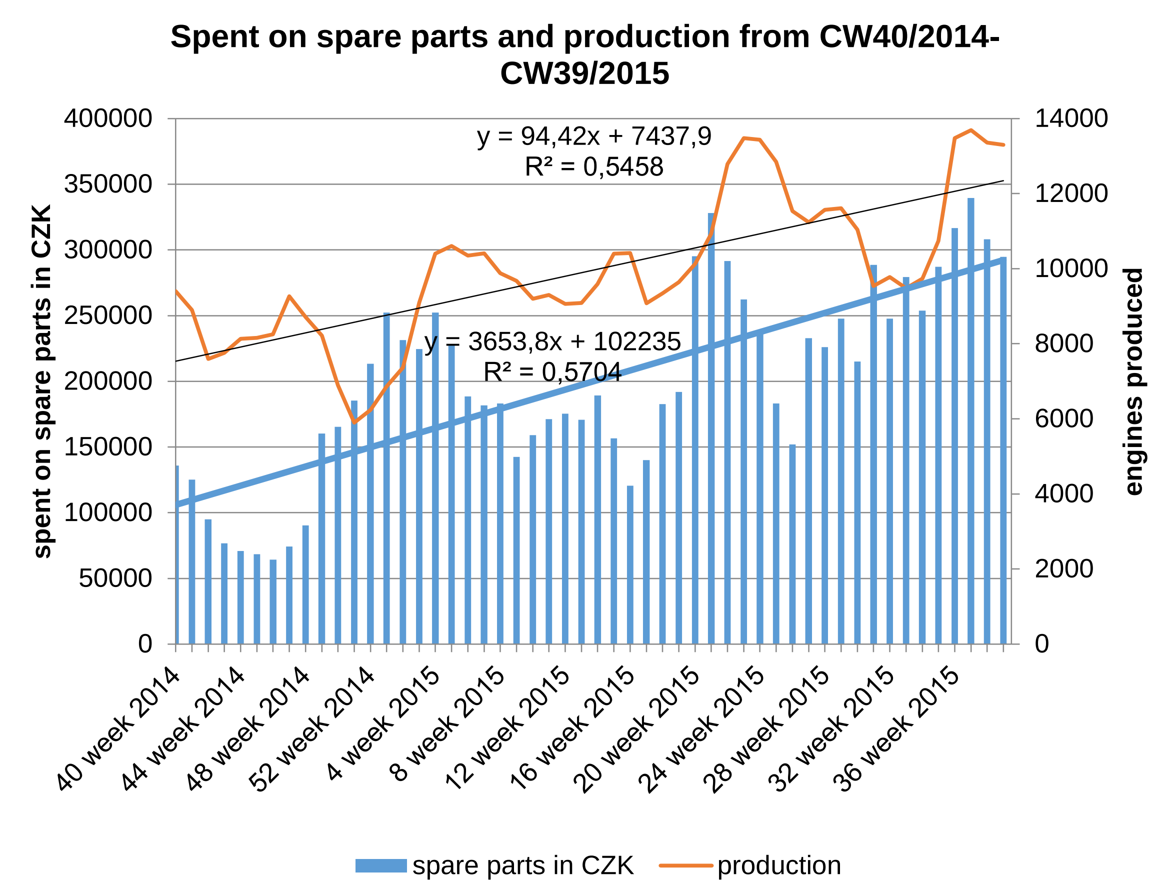
Tab. 5 Correlation between spare part spent and engine production before TPM introduction

	spent on spare parts	engine production
spent on spare parts	1	
engine production	0,083861	1

Source: own processing with Microsoft Excel

In comparison, the dataset after the introduction of TPM shows, that the increase of spare parts spent is with an incline of 3653,8 lower than before the implementation with 4865,4. Although the production is rapidly increasing, while the incline before was 61,533, after the adaption of TPM the production incline grew to 94,42. This shows that the regular maintenance should create a decrease within a longer timescale. As the adaption of TPM takes up 3-5 years (McCarthy, rich, 2004) the long term effects will be seen within the next years.

Another interesting outcome is that the expenditures are now correlating more with the factor 0, 56[9] from Tab.6. This supports the case that with a higher production more parts are changed and that the wearing of the parts is monitored better than before the TPM implementation.



Source: internal data from Škoda Auto production

Fig. 15 Spare parts after TPM introduction

Tab. 6 Correlation between spare part spent and engine production after TPM introduction

	spent on spare parts	engine production
spent on spare parts	1	
engine production	0,556425	1

Source: own processing with Microsoft Excel

9 Rounded from original 0,556425

2.8 Questionnaire of TPM

To evaluate the soft factors of TPM implementation a survey with the operators on the production line was carried out. Further the operators had the opportunity to mention weaknesses of the current TPM model and make suggestion how to improve the system.

2.8.1 Methodology

In order to get an idea of the operators' view of TPM and how they evaluate a questionnaire was designed with a 6 step scale. The number 1 says that the respondent fully agrees, while the number 6 states that the person fully disagrees. As range even numbers were used in order that the respondent not to choose the middle range. Further there are two open answer questions to involve the operators into the optimization of TPM. One more open answer question was "What is the basic idea of TPM?"[10] The aim of this question was to see what people think of TPM after they were provided with training and are working in the area. To separate operators which know the situation before introducing TPM one question was asking: „Have you worked here[11] before June 2014". So in the evaluation it can be seen a differentiation between these two groups. The open answer question regarding the basic idea of TPM was not differentiated as all the operators should have had the training on TPM.

Within the evaluation of the survey the problem of central tendency occurred (Wagnerová, 2008). Because the people are used to tend to the middle value but with the even range of values this chance was not given. Therefore the respondents chose the values 3 or 4 because they were nearest to the middle value. So the attempt to evaluate the survey with averaging the total numbers failed as it had no significant difference. There is also the method of choosing only the extreme values. In this case that would mean to take only the values 1, 2, 5, 6 into account. Both middle values 3 and 4 would be left out. But as many respondents chose this possibility, the survey would lose many respondents, so a third method was used. The total count of each value for the belonging question is shown in one graph. This value then differentiates between the operators who

[10] See appendix 1
[11] In this department

worked in the department before the TPM implementation and the operators who joined the department afterwards. In total this survey had 45 respondents.

2.8.2 Evaluation of Questionnaire

The evaluation was done according to the methodology described in 2.6.1. The evaluation of question no. 1 in Fig.17 shows that most operators chose value 3 and they probably think that the situation improved only in some areas. Further the total count[12] for values 4 and 5 is 8 whereas the total count for values 1 and 2 is 9 which is similar. So the outcome can be seen that the operators are not clearly thinking that there is an improvement of the situation after implementing TPM.

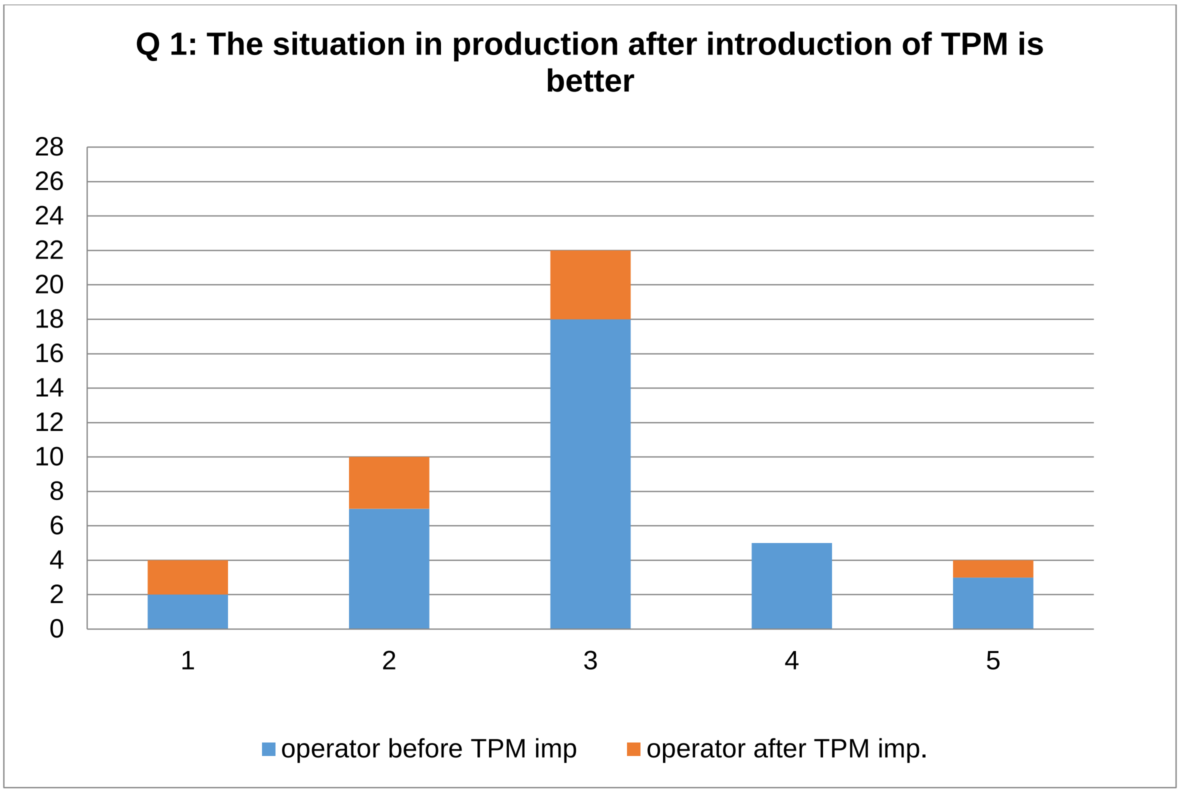


Fig. 16 Evaluation of question 1: The situation in production after introduction of TPM is better

Source: own processing

The second question is dealing with the handling of the machinery. The operators should work together with the maintainers during the TPM shift in order to get familiar with the machinery. The evaluation in Fig. 18 shows that most of the

[12] Total count is here considered without operators that joined the department before TPM implementation

respondents chose values 2 or 3. If the values 1, 2 and 3 are combined, the count of votes is 26 against the disagreeing field of values 4, 5 and 6 with a count of 9. This means that 75% of the respondents who worked in the department before the TPM implementation think that they have a better knowledge of the machinery. This can be considered as a success of the TPM implementation; the operators gained more experience with their machinery and will be able to detect failures earlier. Also the communication with the maintenance department will improve as the operators can describe occurring problems in more detail.

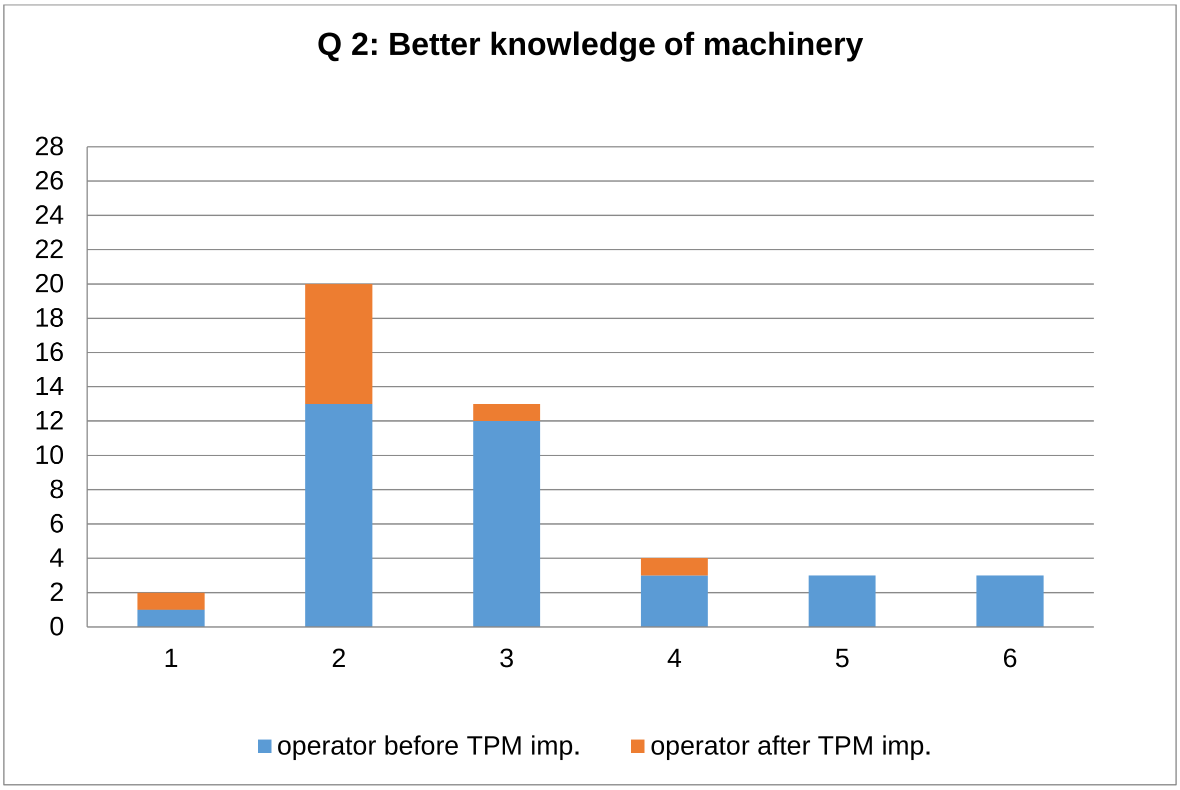


Fig. 17 Evaluation of question 2: I have better knowledge of machinery

Source: own processing

The following question is tackling the cross departmental communication. It was asked if the operators think that their observations are taken into account. The highest scores where values 3 with 13 counts and values 4 with 9 counts. When taking a look at the distant values 2 with 7 counts and values 5 with 3 counts the distribution is tending to value 2. This shows that the operators are not really convinced that their observations are taken seriously. The distribution of values is widely spread and here is given room for improvement.

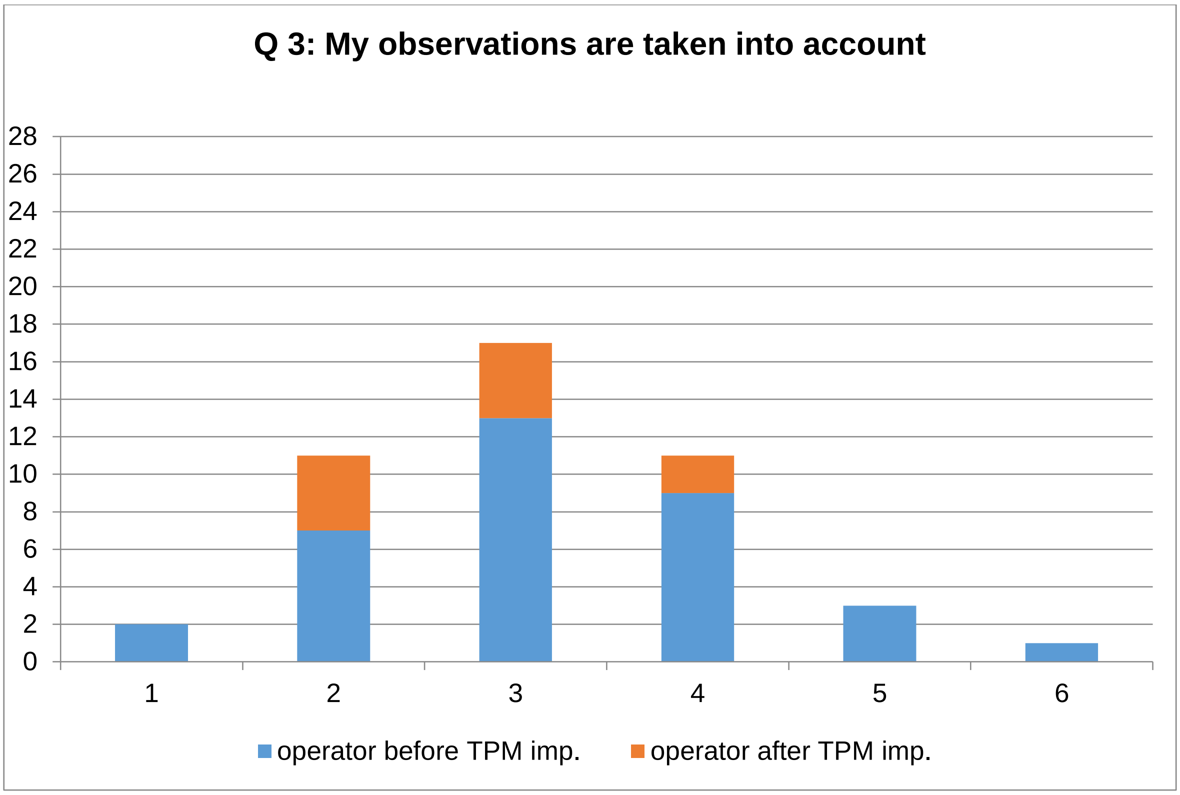


Fig. 18 Evaluation of question 3: my observations are taken into account

Source: own processing

Question 4 is closely linked to the previous question, as it has the aim to examine the cooperation between the maintenance and production department. It was asked if this cross departmental work has improved. The outcome in Fig.20 shows that the respondents are not sure if the cooperation has improved as nearly 65%[13] chose value 3. As the value is not strongly agreeing with the statement that the cooperation is improving here the communication lack can be demonstrated even better than with the previous Fig. 19.

[13] 22 out of 36 respondents chose this value

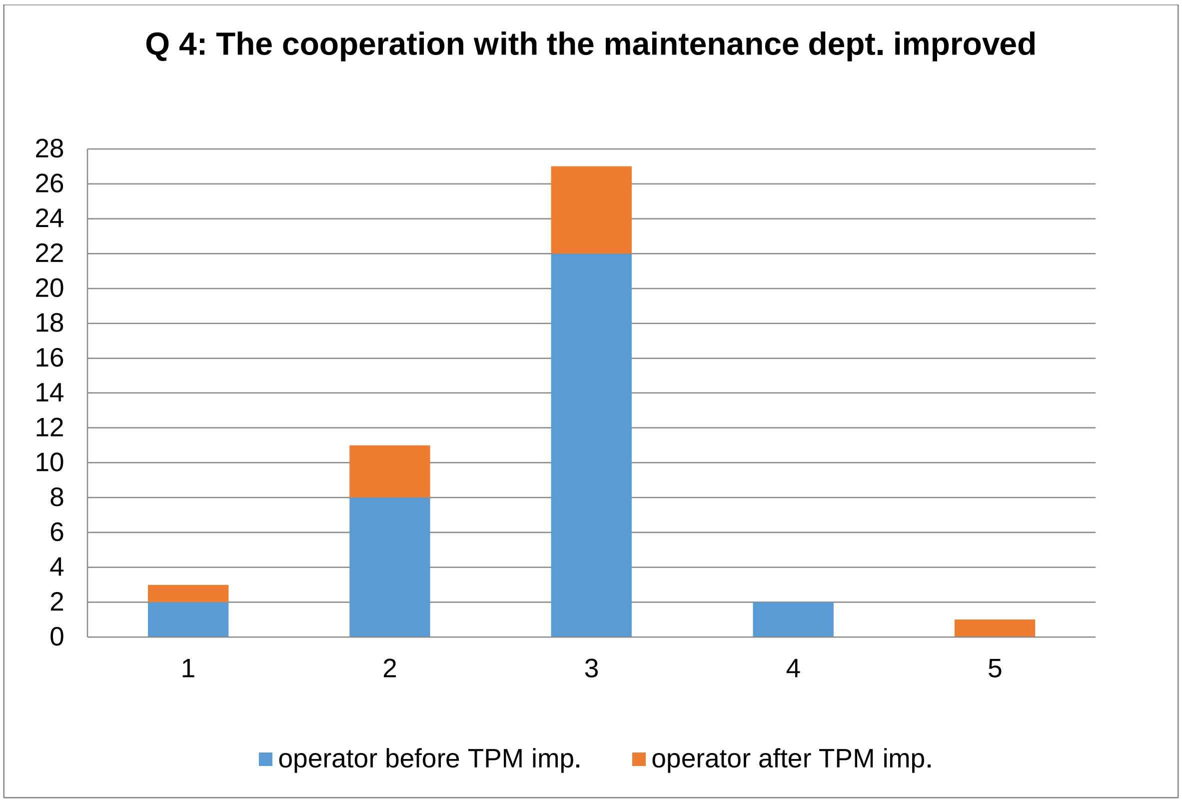


Fig. 19 Evaluation of question 4: The cooperation with the maintenance dept. improved

Source: own processing

Now the survey was dealing with the subjective view on failures on the machinery. It was asked if the operators think that the number of failures decreased after the introduction of TPM. With the evaluation in Fig. 21 the distribution of values is spread between values 2, 3 and 4. But when taking the counts for value 2 and 3 together it is still 66%[14] of the respondents, who worked in the department before TPM introduction, think that the number of failures has decreased. But the share of 29%[15] voting for value 4 and 5 should not be forgotten. It was already proved in chapter 2.4 that the technical losses decreased. So it should be considered to provide the operators with this numbers in order show objective facts that TPM reduced the failures.

[14] 22 out of 35 respondents
[15] 10 out of 35 respondents

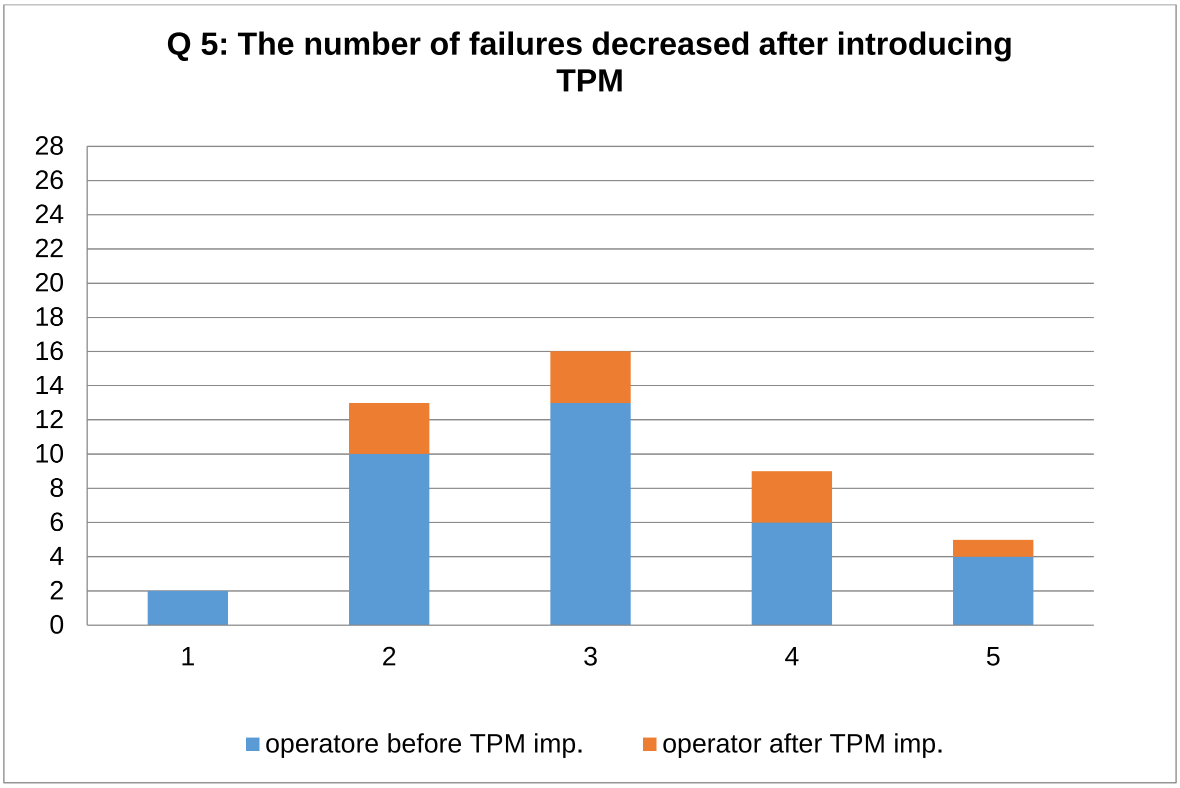


Fig. 20 Evaluation of question 7: The number of failures decreased after introducing TPM

Source: own processing

This question is closely linked to the previous question. But this time it was asked about the operators views regarding whether the total time spent on losses decreased after the implementation of TPM. In Fig.22 it is demonstrated that 76%[16] of the respondents chose values 2 or 3. So they seem to be convinced that the total time of losses decreased after the implementation of TPM but they are from the previous question not convinced that the number of failures is turning down.

[16] 26 out of 34 respondents

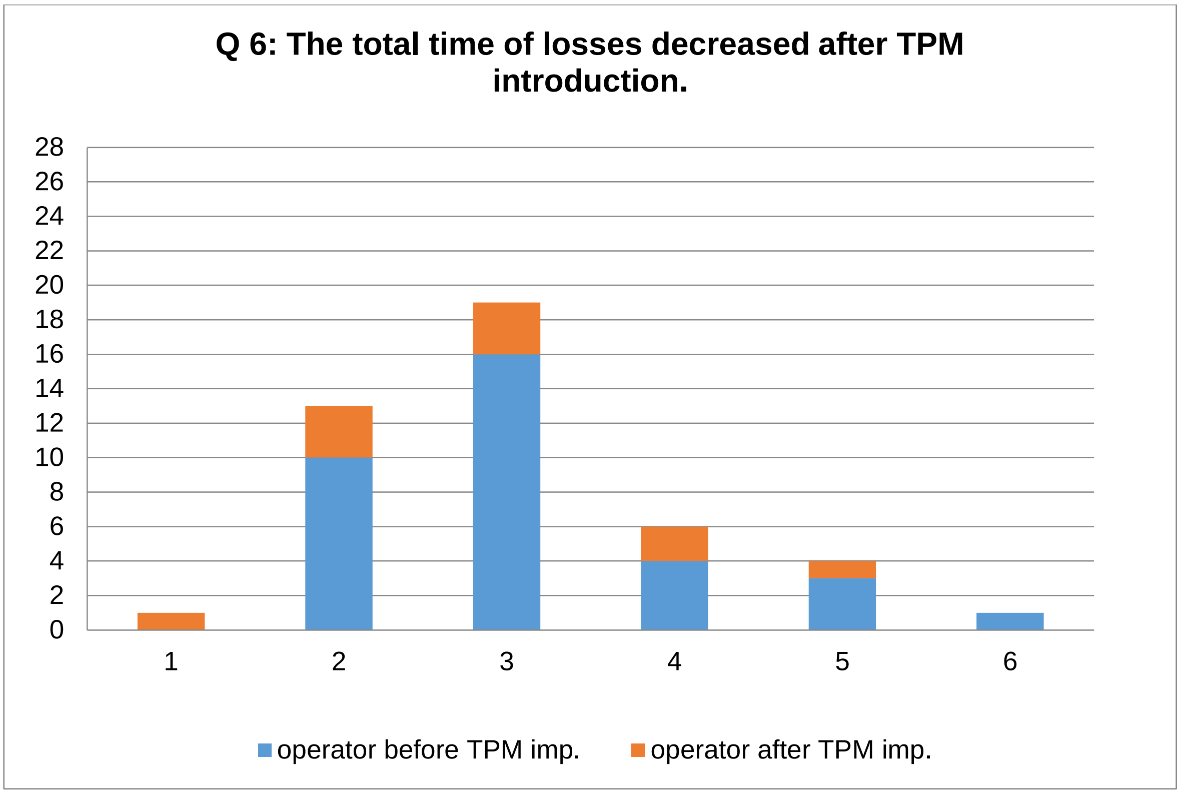


Fig. 21 Evaluation of question 8: The total time of losses decreased after TPM introduction

Source: own processing

The last question was dealing with whether the operators think that the TPM system can be improved. Here the distribution is showing that the ascending values of 2 and 3 are chosen by 78%[17] of the respondents. Further only 2 operators chose the values 5 and 6, meaning that they think TPM cannot be improved. But as a part of TPM in continuous improvement[18], the respondents of 5 and 6 probably do not remember the TPM key values. Training provision for the operators in order to communicate the key values should be considered.

[17] 25 operators out of 32
[18] Described in chapter 1.3.7 p 21

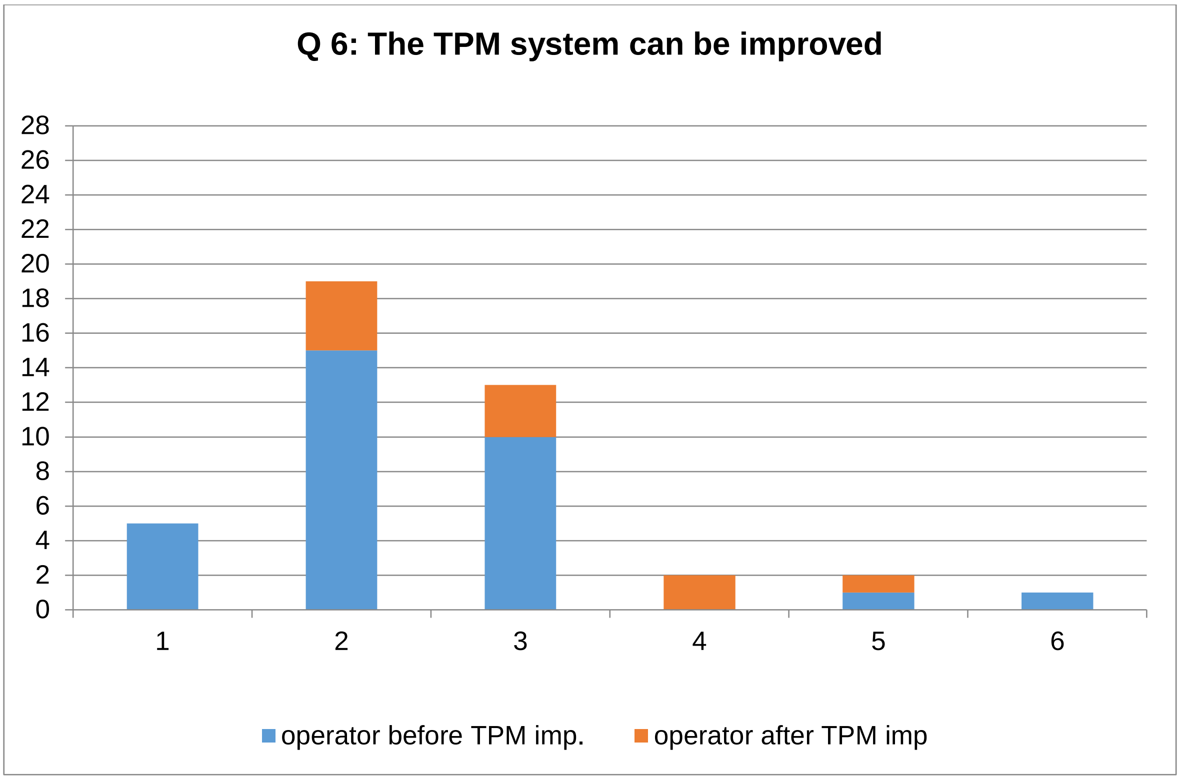


Fig. 22 Evaluation of question 10: The TPM system can be improved

Source: own processing

The respondents had also the possibility to enter their opinion on the topic what can be improved within the TPM system. Four respondents mentioned that the TPM time should be reduced. This issue was discussed with the production line manager. He said that at the moment the survey a lot of specific work was done only by maintainers and therefore the maintainers could have the feeling that nothing is going on. But it is planned that the operators will take a part of the specific workload from the maintainers. Moreover 3 respondents answered that it should be less cleaned during the TPM shift and more technical issues should be solved. The comment is combined to the previous issue as the operators are not doing specific maintenance work but more cleaning. Further 3 respondents answered that there is a lack of communication, as the maintainers do not listen to them. This remark was mentioned in a regular meeting between production and maintenance. The issue will be now tracked and mentioned in the meeting if necessary. Another interesting outcome was that 4 operators mentioned that the total numbers of maintenance workers is too low. And with the high workload the long term problem are not solved sufficiently. This statement was also discussed with the line manager and it supports the attempt to gain more maintenance specialists.

2.8.3 Testing of independence of questions

If the respondents are answering independent on each question was evaluated with a test. As it was already stated that the central tendency was an issue within this survey, it is even more important to see if the respondents chose the same value for different questions. For this purpose the chi square test would be most suitable, but as the values must be bigger than 5 and the condition is not fulfilled, the method cannot be applied (Pecáková, 2011). If the former condition is not met, the Fisher exact test needs to be applied. But for this test the answers need to be broken down into a 2x2 contingency table. This would mean that the values 1-3 need to be cumulated and the same would be done with the values 4-6. But as a consequence a large amount of data would be lost and the meaningfulness would be decreased. Therefore as a third method the Spearman correlation coefficient was applied (Řezanková, 2010). First the correlation between the second question: “My observations are taken into account” and the third question: “The cooperation with the maintenance dept. improved” was tested. The tests were provided with the statistic software R. The coefficient is connecting each value with an order then calculation the correlation – see 5.

$$5 \quad r_s = 1 - \frac{6xD^2}{n(n^2-1)} \qquad (5)$$

The result of the test was that r_s had a value of 0,407965 which equals 40,7965% correlation. This can be considered as not sufficient in this case (Řezanková, 2010). Further the assertion that the coefficient that the coefficient is 0 needs to be checked, with the null hypothesis $H_0 = p_s = 0$ needs to be tested to confirm the coefficient see – 6.

$$6 \quad t = r_s \sqrt{\frac{n-2}{1-r_s^2}} \qquad (6)$$

The result in this test was with t = 0,01671 below the critical value of α= 0,05 rejects the null hypothesis of independence and the dependence is proved.

The second pair of questions was between “the number of failures decreased after introducing TPM” and “The total time of losses decreased after TPM introduction”. Here the coefficient had the value 0,783662 which equals 78, 3662%. This can be considered as a strong correlation between these questions. The testing of the null hypothesis was with t= 4,239e-08 far below the critical value of α= 0,05. This leads to the rejection of the null hypothesis of independence, and the dependence is confirmed. But in comparison with the first independence test the second dependence is much higher based on the higher coefficient and the lower t-value.

Conclusion

This thesis dealt with the sources of losses on the production line. The theoretical backgrounds of TPM were shown. The history of TPM and the indicators for measuring the efficiency and the development within the production have been shown. Within the practical part of this thesis a critical view on the production times were done in order to evaluate the impact of the TPM system on the engine processing line. It was proved that the impact on the technical losses and the spendings on spare parts decreased. With the optimization of the data collection within the maintenance department it will be easier to identify the roots of the spending on spare parts. The analyzes showed in most cases a trend of slight decreasing losses. But it needs to be taken into consideration that the total effects of TPM can be evaluated within the next years. One reason is that then the timescale will be larger and so the quality of the dataset will increase. The other reason is that with continuous improvement the TPM processes will be better and therefore also this should lead to a further decrease. One of the most important factors which were measured was the OEE. But with the OEE focusing only from April 2014 the dataset was too small for proper prediction models. It was found out that there is a slight decrease within the OEE, but it is inevitable to track the OEE within a longer timescale. With the implementation of measuring the efficiency of each machine it should be possible to get better data and also find bottlenecks of the production.

Then a survey was done to measure the soft factor, which is the operator and his opinion on the success of TPM and what he thinks could be improved. The outcome was that the operators think that TPM is only cleaning the machinery. Here training was advised in order to show the personnel the range of TPM application. Further the communication between the production and maintenance department is lacking. This issue was also recognized by the author during meetings with these two departments. It was advised to improve the communication with TPM boards. Also should the personnel from each department spend several weeks within the other department in order to gain an idea of the department problems. Another possibility to improve the communication would be teambuilding events, in which the issues could be discussed in a quiet atmosphere. Moreover the survey showed that the long term problems are not solved sufficiently according to the operators. This was discussed with the production line manager and decided that the operators will get some of the easier workload of the maintainers, that they have enough time for solving long term issues and not only operative problems.

In conclusion TPM creates an added value for the engine processing line, as the losses decreased and the machinery is in a better condition. So that the increasing efficiency of the line is compensating the time in this is provided TPM. But as TPM in a continuous process optimization needs to be carried out in order to achieve a higher performance.

References

AL-RADHI, M., *Erfolgreich produzieren mit TPM*. Munich: Hanser, 2002. ISBN 978-34-46218734.

KOŠTOURIAK J., FROLÍK, Z., et. al. *Stihly a inovativni podnik*. Prague : Alfa Publishing, 2006. ISBN 80-86851-38-9.

LEVITT, J*., Preventive and Predictive Maintenance*. New York: Industrial Press, 2011. ISBN 978-0-8311-3441-9.

MCCARTHY, D., RICH, N. *Lean TPM A blueprint for change.* 1st ed. Oxford: Butterworth-Heinemann, 2004. ISBN 0-7506-5857-6.

PECÁKOVÁ, I., Statistika v terénních průzkumech, Prague: Professional Publishing, 2011. ISBN 978-80-7431-039-3

ŘEZANKOVÁ, H., Analýza dat z doatzníkových šetření. Prague: Professional Publishing, 2010. ISBN 978-80-7431-019-5.

WAGNEROVÁ, I., *Hodnocení a řízení výkonnosti*. Prague : Grada Publishing, 2008. ISBN 978-80-247-2361-7.

WILLMOTT P., MCCARTHY D. *TPM- A Route to World-Class Performance.* Oxford: Butterwoth-Heinemann, 2001. ISBN 0-7506-4447-8.

Figures and Tables

List of Figures

List of Tables

Appendices

Appendix No. 1

Questionnaire of TPM on the engine processing line

This questionnaire is anonym and is serving on the evaluation of TPM

		agree					disagree
1.	The situation in production after introduction TPM is better	1	2	3	4	5	6
2.	I have better knowledge of the machinery	1	2	3	4	5	6
3.	My observations are taken into account	1	2	3	4	5	6
4.	Have you work here before June 2014?		YES			NO	
5.	The cooperation with the maintenance dept. improved	1	2	3	4	5	6
6.	What can be done better on TPM according to you?						
7.	The number of failures decreased after introducing TPM (according to my opinion)	1	2	3	4	5	6
8.	The total time of losses decreased after TPM introduction (according my opinion)	1	2	3	4	5	6
9.	What is the basic idea of TPM						
10.	The TPM system can be improved	1	2	3	4	5	6
11.	How?						

Thank you for your cooperation

ANNOTATION

AUTHOR	**Bc. Robert Turinsky**		
SPECIALISATION	Business Administration and Operations		
THESIS TITLE	**Analysis of TPM on the EA 211 engine processing line**		
SUPERVISOR	**Ing. Petr Novotný, Ph.D.**		
DEPARTMENT	**KLRK - Department of Logistics and Quality Management**	**YEAR**	**2016**

NUMBER OF PAGES	**62**
NUMBER OF PICTURES	**22**
NUMBER OF TABLES	**6**
NUMBER OF APPENDICES	**1**

SUMMARY	**The aim of this master thesis is the evaluation of TPM on the EA 211 engine processing line at ŠKODA AUTO a.s.** **The theoretical part is describing the process of implementation with the various steps. Then methods of measuring the success of TPM, in which the OEE is one of the key indicators. Further methods of improving communication.** **The practical part is dealing with losses. Such as retooling loss, technical loss. They were measured and the impact of TPM was being analysed. Further the OEE was analysed. Moreover a survey was carried out, to get a feedback from the personnel and their opinion on TPM. Finally suggestions to optimize the TPM system were given.**
KEY WORDS	**TPM, OEE, Total productive maintenance, Škoda Auto a.s., losses**

THESIS INCLUDES UNDISCLOSED PARTS: No