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Reduction of Life-cycle Costsof Locomotivesby Leaning Maintenance Process

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Summary

Increasing the role of rail in balancing the transport of goods is a big challenge all over the world nowadays. Statistics clearly show a large disproportion of the volume transported by various means of inland transport where the railway business is still in the minority. One of the reasons is the cost of transported goods. It is important to know how costs affecting the final price of transported goods by rail are divided in order to reduce them. This paper presents the possibility of using life cycle costs of the product in order to take productivity to the next level and save considerable amounts of time, money, and resources. The aim of this article is to define what are Life Cycle Costs and if lean tools may be applied in transport companies. The research has been conducted over the number of years in one of the largest rail freight operator in Poland. The main goal of the investigation was to analyze costs of the diesel locomotive maintenance process in a whole lifecycle and investigate the impact of using lean tools on those costs. In this project lean tools such as: Standard Work Combination Sheet, Spaghetti diagram, Visual Management, Cause and Effect Diagram, PDCA, 5S, standardization cards were used. For better analysis Voice of the Customer and Critical to Quality tools were added. The results of this analysisare presented in this paper and prove the big impact on reducing time, improving product quality as well as integrating people, data, processes and business systems. The use of lean is deliberate because it can lead to 50% cost reduction of the P1 maintenance level on diesel locomotives with a significant reduction of working hours up to 60%. The outcome of this analysis should help the company to achieve a significant reduction in the cost of maintaining locomotives, which will contribute to a lower cost of transporting goods by rail.

Keywords: lean management, life cycle costs, locomotive maintenance process

1. Introduction

Transport is one of the most important sectors of the national economy. In 2013, revenues from the sale of services in all transport companies amounted to PLN 164.1 billion, while the number of people employed in them were 495.2 thousand [17]. In addition, the efficiently functioning transport of goods is indispensable for the proper functioning of many other sectors. The transport of goods, along with a parallel flow of cash creates a system necessary for the functioning of the market economy. The role of the goods transport sector in Poland is also important due to the geographic location of the country, which predisposes it to play the role of a transit country in trade between the countries of Western and Eastern Europe. Publicly available studies (eg. GUS publications) distinguish six basic types of transport: road, rail, air, pipeline transport as well as sea and inland waterway transport. Two basic measures are used to measure the volume of transport: the mass of transported goods (including packaging) expressed in tonnes and transport work expressed in tonne-kilometers (hereinafter tkm)[3].

In the years 2005–2013, the volume of transport measured by the mass of transported goods increased by 33% and in 2013 amounted to 1,8b tonnes (Tabl. 1). The increase was mainly caused by a significant increase in the mass of goods transported by road transport, whose transport increased in the discussed period by about 44%. An increase of 8.2% was also recorded in air transport in 2005–2013. Other types of transport recorded a decrease in the weight of transported goods. Particularly noteworthy is the second of the basic types of transport – rail transport. While the volume of cargo transported by various means of transport increases year by year, railway transport in 2013 barely managed to compensate for the result from 2005.

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[3] 1 tonne-kilometer corresponds to the work done when transporting 1 ton of goods for a distance of one kilometer.

Table 1

Transport of loads (in thousands of tons) of particular types of transport in Poland in the years 2005–2013[4]

Mode of transport	2013	2010	2011	2012	2013		2005	2013
	K tonnes	Year before = 100				2005 = 100	Structure in [%]	
Total	1848348	105	107	94	103	133	100	100
Road transport	1553050	105	107	94	104	144	78	84
Rail transport	232596	105	106	93	101	100	17	13
Other	62702	97	97	96	96	86	5	3

[Own study based on GUS data].

The question should be asked: why does the volume of transported goods by rail not increase with the general increase in cargo transport in Poland? Rail carriers, being the direct and the most important stakeholder in this situation, decided to analyze the factors affecting the improvement of competitiveness of rail transport on the freight market and to improve those factors on which they have the greatest impact. The following paper describes the results of remedial actions aimed at improving the market competitiveness of one of the key railway carriers. The company decided to analyze the costs related to rolling stock throughout the entire product life cycle. In the first stage, the costs of diesel locomotives having a significant impact on the costs of transporting goods were analyzed. Then, it was decided to use the Lean philosophy tools to reduce the costs incurred.

2. Description of the current situation

One of the largest rail freight carriers in Poland was selected for the analysis. The analysis covered the years 2014–2016 and concerned three types of diesel locomotives.

2.1. Company description

The company in which the analysis was carried out has a license for rail freight. In addition, it has its own repair facilities and offers siding services. The company develops and invests in new technologies, as exemplified by plans to modernize the fleet of locomotives and introduce new types of locomotives for use. The company offers comprehensive transport and logistics services. It specializes in the transport of coal as well as chemical products, mineral oils and building materials.

The company facesa gradual decrease of the importance and share of railways in the transport of goods for road transport.Shippers, senders and recipients of goods choose road transport, because in their opinion it is cheap and convenient and because the goods are picked up and delivered from door to door. The company conducted research which showed that the competitive advantage of road transport is undoubtedly price, transport time and very high flexibility, which is adapted to the individual needs of the recipient.

By the decision of the board, as a first step the company started work on reducing costs through the whole life cycle of assets- mainly locomotives.

2.2. Life-cycle costs

Life-cycle costing (LCC) is getting more and more attention in many areas of life. LCC is a sum of all costs over the full life span or a specified period of a good, service, structure, or system [3]. It includes purchase price, installation cost, operating costs, maintenance and upgrade costs, and remaining (residual or salvage) value at the end of ownership or its useful life. The asset life cycle approach is a developmental or holistic approach, enabling the issues that impact on assets to be reviewed at different stages of its life. By using this approach it is possible to analyze the information available and understand and consider financial implications.

For the analysis all the costs were divided into two groups: relevant and non-relevant. The company has not till now faced ‘upgrades costs’ and ‘remaining value’ and therefore these will not be considered in further analysis (Table 2).

[4] Dynamics indices and structure were calculated without shunting transport in rail transport, except for 2005.

Table 2

Evaluation of costs due to their occurrence

The type of costs	Relevant	Non-relevant
Purchase price	X	–
Installation costs	X	–
Operating costs	X	–
Maintenance costs	X	–
Upgrades costs	–	X
Remaining value	–	X

[Own study].

Based on the company's experience thepercentage breakdown of LCC costs for locomotives is visible and presented below (Table 3): 74% of LCC costs are operating costs, 14% are maintenance costs and just 12% of LCC costs are purchase and installation costs.

Table 3

Percentage breakdown of LCC costs for locomotives based on the company's experience

Division of costs	Locomotive in cargo transport [%]
Purchase and installation	12
Operating	74
Maintenance	14

[Own study].

The company has no impact on purchase price and installation costs nowadays. In order to reduce costs the company decided to analyze further the maintenance costs of assets.

Division of total maintenance costs

Out of Life Cycle Costs Analysis the company started to investigate maintenance costs of diesel locomotives. All vehicles (including those used outside the public rail network, eg only on sidings) under national regulations must have maintenance system documentation (DSU). This documentation includes information about the vehicle, the structure of the inspection and repair cycle, descriptions of activities performed at particular levels of maintenance, measured parameters, etc. In addition, it also defines the requirements for the equipment of workshops and the competence of employees performing maintenance. The entities are obliged to comply with the regulations resulting from it as part of the maintenance process. According to the DSU, each locomotive should be subjected to periodic reviews. We distinguish seven levels of inspections on diesel locomotives analyzed in the company: P1, P2/1, P2/2, P2/3, P3, P4, P5 For better understanding the distribution oftotal maintenance costs has been prepared. Analysis accumulates all levels of inspections for three types of diesel locomotives done in 2014 (Table. 4, Fig. 1).

Table 4

Presentation of the number of inspections carried out (divided into particular levels) together with workinghours in 2014

Level	Working hours	Number of inspections
P1	62,290	3026
P2/1	25,055	263
P2/2	27,143	187
P2/3	15,262	76
P3	17,368	16
P4	34,612	7
P5	52,271	6
SUM	234,001	3,581

[Own study based on data in company's SAP system]

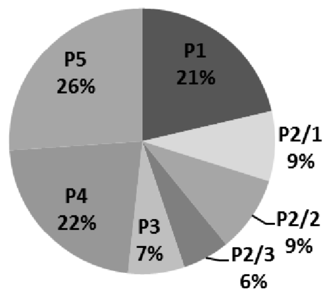

Fig. 1. The distribution oftotal maintenance costs for every level of inspection run in 2014 [own study]

It is clearly shown that three levels of inspections P1, P4 and P5 cost the company almost 70% of total maintenance costs. The other four levels of inspections P2/1, P2/2, P2/3 and P3 take only 30% of total maintenance costs. For a better understanding of all maintenance levels it is important to look at the number of inspections of each level. The most common one is P1 maintenance level, which was performed 3026 times in 2014. The P4 and P5 level inspectionsare more complex and last up to several months. It is important to understand what causes such high costs in every type of maintenance. The costs were divided into three groups: cost of working hours, cost of material and cost of external services. After deep analysis we came to the conclusion that more than 80% of costs in P1, P2/1, P2/2, P2/3 and P3 inspection levels are caused by working hours (Fig. 2).

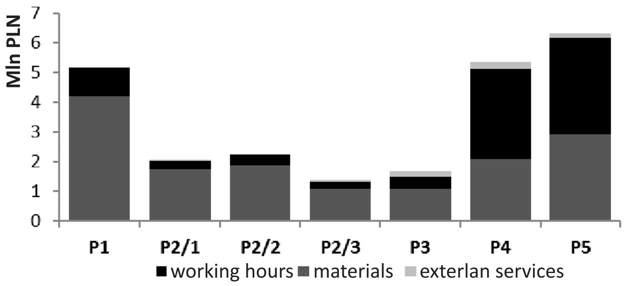

Fig. 2. Cost allocation – total costs divided into working hours, material and external services [own study]

A closer look at light maintenance inspections

Thelocomotive maintenance process is divided into light and heavy maintenance inspections. For light maintenance inspections we include: P1, P2/1, P2/2, P2/3. For heavy maintenance inspections we include: P3, P4, P5.

The total number of repairs in Light Maintenance area amounted to 3552 in 2014 in the described company. The total costs in Light Maintenance area amounted to 10,9 mln in 2014 in the analyzed company; total number of working hours in Light Maintenance area amounted to 129 50 in 2014 in the analyzed company (Fig. 3, 4, 5).

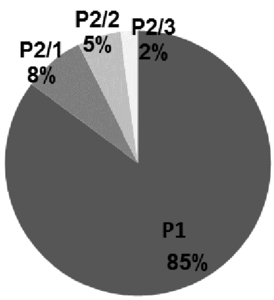

Fig. 3. Division of number of repairs in Light Maintenance into specific type of inspection [own study]

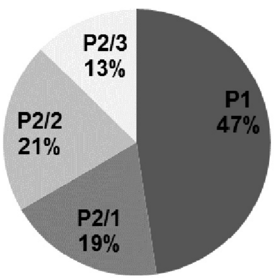

Fig. 4. Division of total costs in Light Maintenance into specific type of inspection [own study]

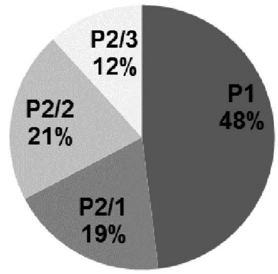

Fig. 5. Division of total number of working hours in Light Maintenance into specific types of inspection [own study]

2.3. Conclusions from the analysis of the current situation

Life cycle costs analysis of diesel locomotives shows that the company has four types of costs: operating costs, maintenance costs, purchase costs and installation costs. Despite the operating costs being the majority of life cycle costs, the company has no impact on them. Infrastructure access, fuel consumption or other factors affecting operating costs have been assessed as hard to influence in the short term therefore this article will not focus on this topic. The same situation is with purchase and installation costs. Those costs occurred once during the purchasing process and will not appear again as the company does not plan to buy that type of locomotive in the future.

Among all the costs maintenance costs are worth analyzing further in order to gather some results in cost reduction process. Total distribution of the maintenance costs for every level of inspection done in 2014 (Figure 1.) shows that one fifth of total maintenance costs is for P1 inspections. Based on facts included in chapter 2.2. P1 is the most common type of inspection (occurred 3026 times in 2014) and yearly consums the largest amount of working hours through all type of inspections levels. The facts that one P1 inspection takes just a few hours and it is run really often, which helps to make further analyses and will help to see quick gains after implementing recommendations.

In connection with the above it is wise to focus on P1 inspection levels in order to reduce costs arising from it. Furthermore all recommendations for P1 could be implemented in P2/1, P2/2 and P2/3 inspections levels as all tasks which occur in P1 are as well included in P2/1, P2/2 and P2/3. Therefore the company made a decision to take steps in order to reduce costs of the P1 maintenance level for diesel locomotives.

3. Lean concept for improvement

Lean philosophy (known as well as lean manufacturing, lean thinking or Toyota Production System) is a recent term which has its roots in the mid of 1950s and describes process improvement activities.

The thought process of lean was thoroughly described in the book The Machine That Changed the World (1990) by James P. Womack, Daniel Roos, and Daniel T. Jones. In a subsequent volume, Lean Thinking (1996), James P. Womack and Daniel T. Jones distilled these lean principles even further into five [20]:

- Specify the value desired by the customer,
- Identify the value stream for each product providing that value and challenge all of the unnecessary steps (generally nine out of ten) currently necessary to provide it,
- Make the product flow continuously through the remaining value-added steps,
- Introduce pull between all steps where continuous flow is possible,
- Strive for perfection so that the number of steps and the amount of time and information needed to serve the customer continually falls.

The core idea of Lean is to maximize customer value while minimizing waste together with having satisfied customers and satisfied employees. In another words, lean means creating more value for customers with fewer resources.It is important to understand customer value and focus on them. The main goal is to provide perfect value to the customer by a process that has zero waste 8 types of waste in Lean are:

- T – Transport – Moving people, products & information,
- I – Inventory – Storing parts, pieces, documentation ahead of requirements,
- M – Motion – Bending, turning, reaching, lifting,
- W – Waiting – For parts, information, instructions, equipment,
- O – Over production – Making more than is IMMEDIATELY required,
- O – Over processing – Tighter tolerances or higher grade materials than are necessary,
- D – Defects – Rework, scrap, incorrect documentation,
- S – Skills – Underutilizing capabilities, delegating tasks with inadequate trainin.

These types of waste are used to describe all wasteful activity in a production environment. No more, no less. Anything that does not add value is considered waste.

3.1. Voice of the customer and Critical to Quality analyses

In order to fulfil the first principle of Lean Philosophy (specify the value desired by the company) the company used a VOC and CTQ tools. Voice of the customer (VOC) is a term used in order to describe the in-depth process of capturing customers' expectations, preferences and aversions. This technique makes it possible to gather adetailed set of customer wants and needs with a hierarchical structure, which are prioritized in terms of relative importance and satisfaction with current alternatives. During the project the company performed a VOC plan as the first step to leaning the P1 process. The VOC plan has been performed with three key clients via phone and during common meetings. The most important customer request was to reduce costs, to meet the budget and have a standardized process (Tabl. 5).

Table 5

VOC plan for cost reduction and standardization of the P1 process for diesel locomotives

Customer	Question	Source	VOC (Customer request)	Importance
Asset Management	What makes our services good enough for our client?	Interview via phone	Released on time	2
		Interview via phone	Good product at the end of service	3
		Meeting	Smaller costs	5
		Meeting	Good realization of the budgeted figures (at least 80% of orders in budget)	5
Coordination Section		Interview via phone	Released ASAP	3
Maintenance dep.		Meeting	Smaller costs	5
		Interview via phone	Standarized process	5
		Meeting	Good realization of the budgeted figures	5

[The company's Project Management data].

Table 6

CTQ table for cost reduction and standardization of the P1 process for diesel locomotives

VOC (Customer request)	Key issues / Core statements	CTQ (Measurable requirements)	Importance
Good realization of the budgeted figures	Number of Working hours	At least 80% of P1s has to be performed according to the budgeted whrs (to be revised in SAP)	5
Standardized process	Time, quality	Variance of P1's on every workshop should be 0	5
Smaller costs (40% of B)	Cost	60% of actual costs= 10whrs	5

[The company's Project Management data]

CTQ tree (Critical To Quality), a tree of critical quality requirements is a tool developed in order to de-code the client's "language" (ie its general needs, expectations) into more specific requirements. The purpose of this transfer is to go from general concepts that are difficult to measure to specific elements that are subject to specific measures. The abbreviation CTQ indicates key factors determining customer satisfaction and the need to identify them. Customers may be surveyed to elicit quality, service and performance data. They may include upper and lower specification limits or any other factors.

The CTQ table was prepared by the project team working on the cost reduction and standardization of the P1 process. Based on the data from the VOC plan, the project team selected the most important customer requirements and worked on each in order to classify them into key issues and gather measurable requirements. In order to achieve all three requirements it was necessary to use lean methodology together with lean tools (Table 6). A CTQ must be an actionable, quantitative business specification. CTQs reflect the expressed needs of the customer.

3.2. Standardized work balancing worksheet – SWCS

Standard Work Combination Sheet (SWCS) is a table that clarifies how much time is spent doing manual work and travelling at each production process. It is used to examine the range of processes that one worker can take care of within Takt time and the amount of time during which machines/systems are operated automatically. These are recorded to help determine which combinations of operations are possible.

The companyperformed around 30 SWCS observations from which 4 types of works were distinguished: electronic works, automatic works, mechanic works and pneumatics works. For each type of work deeper analysis was conducted. All measured activities were assigned to one of the groups: value added, non value-added and value-enabling type of work. The results of these observationsare shown in the figure below (Fig. 6).

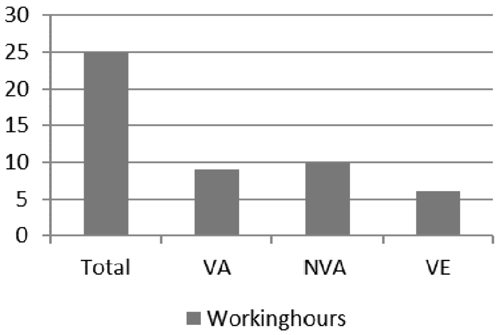

Fig. 6. VA/NVA/VE status per one P1 inspection before improvement [own study]

Based on the analysis performed, in the process of P1 maintenance inspections are value-added tasks, non value-added tasks and value-enabling work which are supporting activities. In the first action non-value activities should be analyzed, reduced or even eliminated from the process. Those tasks do not bring any value to the client and in lean management methodology are treated as pure waste. It is helpful to look deeper into value-added tasks and value enabling activities in order to look for some solution to improve those tasks.

3.3. Spaghetti Diagram

A spaghetti plot (also known as a spaghetti chart, spaghetti diagram, or spaghetti model) is a method of viewing data to visualize possible flows through systems. Flows depicted in this manner look like noodles, hence the coining of this term [4]. The spaghetti diagram is one of the tools of the lean methodology (used in the initial phase) allowing the observation of the movement of the product (or service, or workers), consistent with the geographical placement of jobs in the workplace.It arises by applying to the designated area the paths determined by product/employee movement in subsequent production phases.

The spaghetti diagram was conducted during random P1 inspections on diesel locomotives. Observation shows that a crew of 5 people performed a total of 3–5 km of routes during the P1 review.

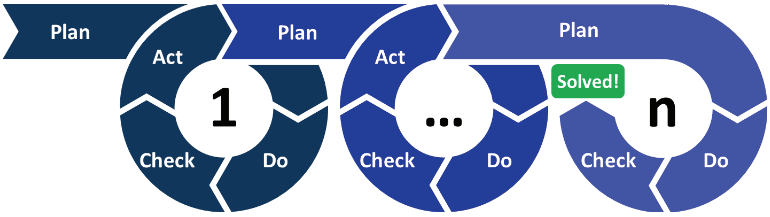

Fig. 7. PDCA loop [4]

3.4. PDCA tool

PDCA (plan–do–check–act or plan–do–check–adjust) is a four-step management method used for the control and continual improvement of processes and products.Also commonly referred to as the Deming Cycle; "Plan-Do-Check-Act" is one basic principle followed to achieve effective problem solving during an improvement activity (Fig. 7).

Constant improvement is an important direction of the effective development of all types of activities undertaken. Achieving a better condition than the current one is the primary goal of the PDCA methodology [10]. Proper implementation of the process requires involvement in determining the direction of improvement of activities, a skillful selection of elements requiring improvement or even finding who should primarily support the whole process of change. Empirical research shows that many people quickly move into action, limiting or even eliminating the entire planning process. The results of such an approach are often innumerable mistakes, long implementation time or quality errors. Among other things, the PDCA method is such an important instrument for generating and standardizing changes.

Lilrank and Kano indicate 7 basic tools of the Japanese approach to quality control: check sheets, histograms, Pareto Diagram, Ishikawa Diagram (diagram fishbone), diagrams, scatter diagram method and Stratification. Together with the PDCA model, these tools provided the basis for the development of the Kaizen method in Japan. The company decided to use some of those tools for PDCA. In addition the company chose some lean tools to improve the process such as: 5S, standardization cards and visual management.

Cause and effect diagram

Ishikawa diagram, cause and effect diagram, also known as fish diagram or as fishbone diagram, as well as error tree diagram is used to illustrate cause-and-effect relationships, thus helping to separate causes from the effects of a given situation and to see the complexity of the problem.

Ishikawa has developed a cause-and-effect diagram in which the analysis starts with the confirmation of an effect (eg failure, failure or other undesirable state) and is conducted in the direction of identifying all possible causes that caused it [16]. Among the reasons, he listed 5 main components – referred to as so-called 5M: Manpower (people), Methods (methods), Machinery (machines), Materials (materials), Management (management). Each of these components breaks down into individual causes, which should be considered individually as problems to be solved.

The company created 5 Ishikawa diagrams, each for different problems which occurred during performing SWCS (Fig. 8). Drawing up those charts has been an effort of many employees of the organization, because the causes of failures usually have their sources in various fields of activity. Therefore, the team was consist of people with a large specialist knowledge, who also had the will to reveal the reasons for defects, including those caused by themselves. It is very useful to use heuristic methods during the construction of the schematic. The project group using its many years of experience wrote down the reasons that most likely had the greatest impact on the outcome. Next step was to analyze whether the identified significant causes really identifies the problem being tested. The results of the analysis has been formulated in the form of conclusions. Finally, the consequence of the graphic form of presenting the causes and effects of potential failures was a transparent consideration of the problem under investigation. The diagram allowed to identify the causes of the problem and determine their mutual dependencies.

Organization method 5S

Method 5S is a workplace organization method that uses a list of five Japanese words: seiri (sort), seiton (set in order), seiso (shine), seiketsu (standardize), and shitsuke (sustain) [12]. It is a collection of techniques and methods aimed at establishing and maintaining high quality places and workplaces. 5S is at the same time one of the basic tools of Lean Manufacturing and Lean Management, because it is directly related to the proper organization of the work environment and improvement of the company's organizational culture, as well as – what is very important – allows to increase the stability of processes. For this reason, 5S is treated very often as a key Lean Management technique, implemented in manufacturing and service companies as one of the first, as it forms the basis for further improvement activities (kaizen activities). In deeper translation 5S stands for:

- *Seiri* – Sifting to segregate and discard;

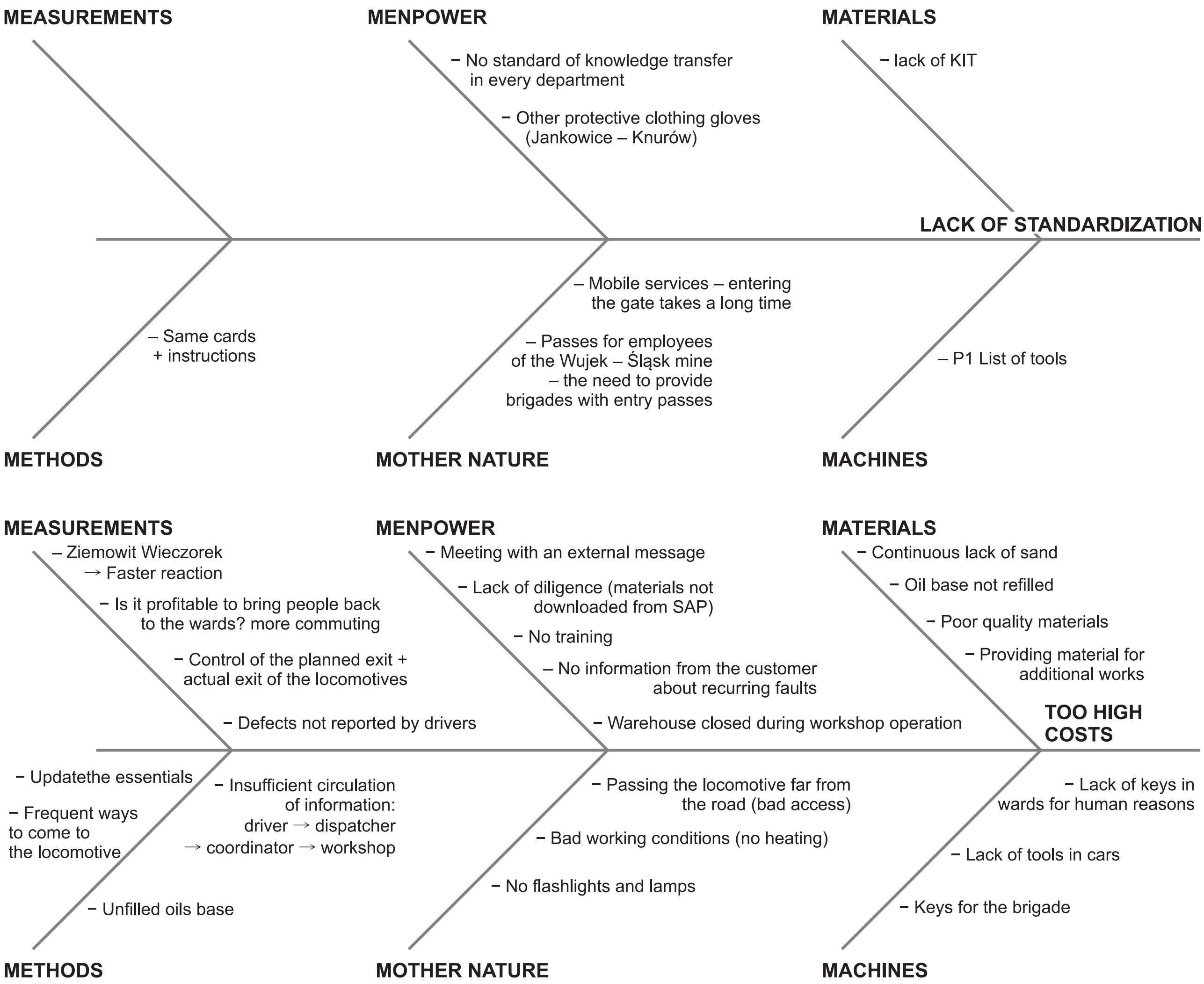

Fig. 8. Examples of fishbones performed by project management team [The company's Project Management data]

- *Seiton* – Sorting the needed items into arranged and clearly identified locations;
- *Seiso* – Seeping and washing, to clean and inspect daily;
- *Seiketsu* – Spick and span, to revisit the first three S's frequently;
- *Shitsuke* – Discipline, building good habits and motivating to sustain improvements.

The company used in a purpose of this article implemented 5S successfully in all production areas.It realized that 5S is a very powerful methodology to set up and maintain a well organised, functional, clean, safe and working environment that boosts performance. This was a precondition for higher productivity and higher quality. By following the sequence of 5S, unnecessary ballast was sorted out, needed items were set in order and cleaned – the focus is firmly on what is needed. Implementing 5S helped to create and maintain an organized, clean and efficient working place and sustain the achieved improvements (Fig. 9, 10). Generate a sense of responsibility of the employees for security, orderliness, cleanliness and efficiency at own working place. 5S supported to motivate the employees by working together on a safe and clean working environment (Team work).

Fig. 9. Example of floor marking for storage boxes [photo by the author]

Fig. 10. Tool shadow board with toolbox shelf
[photo by the author]

Standardization Cards

We can standardize all processes that meet two basic conditions: they are repeatable and can be described. Standardization cards consist of the most efficient combination of people, machines, and materials required to accomplish production in such a way as to minimize waste.The standardization cardsare used to outline and clarify the sequence of production processes and the sequence of operation for the workers in a cell. It is also used to examine and document the flow of people and materials and to illustrate the locations of standard works together with tact time. Quality checks and safety precautions are also symbolized on this sheet using standard icons. Expresses flow in the dimension of time and in the dimension of space.

Standardization cards has been prepared by highly qualified engineers by collecting and recording data on a few forms. Furthermore during the workshop front-line supervisor together with clients and engineers prepared new, improved process. Standardization cards (which in reality became a book of standardized P1 maintenance process) consist of takt time for every type of locomotive, sequence of works and division of work between specializations. As well standardization cards have included standard inventory (with precisely selected types of material and their quantities) in order to keep the process smooth.

Visual management

Visual Management refers to the means by which anyone can tell at a glance if production activities are proceeding normally or not. A communication, discipline and pacing tool. When the normal and abnormal state of production operations can be clearly and visually defined, Visual Management is possible. In visual management, simple tools are used to identify the target state, and any deviance is met swiftly with corrective action.

Performance Management is a Management Tool. The Performance Management Process encourages "contribution to the whole", "target orientation" and "trust and integrity" in our day to day business.Regular, structured team meetings around whiteboards displaying relevant KPIs, concerns and actions to drive corrective action and continuous improvement.

The company implemented Visual Management Boards which provide the ability to understand the actual condition of business performance in a visual way and measure "the right things right, at the right frequency". It gives the ability to differentiate between the "normal" and the "abnormal" situations immediately and improve team building and communication through regular face to face meetings.Performance Management meetings create a focused forum and are social mechanisms for candid conversation about performance and how to close the gap between 'Target' and 'Actual' conditions.

During implementation the reaction of the organisation to Performance Management was critical. Without leadership recognition and response, performance would not be achieved.

The implementation of Visual Management shows that Performance Management process provides the flexibility to change business focus and direction quickly.

4. Effects of implemented Lean tools

VOC, CTQ answered the question: what the customer expects from our product. Lean tools used in the project of reducing Life Cycle Costs of diesel locomotives brought significant results in both: costs and time of P1 inspection. After the project the costs has been reduced at around 33% (Fig. 11) and workinghours dropped from average 27 to 13,5 (Fig. 12). Method 5s reduced the time of "Searching" and "Getting" activities to around 5% of the working time of an employee. Employees develop a higher sense of quality, productivity and safety by applying the 5S methodology. Thanks to 5s, spaghetti diagram, fishbone diagram and standardization non-value added activities were almost completely reduced. Research shows that by using PDCA in the process and Ishikawa Diagram is possible to improve the process. Moreover the companyselected and identified a number of the reasons that were likely to have the greatest impact on the outcome and analyzed whether the identified significant cause really identifies the problem being tested and determined how to eliminate the most likely process of developing the nonconformity under investigation.

Standardization cards brought many benefits to the process e.g documented, new, improved process for all shifts and all localizations, reduction in variability, easier training of new operators and became a baseline for improvement activities. Standardization cards made the working culture more disciplined and involved team members to continuously improve the process. Moreover it became a learning tool that supports audits as well as promotes problem solving.

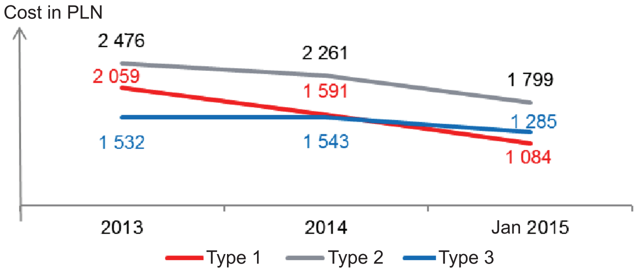

Fig. 11. Average cost per P1 before and after Leaning [own study]

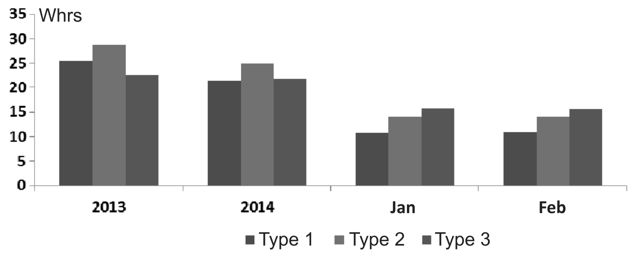

Fig. 12. Average number of workinghours per P1 before and after Leaning [own study]

5. Conclusions

Over the last 20 years meaning of transport was gradually increasing. The increase was mainly caused by a number of goods transported by road and air. Participation of the other types of carriage including rail transport was dropping down. The companies realized that they should improve quality of their services and reduce costs. In order to achieve intentional target they introduced special tools.

In this context, we can say that the Lean Management tools should be the basics and fundamental tools in order to gather competitive advantage on a railway market by reducingthe maintenance costs of rolling stocks. In addition – the current goals should be to gather and constantly update the customer expectations.

The selected research results presented in the article are strong evidence that such tools as LCC, VOC, PDCA or 5S maximize customer value while minimizing waste together with having satisfied customers and employees.

This article prove that it is very important for the companies to standardize all processes that meet two basic conditions: they are repeatable and can be described.

Visual Management refers to the means by which anyone can tell at a glance if production activities are proceeding normally or not, that system basing on communication, discipline and pacing tool.

Implemented Lean tools caused positive impact. Companies know the customer expectations, the inspections are cheaper and faster, moves which were pure waste are reduced, the employee stopped wasting the time for searching and they work is productivity and safety. Standardization cards improved process provide easier training of new operators, made the working culture more disciplined and involved team members to continuously improve the process.

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