KAUNAS UNIVERSITY OF TECHNOLOGY

MECHANICAL ENGINEERING AND DESIGN FACULTY

Tadas Darginavičius

DEVELOPMENT OF PRODUCTIVITY IMPROVEMENT MODEL AT INDUSTRIAL ENTERPRISES

Master's Degree Final Project

Supervisor
Assoc. Prof. Dr. Rūta Rimašauskienė

KAUNAS, 2017

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(Title and code of study programme)

"Development of productivity improvement model at industrial enterprises"

DECLARATION OF ACADEMIC INTEGRITY

23 May 2017
Kaunas

I confirm that the final project of mine, **Tadas Darginavičius**, on the subject "Development of productivity improvement model at industrial enterprises" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

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FACULTY OF MECHANICAL ENGINEERING AND DESIGN

Approved:
Head of
Production engineering
Department

____
(Signature, date)

Kazimieras Juzėnas
(Name, Surname)

MASTER STUDIES FINAL PROJECT TASK ASSIGNMENT
Study programme INDUSTRIAL ENGINEERING AND MANAGEMENT

The final project of Master studies to gain the master qualification degree, is research or applied type project, for completion and defence of which 30 credits are assigned. The final project of the student must demonstrate the deepened and enlarged knowledge acquired in the main studies, also gained skills to formulate and solve an actual problem having limited and (or) contradictory information, independently conduct scientific or applied analysis and properly interpret data. By completing and defending the final project Master studies student must demonstrate the creativity, ability to apply fundamental knowledge, understanding of social and commercial environment, Legal Acts and financial possibilities, show the information search skills, ability to carry out the qualified analysis, use numerical methods, applied software, common information technologies and correct language, ability to formulate proper conclusions.

1. Title of the Project

Development of productivity improvement model at industrial enterprises

Approved by the Dean Order No. V25-11-8, 21 April 2017

2. Aim of the project

The main object is to develop a productivity improvement model and test it in real company.

3. Structure of the project

Introduction, Problem definition, importance and relevance of the Lithuanian industrial enterprises, Production efficiency improvement in metal industry, theoretical studies, Productivity improvement in industry, empirical studies, Productivity improvement model for metal-processing enterprises, Conclusions and suggestions, Appendixes, References.

4. Requirements and conditions

To prepare final project according to KTU regulations and requirements.

5. This task assignment is an integral part of the final project

6. Project submission deadline: 2017 June 1st.

Student Tadas Darginavičius ______________________
(*Name, Surname of the Student*) (*Signature, date*)

Supervisor Assoc. Prof. Dr. Rūta Rimašauskienė ______________________
(*Position, Name, Surname*) (*Signature, date*)

Tadas Darginavičius. Development of Productivity Improvement Model at Industrial Enterprise. Master's Final Project / supervisor Assoc. Prof. Dr. Rūta Rimašauskienė; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.

Research field and area: Technological Science, Production Engineering.

Keywords: *Lean, TOC, efficiency improvement, productivity.*

Kaunas, 2017. 61 p.

SUMMARY

In this final master work, ways how to improve efficiency of industrial enterprises were analysed. A productivity improvement model has been developed, which is mostly suitable for enterprises working in metal-processing sector.

In the first part of the work literature about manufacturing and its efficiency was analysed. Tools how to identify problems and defects were discussed. Ways how to increase productivity and eliminate drawbacks were examined. Principles of Lean and TOC were investigated.

In the second part, trends of overall Lithuania industry and metal-processing sector is given. Data received from questionnaire was analysed, which has been sent to industrial enterprises.

In the third part, a productivity improvement model is presented. All the steps of a model are analysed and described. Theoretical model has been tested at metal-processing company. The results are given with real examples. Solutions are submitted and calculations done to prove a model's usefulness.

The final work consists of four parts: introduction, analysis of literature, analysis of research and experimental part.

Scope of work is – 61 pages, 16 tables, 36 figures, 19 bibliographic sources.

Tadas Darginavičius. Modelio produktyvumui kelti pramonės įmonėse kūrimas. Magistro baigiamasis projektas / vadovas doc. dr. Rūta Rimašauskienė; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

Mokslo kryptis ir sritis: Technologiniai mokslai, Gamybos inžinerija.

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Kaunas, 2017. 61 p.

SANTRAUKA

Šiame baigiamajame magistro darbe yra analizuojama kaip pakelti pramonės įmonių efektyvumą. Sukurtas produktyvumui kelti modelis, kuris labiausiai tinkamas metalo apdirbimo įmonėms.

Pirmoje dalyje analyzuojama teoriją apie gamybą ir jos efektyvumą, apie primones kaip identifikuoti problemas ir defektus, apie būdus pakelti produktyvumą ir pašalinti trūkumus. Pateikiami pagrindiniai Lean'o ir TOC'o principai.

Antroje dalyje apžvelgiamos Lietuvos pramonės ir metalo apdirbimo sektoriaus tendencijos. Duomenys gauti iš klausimynų yra analizuojami ir apibendrinami.

Trečioje dalyje pateikiamas produktyvumo kėlimo modelis. Žingsniai kaip juo naudotis yra aprašomi. Teorinis modelis yra išbandomas metalo apdirbimo įmonėje. Gauti rezultatai yra pateikiami su tikrai pavyzdžiais. Pateikiami sprendimai ir skaičiavimai pagrindžiantys modelio naudingumą.

Baigiamasis darbas susideda iš keturių dalių: įvadas, literatūros analizė, tyriamoji dalis ir ekspermentinė dalis.

Darbo apimtis – 61 lapų, 16 lentelių, 36 figūros ir 19 literatūros šaltinių.

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Introduction

Actuality of theme. Prosperity of industrial enterprises is the main driven force of high level economy in a country. Industrial enterprises have significant influence in creating GDP (Gross Domestic Product) of the country, therefore it has great importance in world's and country's economy. However, nowadays companies face difficulties to maintain business profitable all the time.

First of all, a constant competition in every field. To survive, to maintain profits and employees, to be a constantly growing company, you have to offer something more than other enterprises. What makes it even harder is that competition is global today. It is not enough to be strong locally anymore, you have to achieve recognition worldwide. Moreover, companies of East countries (India, China, etc.) are growing and becoming more competitive. These enterprises can offer cheaper labour force, which basically means lower manufacturing costs and higher profits. So the only way for Lithuania's industrial enterprises to be attractive and be selected as manufacturers is high quality, rapid production and on time delivery. The truth is Lithuania is not recognized anymore as a country with the lowest salaries, so constant improvements and investments in quality, production and delivery have to be done. This guarantees a satisfaction of clients, profits, recognition.

Many industrial enterprises believe that new equipment ensures faster production. It is true enough, however, hardly possible. A new equipment usually costs a fortune, so it would not be a smart idea to keep your machinery and tools always updated. Furthermore, delays, idles and other time wastes are usually generated by other processes, not by machines/ equipment. So, the smarter idea would be to have your enterprise analysed by the management in order to find main failures and turnovers which costs a lot of time and money. The best way to do that is to integrate productivity improvement model in the company. These systems allow to define the problems, measure, analyse and utilize them.

With systems like Lean and TOC companies use less resource to create greater value for customer and increase competitiveness. However, one or two people cannot change anything, contribution has to be made by all employees. Only this way a company growth could be achieved.

It should be considered that business area is changing rapidly and it is really hard to predict which fields will be growing and developing next year. Therefore, every company must learn to adjust and adapt really fast to the changes.

To sum up, industrial companies in Lithuania have to ensure the highest quality, the highest level of productivity and a delivery on time. In addition to that, these enterprises must be flexible and adjust fast to changing economical situations.

Problem. Manufacturing in Lithuania could be still called in its prime days. Most of a companies are still managed by old standards, what makes tough to compete with other European countries. What is more, not enough is invested in research and development. To respond quickly to global changes, enterprises have to be innovative, modern and flexible. One way to achieve that is to integrate efficiency raising systems like Lean and TOC. Most of the companies in Lithuania know those systems, they even try to integrate those systems, but usually they fail or they do not get the result they could.

Goal. To develop productivity improvement model and test it in a real company.

Tasks. Main goals of the terminal tasks are:

1. To make an analysis of theoretical – methodical literature of Lean ant TOC systems, their main tools how to identify and solve drawbacks.
2. To analyse metal-processing sector and overall industry trends in Lithuania and EU;
3. To develop productivity improvement model of Lean and TOC for industrial metal-processing enterprises.

1. Analysis of theoretical literature

1.1 Lean manufacturing

“Lean Manufacturing is a philosophy of production that emphasizes the minimization of the amount of all the resources (including time) used in the various activities of the enterprise. It involves identifying and eliminating non-value-adding activities in design, production, supply chain management, and dealing with the customers” [1]. This helps for a company to save a lot of resources. Integration of Lean philosophy in a company ensures higher efficiency of manufacturing or in other words higher productivity. Without huge investments a company can produce products with higher quality in less times with less resources. All these factors may influence company’s welfare, profits, competitiveness ability, satisfaction of a customer, etc. Lean philosophy helps to identify manufacturing weaknesses and eliminate them. Non-value-adding processes have to be removed in order to reach higher aims and profits.

“Lean brings action and intuition to the table. Based on the principals of the Toyota Production System and kaizen (continual improvement) breakthrough methodology, lean focuses on creating one-piece flow with just-in-time management of inventory and materials” [2]. Kaizen events have to be organized as often as it needs to be. It is a really great way to gather employees and discuss with them. In these discussions workers should be encouraged to take responsibilities, motivated to search for drawbacks and find solutions for appearing problems and questions. Lean is only effective, when everyone participates, so Kaizen meetings is a great way to educate people, to unite your employees and ensure everyone’s contribution.

Many productions companies used the Toyota manufacturing as an example globally. This example involves a philosophy of continuous improvement which means a totally different view towards manufacturing. A production culture Toyota has invented encourage to challenge all the processes and activities in a company in order to reach higher level of performance. “By empowering its people, creating teams that interact to meet objectives, and designing its production to optimize performance, Toyota is able to refine its processes and create products that are superior to its competitors” [3]. These rules have made Toyota become an example to other enterprises beyond the automotive industry. "Waste elimination is one of the most effective ways to increase the efficiency of a production system. Waste is always the first and cheapest area to change because it usually doesn't require capital expenditures" [4]. Wastes such as overproduction, waiting, transporting, inappropriate processing, unnecessary inventory, excess motion, and creation of defects are reducing the efficiency of a work station. The efficiency of the entire manufacturing route could be risen significantly only by reducing or even eliminating any of those wastes.

Whole production cycle could be shortened and profitability increased by identifying wastes and by analysing processes which are taken in a manufacturing company. A total amount of time it takes to finish an order or total amount of recourses and labour force needed to produce a product could be reduced by identifying processes which do not add value and by eliminating them. [5].

“Creating excess motion also slows down the production process. Designing work centres allows employees to complete their jobs with as little repositioning as possible makes production much more efficient” [5]. The simplest processes as walking distances between workstations could have huge influence on time it takes to complete a job. By reordering workstations in a more convenient way could highly reduce productions cycles. Moreover, improvements could be achieved by implementing shadow dashboards. It would be easier to locate equipment and tools and this way less time it would take to produce a product.

In order to control production and make decisions on manufacturing processes, key employees should have high visibility on it. It would ensure easier way to identify appearing problems, follow work of work centres and see if everything is going according to a plan. It is much less possible to find a problem, waste or drawback if there is no visibility. “Properly functioning work areas allow managers to compare the expected output of the work area against the current output to determine the performance of a work area. If the proper systems are not in place to allow this visibility it is difficult to prioritize resources to achieve desired objectives” [6].

Theory of Constraints (TOC)

The theory of constraints is a philosophy which leads to an identifying and an elimination of any weaknesses in the production processes. A weakness is everything what stops from achieving highest results and company’s aims. In order to that, first manufacturing processes have to be understood.

The system was developed to optimize production. It was also called as optimized production technology. It manages all the processes and operations. There are five steps of theory of constraints:

1. Identify a bottleneck;
2. Find a way hot to eliminate it;
3. Subordinate all other processes to above decision;
4. Eliminate a constraint;

5. If a constraint is removed, return to step 1.

If a TOC is implemented successfully, these are possible benefits:

- Higher profits;
- Improvement of the operation;
- Improved capacity;
- Decreased production cycles;
- Reduced inventory [7].

1.2 Main Lean tools

The most popular tools are described below. Each tools involves a small description about it and how it works.

Andon

Andon is a tool used for reporting about a problem in a specific workstation. There are so called Andon signals which are great to visualize manufacturing status. It is a really fast way to let managers or other responsible personnel know about occurred situation. For example, significant part of products is defected. A responsible person of a workstations triggers Andon signal, which may be a simple phone. Using a phone, he reports about a problem immediately and Andon team has to gather as soon as possible to find possible solution. Solutions are implemented. Andon helps to save a lot of time it takes so solve a problem, because Andon team gathers immediately after defects appeared [8].

A3

A3 is a tool used to find solutions for a problem or for a continuous improvement. There are simple and strict steps which lead to solving a problem. All the steps are performed on a ISO A3 single sheet paper. The whole process is based on a Plan-Do-Check-Act cycle. The most usual steps are: giving a name to a project, selection of a team, description of a problem, identifying root causes, setting goals to a project, finding possible solutions, calculations and implementation [8].

Jidoka

Jidoka is a tool which is mainly responsible for product quality. The main principles of Jidoka could be written in four steps:

1. Discover a defect;
2. Stop the production;
3. Solve a problem;
4. Analyse and eliminate root cause.

This tool often is described a "automation with human touch", which basically means that if a problem occurs, the machine stops and a worker will stop a production line. This way production of defected parts is prevented. What is more, a deeper analysis ensures that a problem would never repeat [9].

Heijunka

Heijunka is a tool used to control a flow of a production. It is a visual tool which helps to see what kind of work has to be done and when. Heijunka could be called as a schedule box which helps to achieve a smoother workflow. The main aim of this tool is to produce goods only when they are needed. Heijunka is highly useful when customer demand fluctuates [10].

Value Stream Mapping

Value stream mapping is a visual tool. It is similar to a flowchart which uses specific symbols also known as "the language of Lean". The main aim is to improve the flow of inventory and information. Value stream mapping shows a current and a future state of a production. The visual system let everyone understand where they stand now and what has to be done to reach future state. With the help with this tool it is easy wastes which have to be removed. [11].

5S

5S is a tool which is considered to be one of the most powerful. It is used to keep your workstation efficient, clean and safe. This way a productivity is improved.

5S could be divided into 5 phases:

1. Sort – Keep your work space clean. Leave only those tools you are using now and remove all the unnecessary equipment;
2. Straighten – All of the tools should have its own place and space. Equipment should always stay in its place unless it is being used;
3. Shine – Tools and machines should be cleaned after using them. This way the equipment stays as new;

4. Standardize – Three phases above should be standardized. Standardization is one of the key principles in Lean system;
5. Sustain – a company should constantly use all these stages to ensure a continues improvement. 5S tools should become a part of the culture [12].

Kanban

Kanban is a Lean manufacturing tool which ensures a constant flow of components or other accessories like belts, bolts etc. This system helps for workers to have what they need when they need. Kanban is also a visual tool which signalises when specific components are running out and have to be refilled. Signals may be plastic markers or simply floor space. This tools to manufacture products without stopping.

Moreover, Kanban can also be used for subcomponents. For example, company uses a lot of identical subcomponents which are needed in higher level of assembly. So more subcomponents could be produced for the future to reduce average production cycle and save some time [13].

Kaizen

Kaizen is a tool needed for successful business development. Main benefits of this tools are:

1. Helps to use all the potential employees have;
2. Increase quality of products;
3. Improve efficiency and save resources;
4. Eliminate wastes [14].

Word Kaizen translated from Japanese means "change for better". This tools goes beyond improving productivity. It encompasses elimination of hard work, raising motivation of workers, making a working atmosphere better. "Kaizen is small improvement, but permanent, with determination and consequence" [15]. An important feature about this tools is that it does not need huge investment or difficult techniques Common sense and conventional techniques are the features needed for Kaizen.

Poka yoke

Poka-yoke is a tool used to avoid defects and mistakes. The main purpose of this tool is to help an equipment operator to eliminate defects of a product by preventing, correcting, or drawing attention to human error as they occur. Three main types of Poka-yoke are recognized:

- Contact method. It finds the defects by measuring products size, shape, colour or other physical attributes;
- A fixed amount. This method alerts an operator if a number of moves needed to make a parts is different;
- Motion step. This method follows if all the steps have been done in a correct order [16].

1.3 Identification of main manufacturing wastes

One of the easiest and most effective ways to increase profits of a manufacturing company is to remove wastes. Processes can either be non-value or either it adds value to whole company. To eliminate waste, first it has to be identified and exact location found. Different companies produce different products but wastes in enterprises are usually similar. Every waste has its own specifics so there are different ways to locate and eliminate them. After elimination the whole performance is of the company is improved [17]. The seven wastes consist of:

Overproduction.

Overproduction is a situation when the products are produced before they are actually needed. This waste costs a lot of money, because overproduction can decrease quality and productivity in a company. What is more, a smooth flow of materials and resources are ruined. The most effective way is to produce when it is needed or in other words "just in time". Overproduction creates higher production cycles and higher storage costs. Elimination of overproduction may show many more problems hiding under it.

Waiting

Waiting is another huge waste. The main reasons for it is: poor material flow, distances between workstations are too long, etc. Elimination of waiting time could save huge amounts of money for a company.

Transporting

Smooth logistics in a company is really important. Transporting can cost a lot of money, so company should try to make it as effective as possible. Unfortunately, this is quite difficult task and there few reasons for that. First, it is hard to determine next workstation of a product, because every product may have different order of processes. Secondly, because there are determined prices of transportation, so it may be difficult to reduce them.

Inappropriate Processing

Some of companies may use better equipment than it is needed. Sometimes simpler and cheaper tools are enough for production, but companies use equipment with high precision. This leads to higher costs which are completely unnecessary. Investing in smaller equipment and using high precision tools when they are needed can reduce this waste.

Unnecessary Inventory

This waste is a direct result of overproduction and waiting. Usage of inventory costs money and if it is not needed money is wasted. What is more, a useful space is taken while there could be done some other value adding processes. Unnecessary inventory makes is difficult to check all the products for defects and may hide some other problems.

Unnecessary / Excess Motion

Moves like bending, walking, stretching, lifting and reaching are involved it this waste. Ergonomics takes a huge part in today's company, because it is not only related to money but and to health and safety issues. So all works should be done with as less moves as possible.

Defects

Defects are a waste which more or less every company face it. Significant part of manufacturing costs consists of reproduction. Material, time and labour time is wasted. This drawback can be reduced through employee involvement and continuous improvement [17].

1.4 Main quality tools to identify the problem

Quality can be controlled only by eliminating weaknesses and drawbacks. To eliminate them, first they have to be identified. There are so called quality tools, which aim is to find drawbacks. Those tools are easy to understand, yet extremely useful in identifying and analysing quality problems. Sometimes workers use only one tool at a time, but often a combination of tools is most helpful. Main quality models [18]:

Flowchart

A flowchart (Fig. 1 is a visual tools used to represent an order of the process. A flowchart is easy to use and understand. By seeing the steps in an operation it is easier to have clear picture of how everything works and where possible weaknesses could occur.

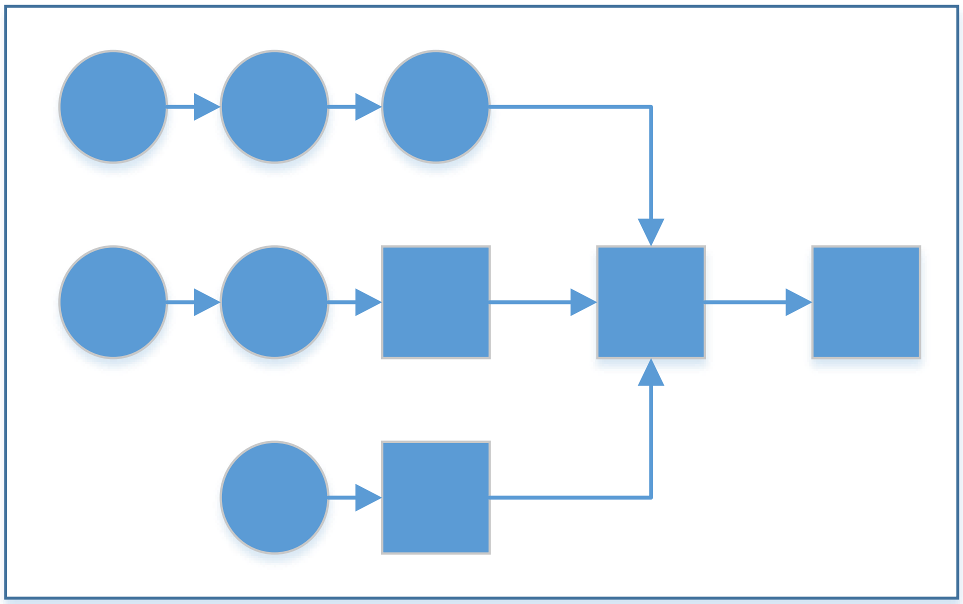

Fig. 1 A Flowchart

Why use flowchart?

- All the steps of the operation can be seen;
- Relationships between steps can be seen;
- It helps to analyse the process;
- Easier to find weaknesses in a process.

Check sheet

A checklist is a list of most usual occurring weaknesses and the total number of times it appeared. This is tool is really easy to observe defective processes. An example of check sheet is shown in Fig. 2. It is obvious that most common problem is ripped material, so this defect is a priority to be solved. A check sheet can be also used in specific dimension like time or location. For example, if defects appear frequently, they may be counted per shift, per machine, per workstation.

Defect type	No. of defects	Total
Broken zipper	///	3
Ripped material	///////	7
Missing buttons	///	3
Faded colour	//	2

Fig. 2 Check sheet

Cause and effect diagram

Cause-and-effect diagrams are tools used for detection of possible causes for bad quality. They may also be called as fishbone chart. An example of this chart is shown in Fig. 3. Specific quality problem as ripped material is a head of a fishbone. A spine is drawn from a head, which connects possible problems with a head. Problems may be various and different for every occasion. In this particular example, problems may be: workers, machines, materials, environment. Each of the cause can have smaller branches which are more specific causes of the main problems. For example, old or not calibrated machinery can cause some quality problems.

Cause and effect diagram is an issue solving tool. It is usually filled by using brainstorming of a responsible team.

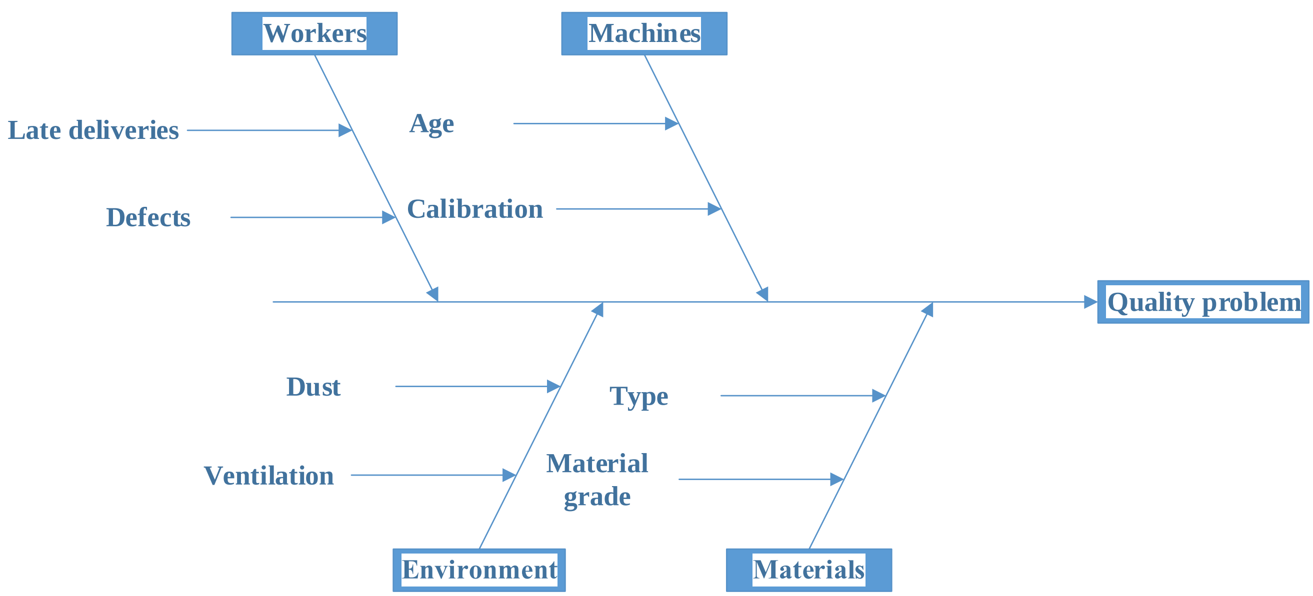

Fig. 3 Cause and effect diagram

Pareto chart

Pareto chart is a tool used to identify most important problems. Philosophy of Pareto analysis is that only few main problems lead to the most defects and other weaknesses are not vital. This analysis is often called 80 – 20 rule, meaning that 80 percent of defects are caused by 20 percent of problems. This technique is usually used in other areas too. The principle of a chart is that it ranks causes of poor quality in decreasing order based on the amount of defects each cause has caused. An example of a Pareto chart is shown in Fig. 4.

Control chart

Control chart is a tool used for controlling specific feature. It helps to evaluate if the operation is processing within expected values. For example, size, weight, widh could be controled. To check if a value is in a control, it is regularly measured. There are two lines in a chart: uper control line and lower control line. These two lines are a limit to specific value. If a value stays within UCL and LCL range, it means a value is controled and there is no problem with a quality. When a value exceeds limits, production should be stopped and problem identified. An example of control chart is shown in Fig. 5.

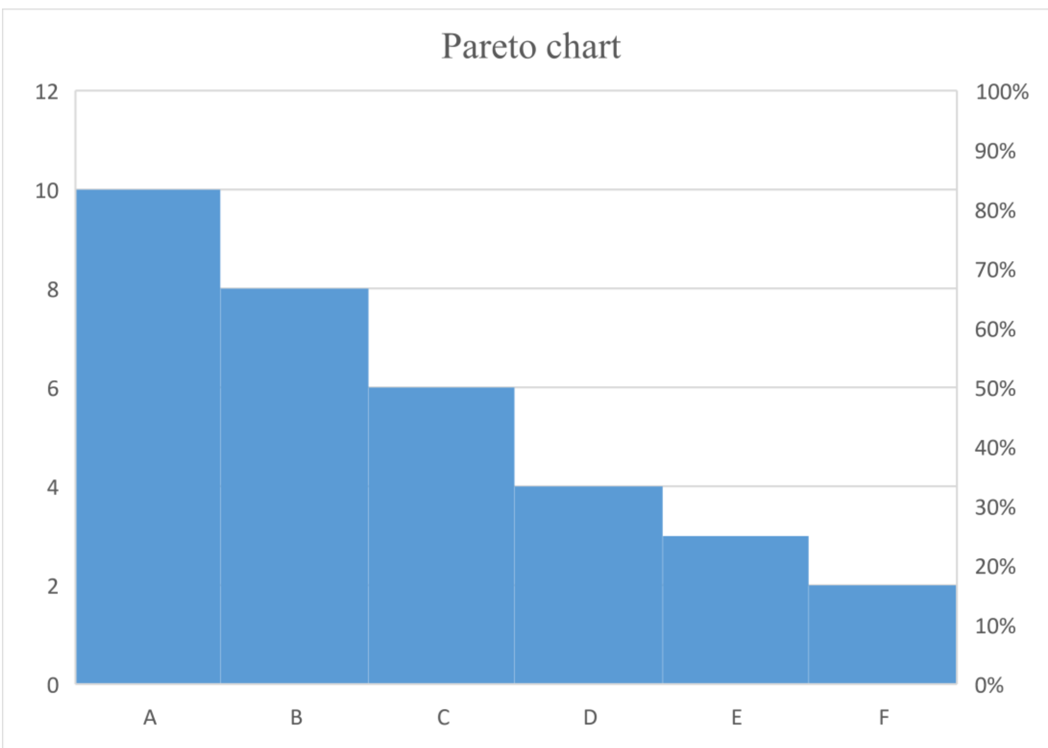

Fig. 4 Pareto chart

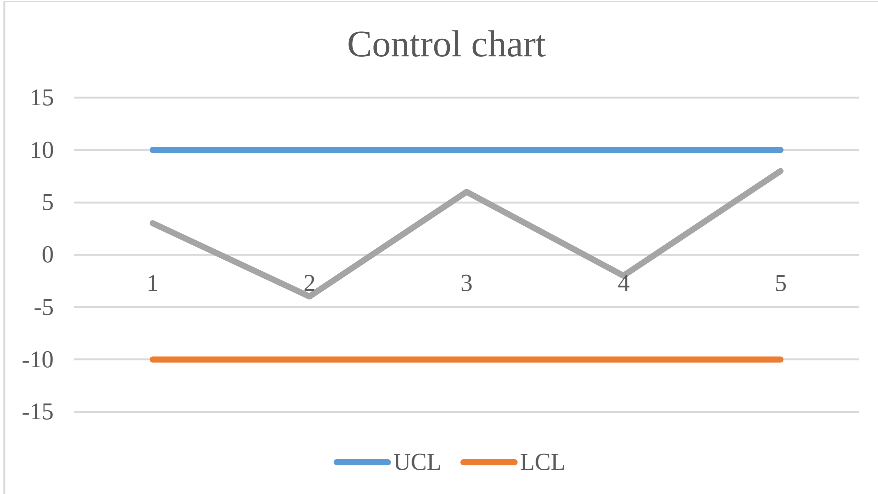

Fig. 5 Control chart

Histogram

A histogram is a visual tool, which represents a distribution of a certain measure. It may be used to make sense of data. Moreover, it allows to see some patterns, which are hard to be seen in tables or charts. What is more, it is a simple way of showing data. An example of histogram is shown in Fig. 6.

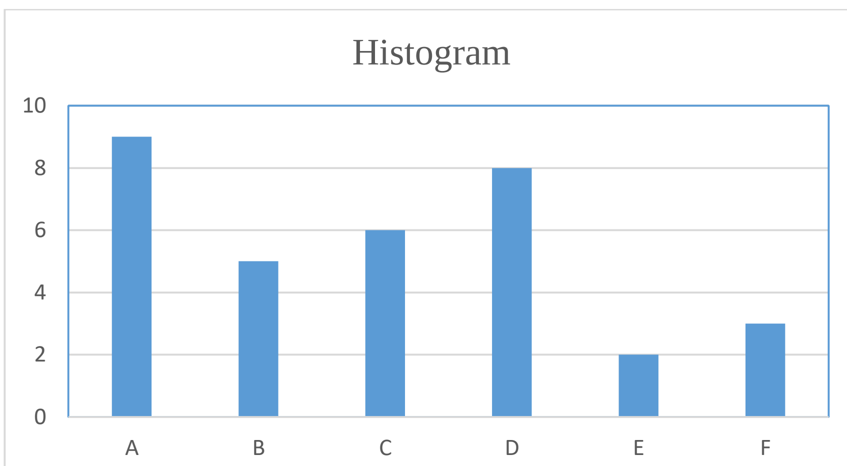

Fig. 6 Histogram

Scatter diagram

Scatter diagram (Fig. 7) is a tools used to show how to values correlate between each other. This diagram shows the strength of the relationship between two variables. For example, increased manufacturing speed may result in higher number of defects. So there might be high correlation between those two values. This kind of correlation would be called positive. There also can be a negative relationship, which mean that increase in one value result in decrease of another one. For example, trainings of the workers may be a cause of decreased number of defects. Correlation value varies between 1 and -1. 1 means there is a strong positive correlation and -1 – negative strong relationship [18].

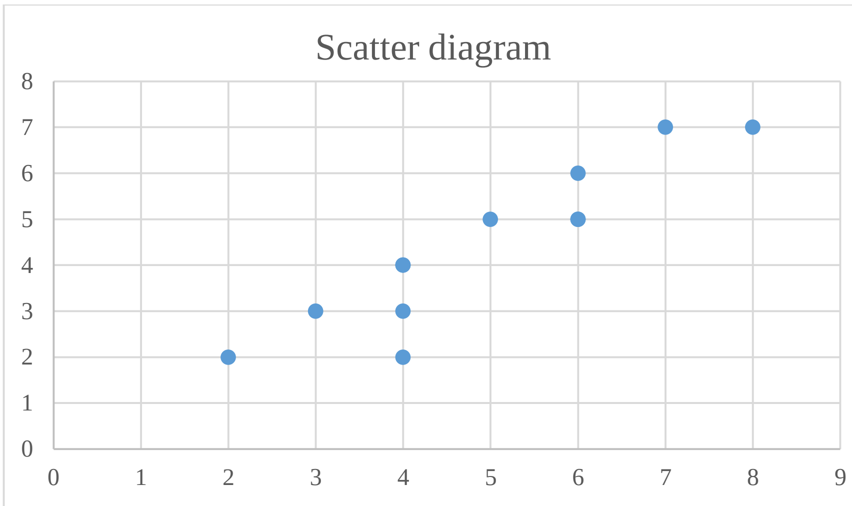

Fig. 7 Scatter diagram

1.5 Conclusions

Analysis of Lean and TOC literature has been done. Main principle of these two systems is to improve companies' processes and operations. There are few tools used to identify bottlenecks in an enterprise. Those tools have been analysed and small descriptions given.

Moreover, most usual wastes in a production company were analysed. Short descriptions were given with examples hot to eliminate them. Seven wastes are: overproduction, waiting, transporting, inappropriate processing, unnecessary inventory, unnecessary/excess motion and defects.

Finally, tools used for problem solving have been discussed. Short definitions about them and how they work were given. Those tools are: Andon, A3, Jidoko, Heijunka, value stream mapping, 5S, Kanban, Kaizen, Poka-yoke.

2. Analysis of industry in Lithuania and EU

2.1 Research methodology

The purpose of this paperwork is to find a way to increase productivity in the selected metal-processing industry. Firstly, the analysis of current situation in overall market will be carried out due to specific characteristics of this field. Industry dynamics, sales, financial performances, etc. will be covered. Furthermore, a metal industry will be looked over in the context of general dynamics of industry in the country. This way we will get a picture of current situation: whether it is upgrading or deteriorating.

Next, three metal industry enterprises were chosen. These companies will be analysed using a questionnaire. The collected data will determine overall situation, how familiar companies are with Lean and TOC systems, main problems and possible solutions for easier productivity improvement.

Identify productivity improvement tools from all mentioned before, which are the most suitable for my case. A selected tools set together with industry analysis and sufficient data collected from my questionnaire will be used to design Lean and TOC integration model. This model will ensure easier and more understanding implementation of the systems.

The idea of this model is to contribute in raising the competitiveness of the metal-processing industry in both European and global level. This is important, because Lithuania is too small as a market for metal-processing enterprises, so in order to compete globally, with foreign companies, we need to be more effective, quicker, more innovative and aim to constantly improve products and operations.

2.2 Analysis of metal-processing industry

The information from Department of Statistics data was used for this statistical analysis. Trends of the overall industry will be analysed, compared to chosen industrial field in Europe and Lithuania.

Table 1 Industrial production index, compared with the previous year, % [19]

Economic activities	2012	2013	2014	2015	2016
All industry	103.60%	103.20%	100.10%	104.90%	102.80%
Fabricated metal products	108.30%	97.40%	115.10%	107.00%	117.00%

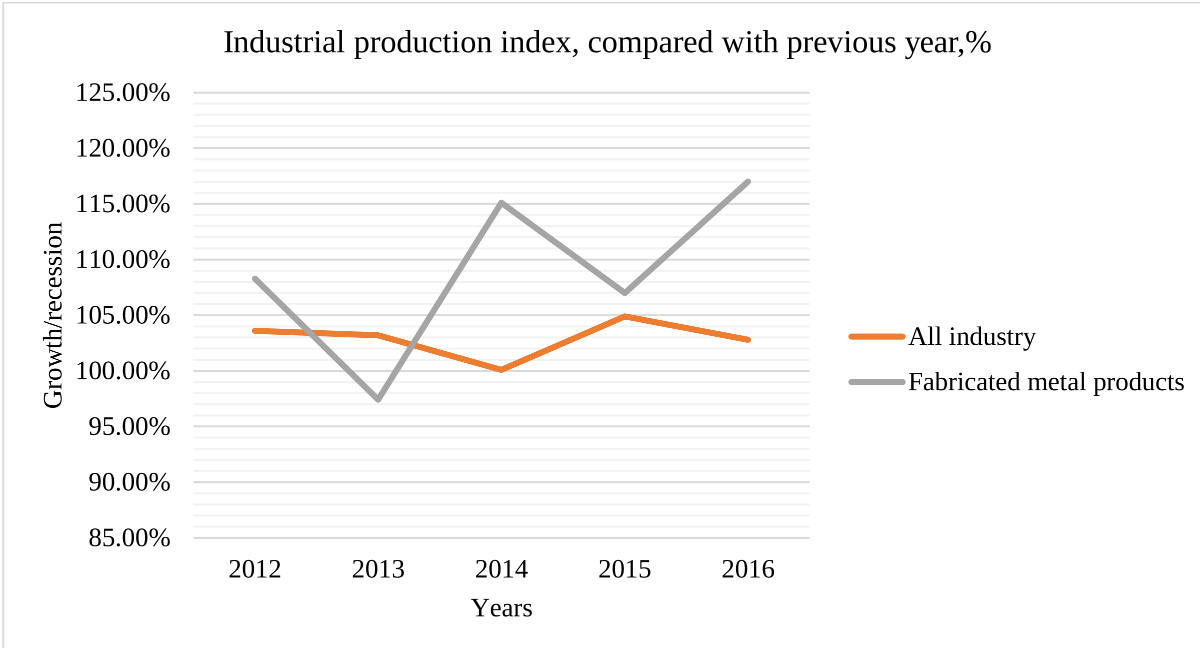

Fig. 8 Industrial production indexes [19]

As can be seen in Fig. 8, industries with small correlations maintained rather smooth growing. Except in 2014, when production index dropped to almost 0% growth. The other group, fabricated metal products, had quite huge fluctuations during the same period of time. 8.3% and two times higher than overall industry growth rate in 2012. The rates were promising, but in 2013 it dropped to 97% or 3% decrease compared with previous year. The decrease could have been even bigger, because according to Lithuania statistical department total number of enterprises manufacturing fabricated metal products in 2013 were 644, while 602 in 2012 [19]. In 2014, a total number of enterprises remained the same, while the production index increased by 15.1%. The growth stayed on and next year, but slightly lower – 7% rate. In 2016, the increase reached five years' peak – 17% growth rate. The number of enterprises at that time was 723.

Table 2 Industrial production index, compared with base – 2010 year, % [19]

Economic activities	2012	2013	2014	2015	2016
All industry	110.10%	113.70%	113.80%	119.30%	122.70%
Fabricated metal products	149.50%	145.70%	167.70%	179.50%	210.00%

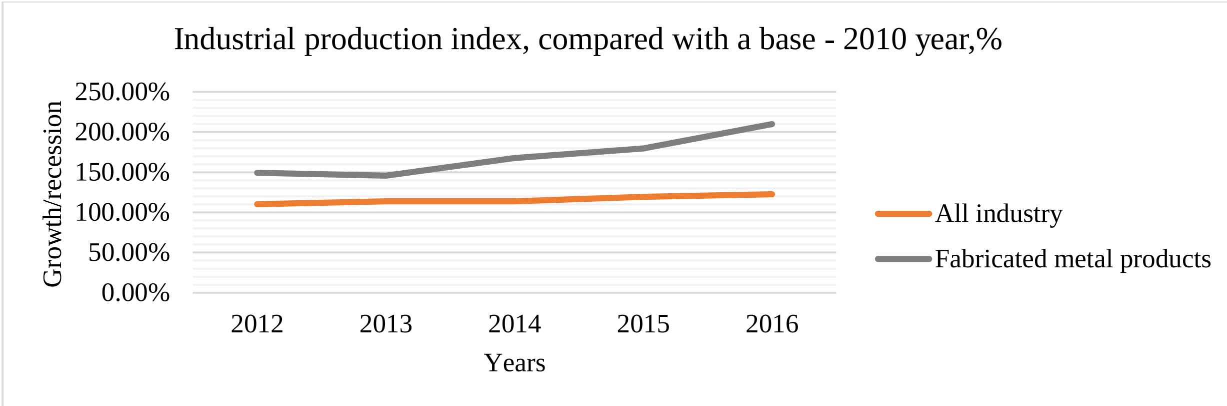

Fig. 9 Industrial production index, compared with base [19]

The curve of all industry production indexes is smooth and increasing steadily but slowly. While the other curve is much steeper. The production in overall industry has grown up by 22.7% since 2010. Increase by 110% or more than two times bigger production has been fixated in metal-processing enterprises. The results are rather surprising. It could be partly based on higher number of companies (see Fig. 10).

Table 3 Number of enterprises in metal-processing industry [19]

Economic activities	2012	2013	2014	2015	2016
Number of enterprises in metal industry	602	644	644	715	723

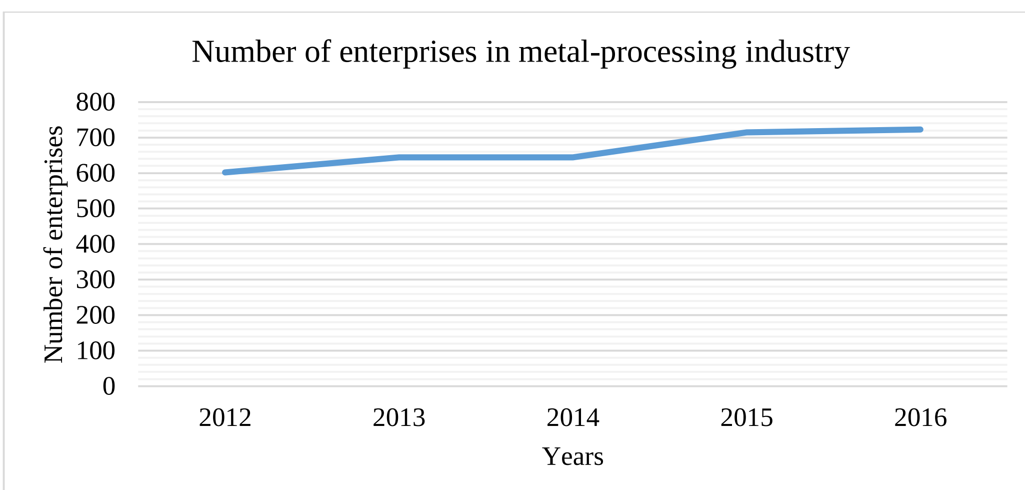

Fig. 10 Number of enterprises in metal-processing industry [19]

More and more companies are established. The number increased by 121 in 2016 compared to 2012 and reached 723 enterprises. Metal-processing sector is growing rapidly.

Looking at Fig. 9 and Fig. 10 some conclusions might be done. The production and demand in metal industry is increasing. It could be said, that enterprises are getting trusted and more clients are reaching out to Lithuania to buy products from.

Table 4 The structure of sold production by market (sold production =100%) [19]

	2012	2013	2014	2015	2016
Lithuanian market	40,20%	44,70%	43,50%	39,70%	35,90%
Non Lithuanian market	59,80%	55,30%	56,50%	60,30%	64,10%

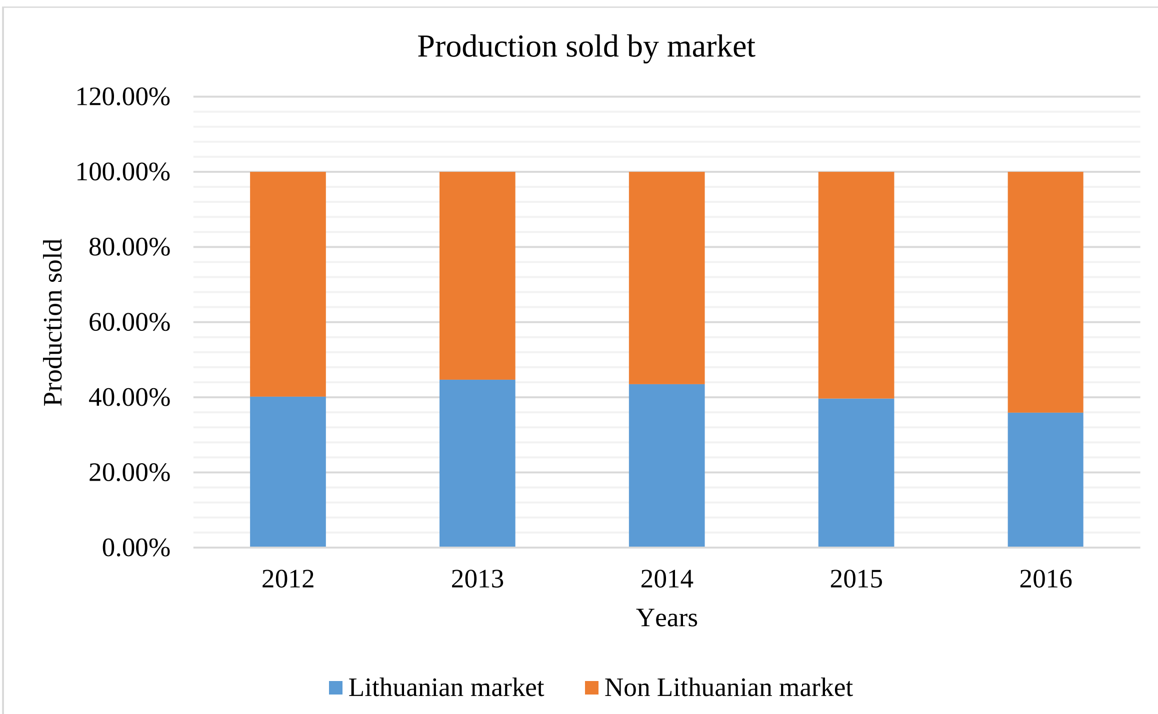

Fig. 11 The structure of sold production by market (sold production =100%) [19]

As it was possible to predict, the production sold to foreign markets is growing – from 59,8% in 2012 to 64,1% in 2016. It must be taken into consideration, that in 2013 production sold in foreign markets shrank. 2015 was the year when the level reached 2012 heights. Lithuania as a market is small, so it is not surprising that enterprises are competing in global level. Innovative enterprises are always looking for new clients abroad to increase their revenue and etc.

Table 5 Competitive position development domestically over past 15 months [19]

Domestic market	2016												2017		
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III
Improved	10	10	8	9	8	9	8	7	8	6	5	6	5	9	8
Deteriorated	5	8	5	5	5	6	5	4	4	9	7	6	7	6	7
Unchanged	85	82	87	86	87	85	87	89	88	85	88	88	88	85	85
Balance	5	2	3	4	3	3	3	3	4	-3	-2	0	-2	3	1

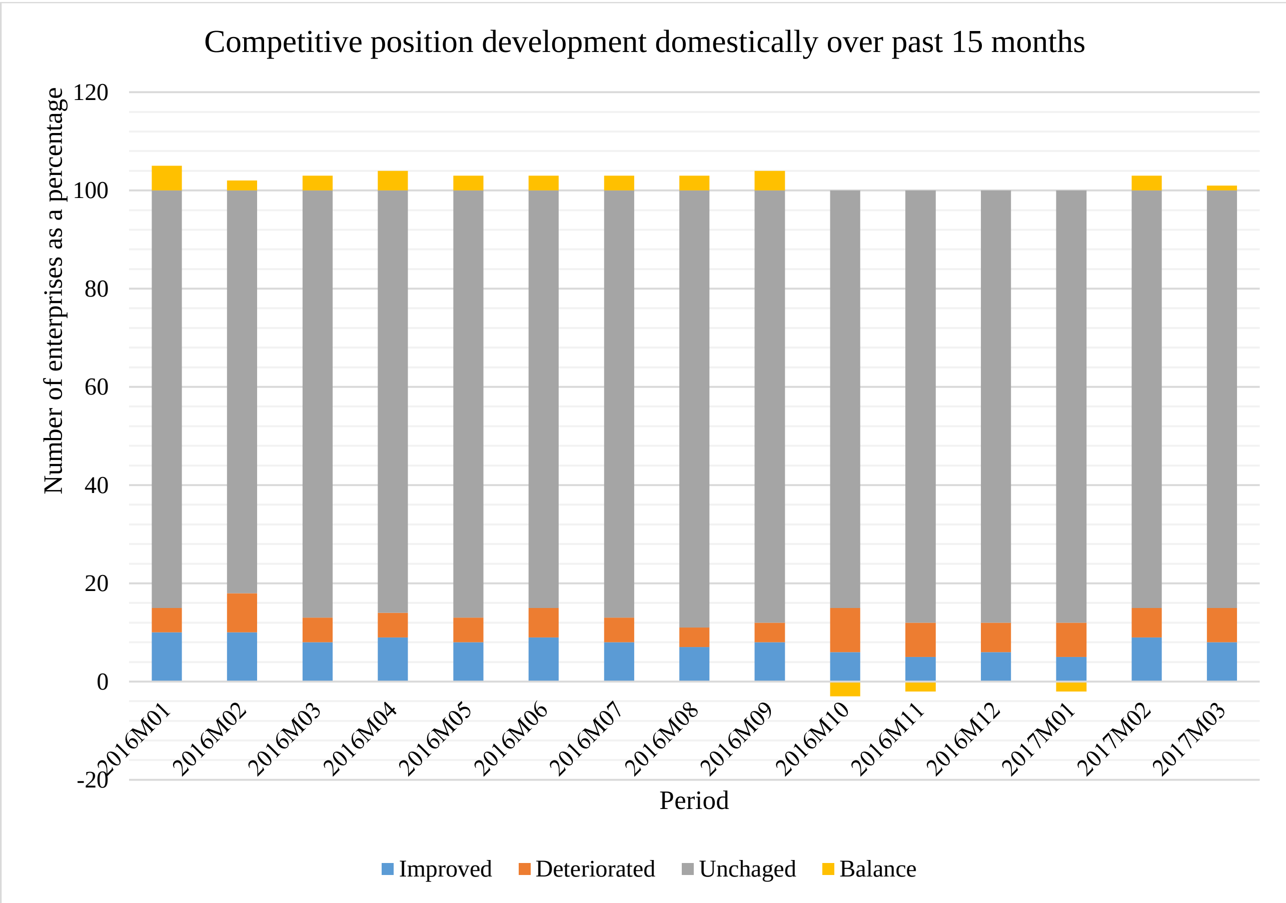

Fig. 12 Competitive position development domestically over past 3 months [19]

More or less, the internal market is very stable. 85% - 89% of companies responded about unchanged situation. Only 5% - 10% improved their competitiveness domestically and the remaining ones replied about getting worse situation. Small market and needs met may be the reason for this.

Table 6 Competitive position on the EU market developed over the past 15 months [19]

Foreign market	2016												2017		
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III
Improved	10	6	8	7	7	7	11	8	6	7	8	8	6	7	6
Deteriorated	5	7	3	6	7	6	4	4	5	3	5	3	4	4	5
Unchanged	85	87	89	87	86	87	85	88	89	90	87	89	90	89	89
Balance	5	-1	5	1	0	1	7	4	1	4	3	5	2	3	1

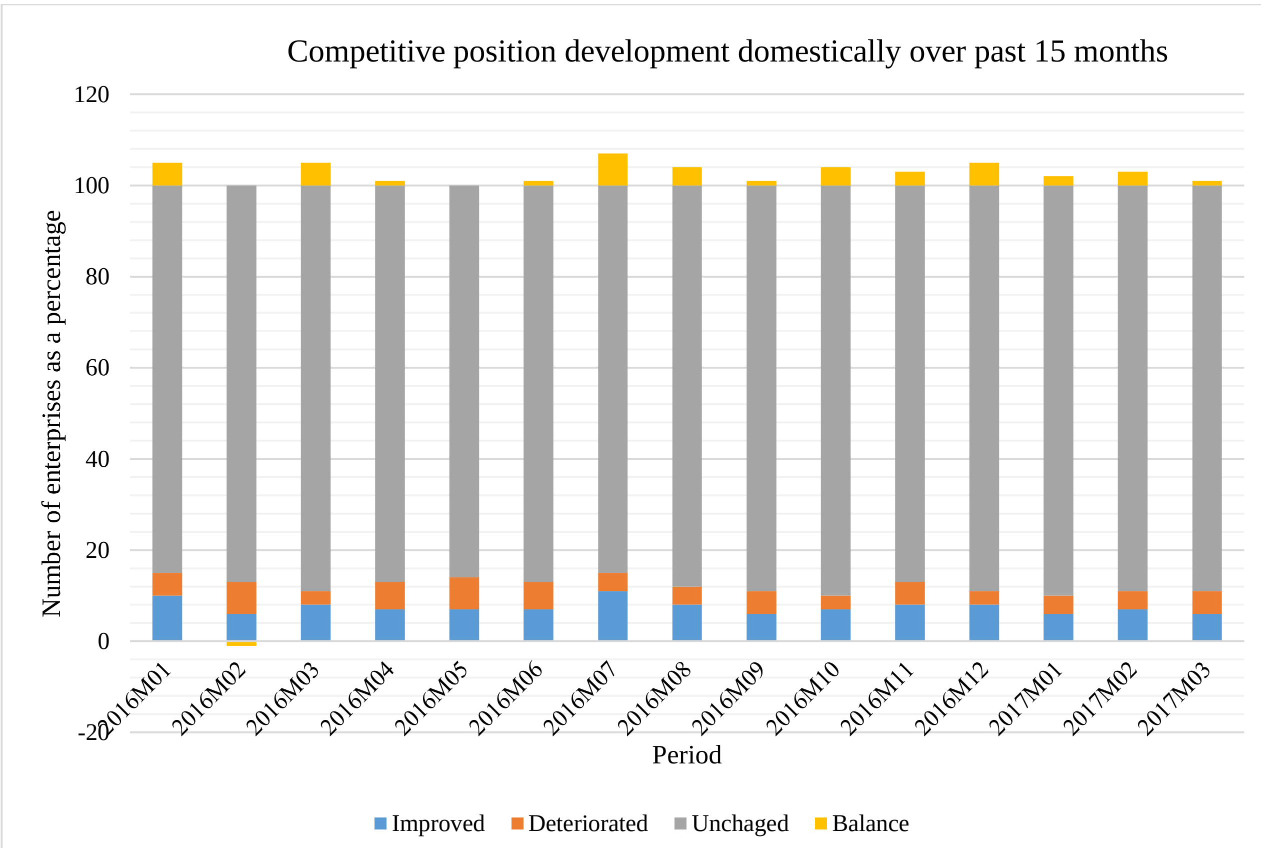

Fig. 13 Competitive position on the EU market developed over the past 15 months [19]

As can be seen, the situation is quite similar to Fig. 12 data while the reasons are different. The competition in the EU markets is fiercer and it is much more difficult for Lithuanian enterprises to compete there. As was predicted, the metal-processing enterprises have to implement lean ant TOC integration model to improve its operations, production management and etc. This way companies will be able to compete successfully in foreign markets.

Table 7 Industrial production demand [19]

	2016												2017		
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III
Above normal	1	2	1	1	0	3	0	0	1	0	0	3	3	3	3
Normal	82	75	66	70	72	75	78	77	75	68	80	74	58	57	48
Below normal	17	23	33	29	28	22	22	23	24	32	20	23	39	40	49
Balance	-16	-21	-32	-28	-28	-19	-22	-23	-23	-32	-20	-20	-36	-37	-46

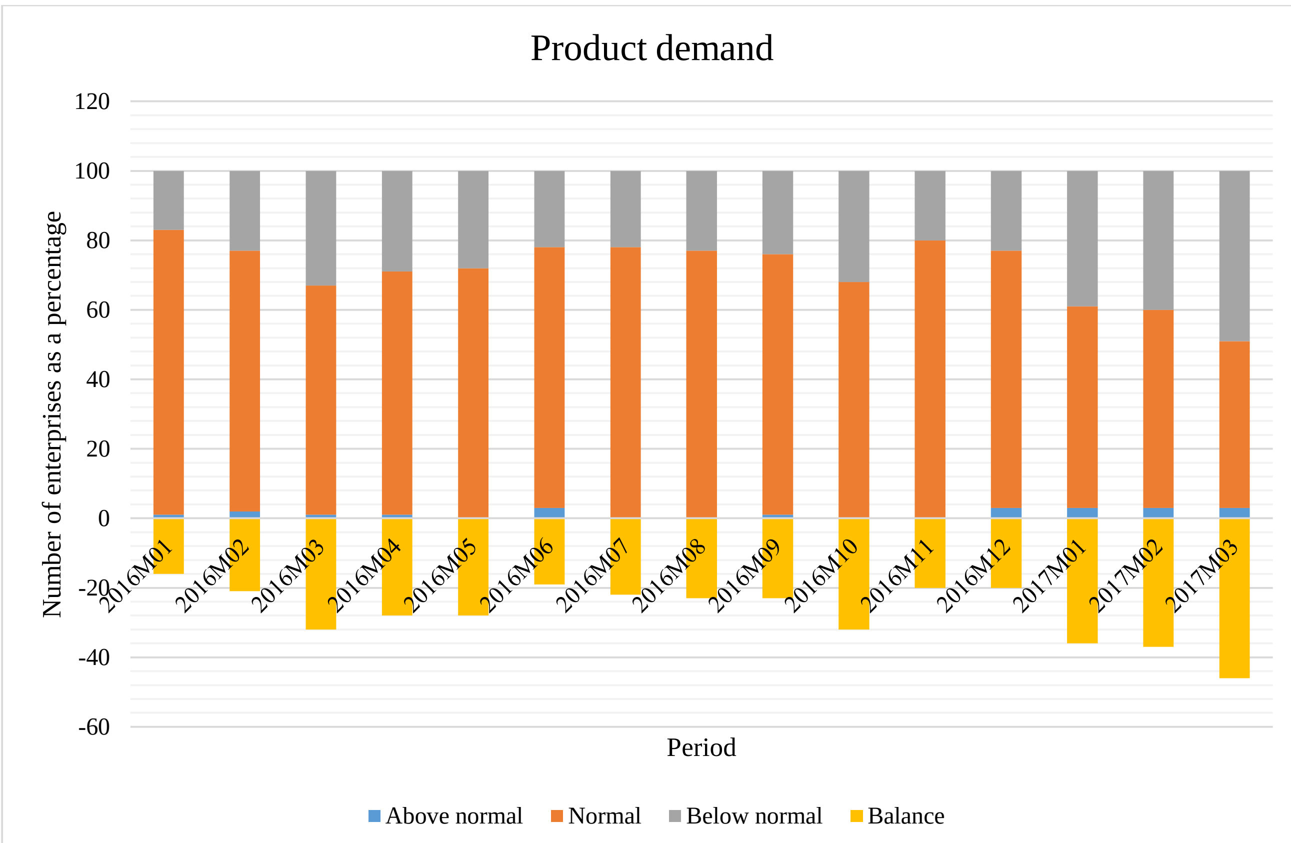

Fig. 14 Industrial production demand [19]

This diagram shows how the production demand is changing over time. As can be seen, very few enterprises described demand as above normal, usually even 0% of companies. Numbers are a bit concerning. The tendency of the last three months is even worse, 40% - 50% of enterprises described the production demand as very low and only 3% as high. The majority defined the product demand as normal, however from 82% in 2016M01 this group shrank to 48% in 2017M03.

Table 8 Industrial production export demand [19]

	2016												2017		
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III
Above normal	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Normal	66	75	63	70	69	77	77	77	78	68	77	74	76	78	70
Below normal	34	25	36	30	31	23	23	23	22	32	23	26	24	22	30
Balance	-34	-25	-35	-30	-31	-23	-23	-23	-22	-32	-23	-26	-24	-22	-30

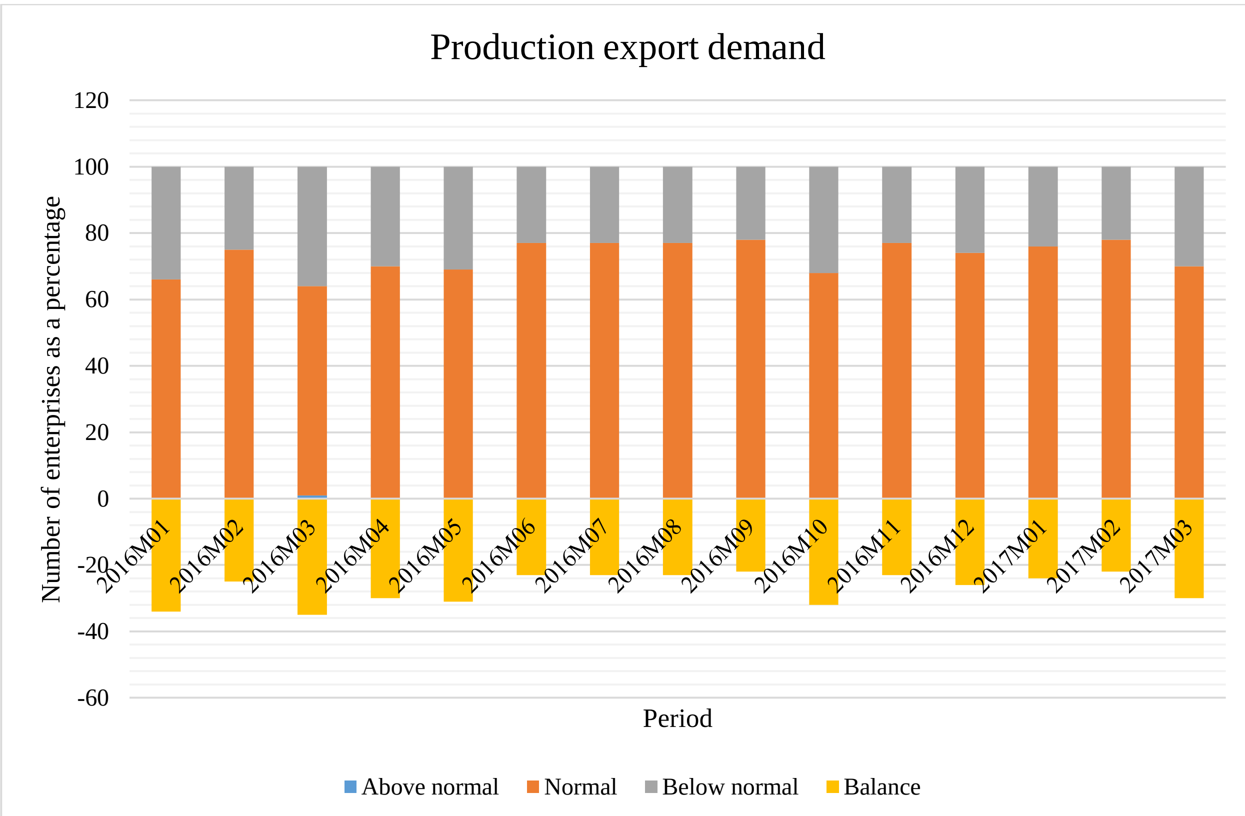

Fig. 15 Industrial production export demand [19]

As can be seen, from the data shown in Fig. 15 the tendencies are steadier than in Fig. 14, however the results are still insufficient. 63% - 78% of companies described demand as normal, which is not so bad. However, 22% - 36% defined export demand as low. That is way too many enterprises. None of the firms had above the normal export demand. The situation must be improved. As mentioned before, metal-processing sector has to become more flexible, become better in organizing operations and production, optimize use of resources.

2.3 Analysis of a questionnaire results

The main objective of this questionnaire is to find out if Lithuanian metal-processing sector companies are using Lean and TOC systems, what do employees think about those systems, do they accept them and understand the possible gain to a firm.

52 persons were questioned, 12 of them from a company “Litvita”, 25 – “Arginta Engineering” and 15 of them – “Strele Industrial”. Questionnaires were completed personally by the employees. The majority of respondents were from technological, purchasing and marketing department.

The main age group of the participants was 30-40 years old (23). 20-30 years old were 13 respondents, 40-50 years old – 8, over 50 years old – 8.

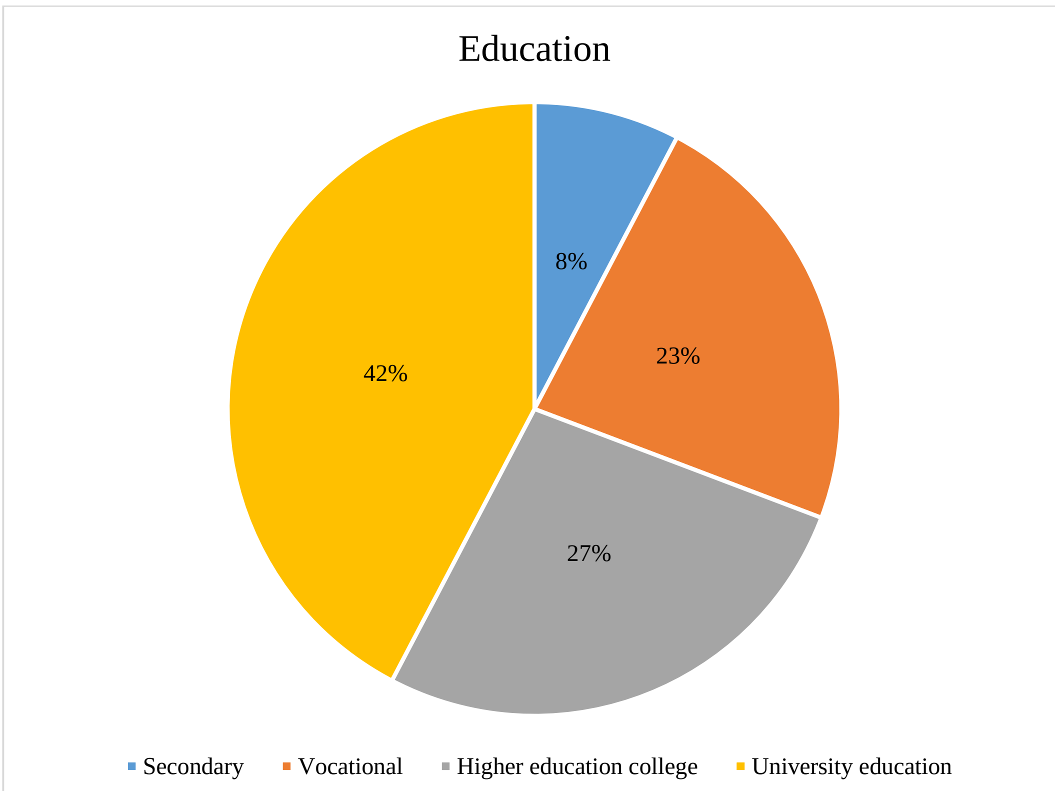

Fig. 16 Distribution of respondents by educational level

As can be seen, the majority of the respondents have graduated from a university – 42%, 27% have higher college education, 12 participants or 23% have technical education and the minority – 8% have secondary education. Most of the workshop workers belong to secondary or vocational education group.

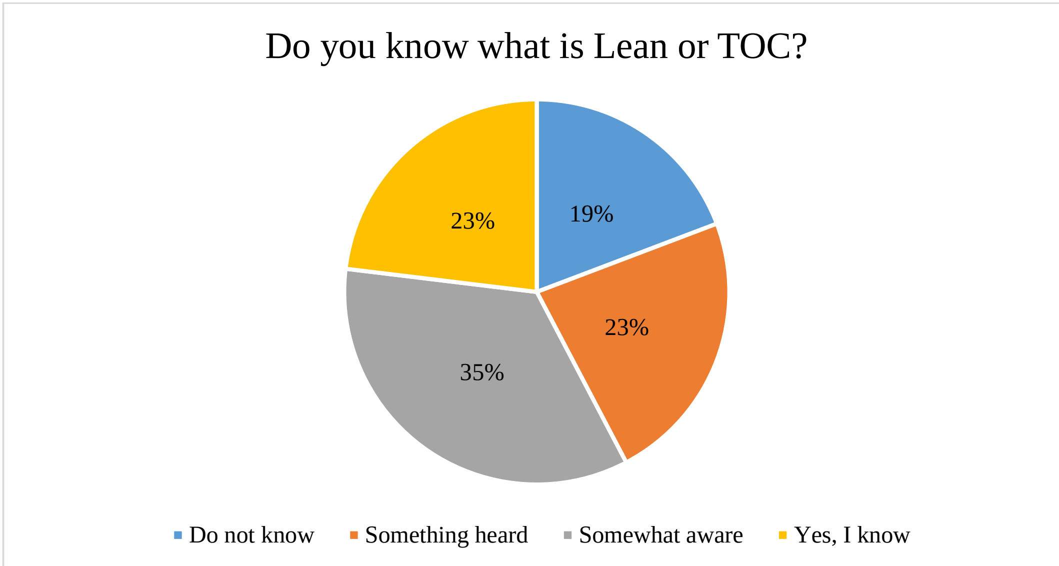

Fig. 17 Distribution of respondents by knowledge about Lean or TOC

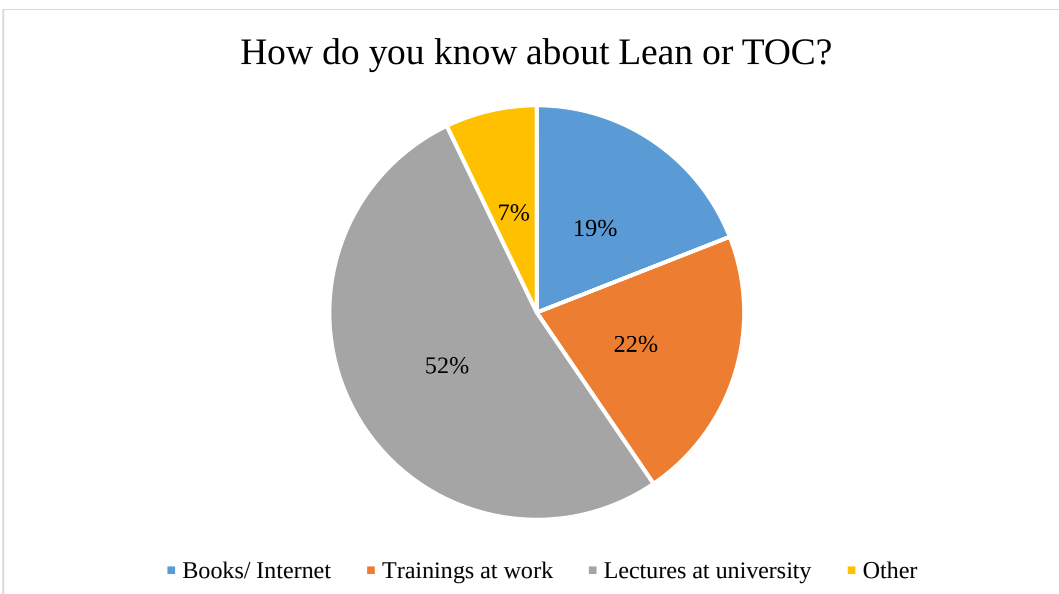

Fig. 18 Distribution of respondents by the ways they know about Lean or TOC

From Fig. 17 and Fig. 18 can be determined how well respondents know about Lean or TOC and how do they know about those systems. 81% answered, that they more or less know something about

Lean and TOC and only 19% have no idea what those systems are. More than half of the participants learned about it at lectures at university/college. 22% had trainings at work, while 19% have read it in the books or on the Net.

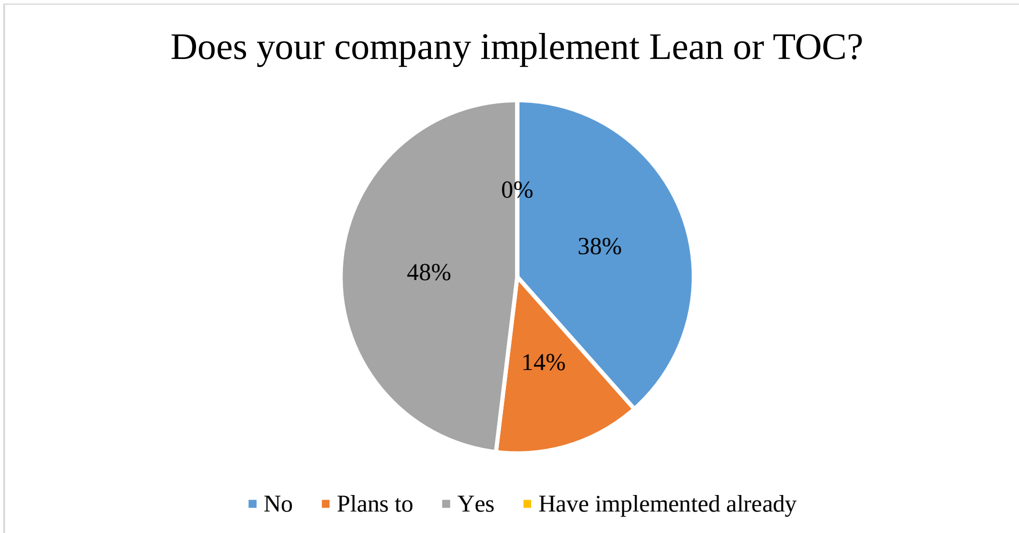

Fig. 19 Distribution of respondents by Lean or TOC implementation in a company

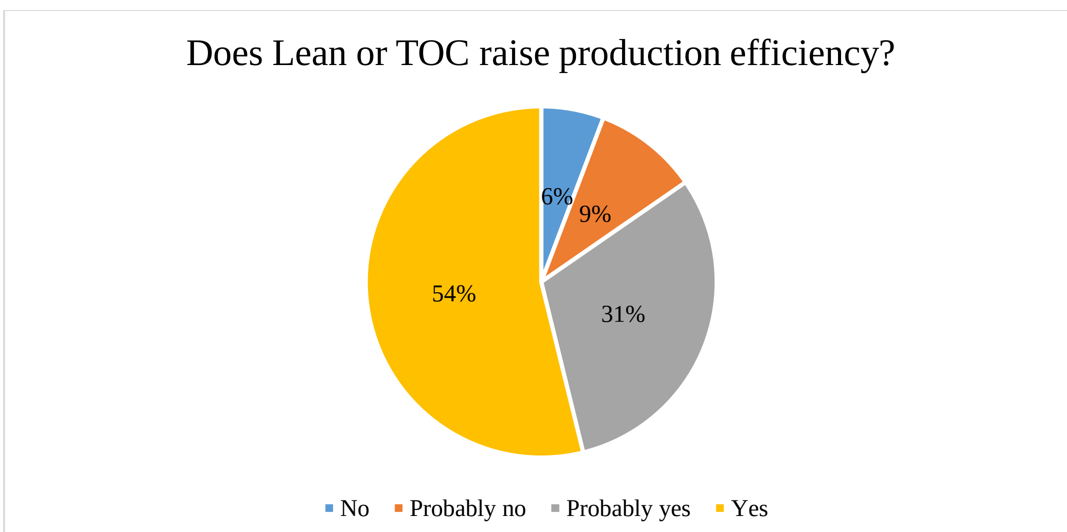

Fig. 20 Distribution of respondents by raising production efficiency integrating Lean or TOC

From Fig. 20 we can see promising results as 85% of participants know or believe that Lean or TOC can help raise the efficiency of the company, while only 15% thinks that it does not. However, the data shown in Fig. 19 is a bit disappointing, 38% of respondents answered that their company is not integrating Lean or TOC. 62% told that theirs does. It can be concluded that, most of people knows about production efficiency raising systems, about possible gain for company using them, but still huge part of them do not use Lean or TOC.

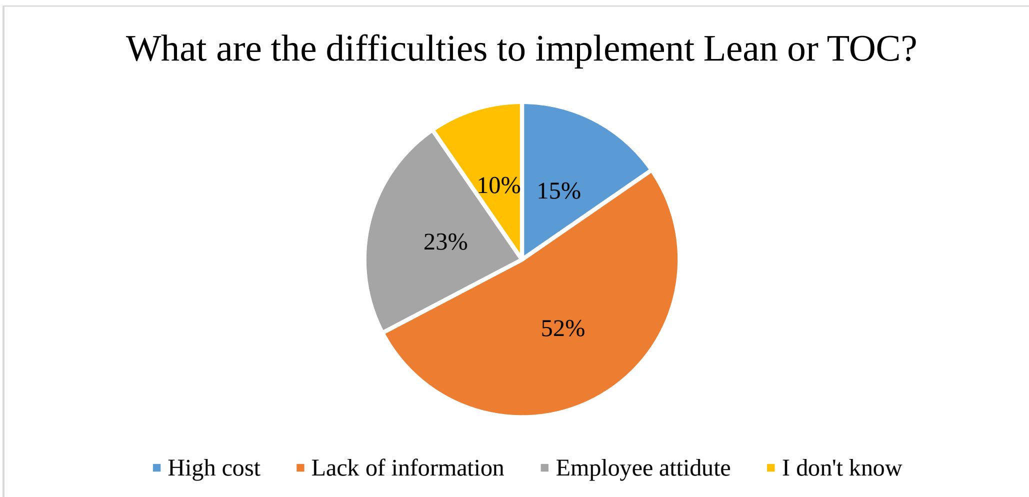

Fig. 21 Distribution of respondents by difficulties they face to integrate Lean or TOC

More than a half of respondents answered, that the main issue to integrate Lean or TOC is lack of information. 23% thinks that an employee attitude is the main problem.

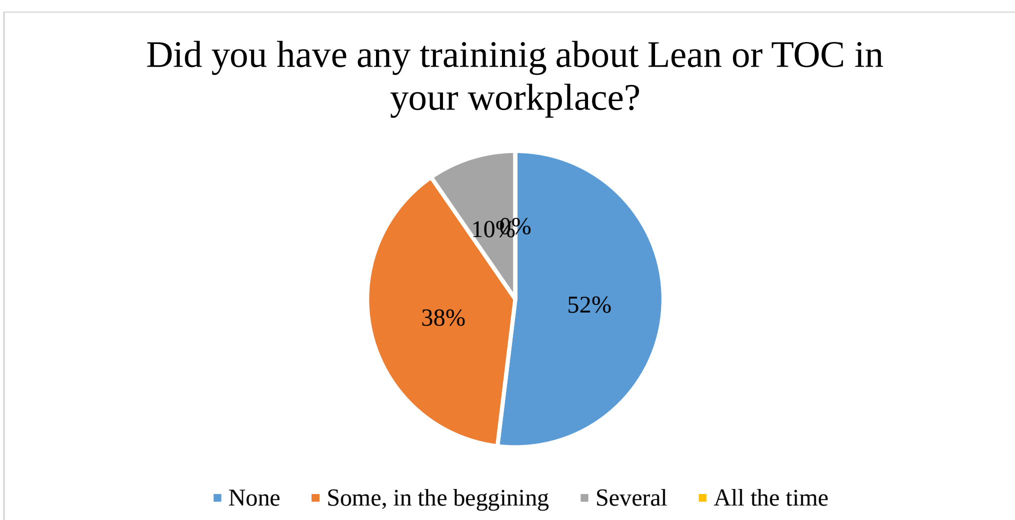

Fig. 22 Distribution of respondents by Lean or TOC trainings in the company

As can be seen none of respondents have permanent training about efficiency raising systems, more than a half of them had some lectures in the beginning of their career in a company. Only 10% had several trainings.

Fig. 21 and Fig. 22 are highly related to each other. The lack of trainings determined not knowing how to use Lean or TOC. An employee attitude is also a cause of no trainings. If workers understood that higher production efficiency means higher profits and possibly higher salaries, they would be more motivate to participate in Lean and TOC integration.

In Fig. 23 it can be seen that employers encourage their employees to take responsibility and solve the occurred problems themselves or at least they are encouraged to propose possible solutions. This is a really great, but for better results, employers definitely have to organize trainings how to use Lean or TOC tools.

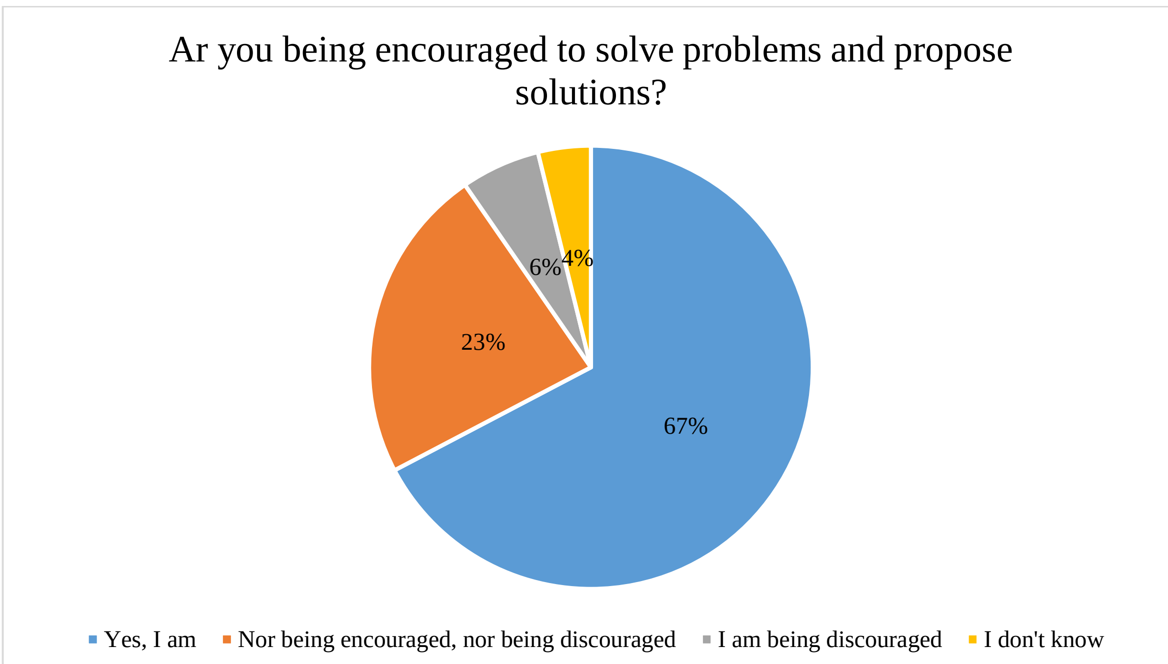

Fig. 23 Distribution of respondents by if they are being encouraged to solve problems

2.4 Correlation analysis of the questionnaires

Analysis of the data collected from the questionnaire gave some hints to possible relationships between answers to questions. For deeper examination the correlation of answers was made and some conclusions came out of this.

Calculations and a chart was made in excel. The formula for correlation coefficient - r:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}; \tag{2.1}$$

r – correlation coefficient;

x – sample value;

$\bar{x}$ – average sample value;

y – next sample value;

$\bar{y}$ – average next sample value.

Table 9 Correlation matrix

Questions	1	2	3	4	5	6	7	8	9
1	1								
2	-0.37	1							
3	-0.30	0.79	1						
4	-0.48	0.38	0.50	1					
5	-0.42	0.78	0.64	0.51	1				
6	-0.10	0.53	0.56	0.18	0.46	1			
7	-0.35	-0.13	-0.30	-0.19	-0.08	-0.20	1		
8	0.25	-0.33	-0.45	0.18	-0.28	-0.37	0.17	1	
9	-0.22	0.47	0.49	0.31	0.35	0.24	-0.21	-0.22	1

The colour of the cell represents how strong the samples are linked to each other (Table 10). The value ranges between -1 to 1. A value of exactly 1 means there is a perfect positive relationship between two variables. A value of exactly -1 means there is a perfect negative relationship between two variables. A value the closer to zero, the weaker relationship it is. All the questions can be found in appendixes.

Table 10 Meanings of the colour

Colour	Meaning
	Very weak or none, from -0.5 to 0.5
	Weak, from 0.5 to 0.6
	Medium, from 0.6 to 0.7
	Strong, from 0.7 to 0.9

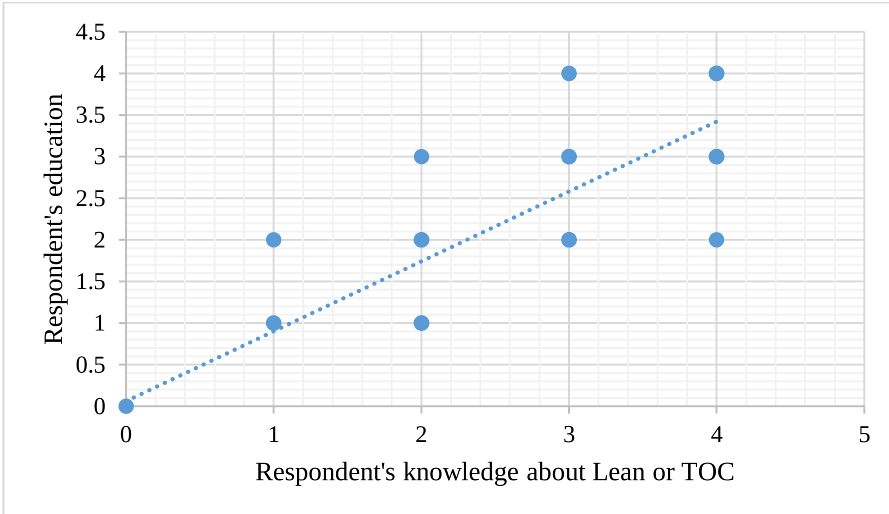

Fig. 24 Dependence between respondent's education and knowledge about Lean or TOC

The highest correlation coefficient is between answers to second and third questions (Fig. 24). As can be seen the higher education a respondent has, the more he knows about Lean or TOC. It is obvious that there are lectures in universities and higher education schools about efficiency raising systems.

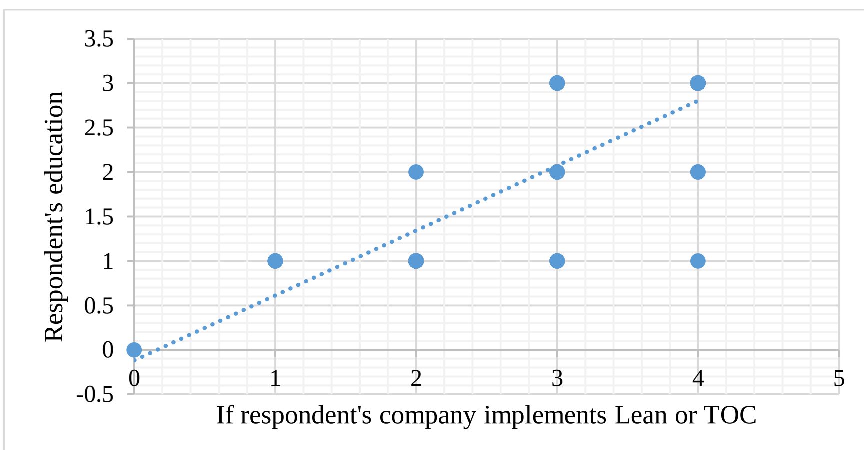

Fig. 25 Dependence between respondent's education and if Lean or TOC is being integrated in his company

Another high correlation is between second and fifth answers (Fig. 25) and medium relationship between third and fifth answers (Fig. 26).

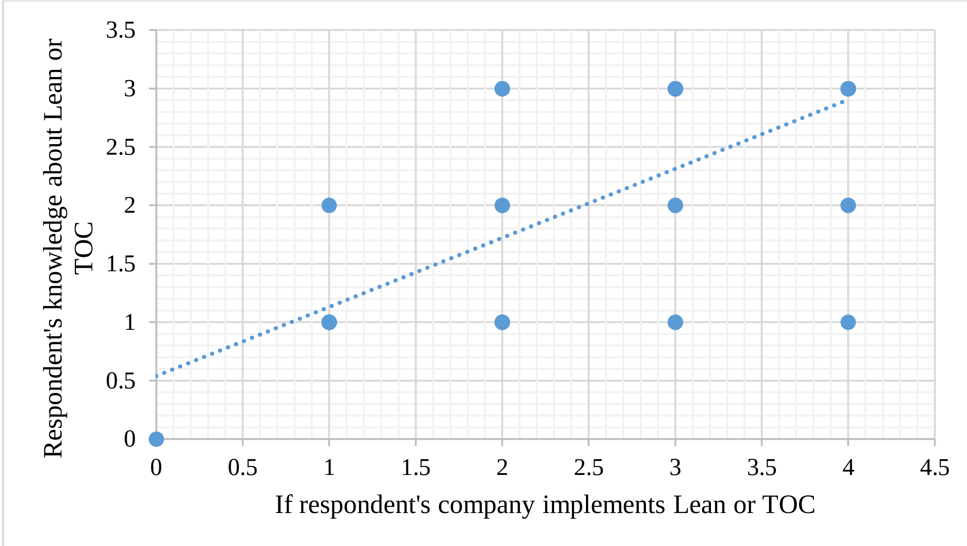

Fig. 26 Dependence between respondent's knowledge about Lean or TOC and his company's implementation of Lean or TOC

As can be seen, respondents with higher education tend to answer that their company implements Lean or TOC, or is planning to do that. The same tendency is with respondents who knows well or are aware of Lean or TOC. Participants with better knowledge answers that their enterprise is integrating efficiency raising systems.

2.5 Conclusions

Summarizing the analysed statistical data, some conclusion may be done. First of all, both positive and negative tendencies can be read.

Positive:

- Production of fabricated metal products was growing as well as overall industry production. To compare with 2010, the production in metal-processing sector grew by 110%, which means more than two times more were produced, while in overall industry the growth was slower and only 22.7% increase was fixated.
- Number of enterprises in metal-processing industry was growing steadily to 723 in 2016 (compared to 602 in 2012).

- Export increased and even 64.1% of production in metal-processing sector were sold in foreign markets. Percentage of production sold in non-Lithuania market grew by 4.3% compared to 59.8% in 2012.

All these statements tell about increased demand in Lithuania and foreign countries. Enterprises and getting more trust and recognition as well as more revenue. Everything seems to be fine, but is it? The trend is optimistic, but how Lithuanian enterprises look in the context of world. In 2016-2017 Global Competitiveness Index awards, Lithuania was ranked 35th (138 total) with 4.6 points out of 7. The results are not the worst, however, they could be better.

Negative:

- The competitiveness level domestically and in the EU practically does not change. 85% - 90% of enterprises respond that their ability to compete stays the same, while only 6% - 10% declares about improved situation. The other feels that the competitiveness deteriorates.
- Demand. As mentioned before, demand seems to be growing, but not enough. 39% - 49% of enterprises domestically and 22% - 30% for export, reported about demand below normal. What is worse, tendencies are quite pessimistic. No signs of improvement.

To sum up the questionnaire and the correlation analysis of it both positive and negative signs can be seen.

Positive:

- 81% of respondents know about Lean or TOC, almost a half of them know them well.
- 85% of participants understand that Lean or TOC gives a positive influence to an enterprise.
- 67% answered that they feel encouraged to solve problems themselves or propose solutions to issues in their job.

The numbers are quite high. It can be expected that people with some knowledge about efficiency systems may come up with great ideas how to improve production, management operations etc. An encouragement for workers might give a confidence boost, they can trust themselves more, no to be afraid of making mistakes and propose some wonderful ideas.

However, negative tendencies also can be seen:

- 38% of respondents answered that their company do not implement efficiency raising systems.
- 52% of participants had no trainings in their workplace about Lean or TOC, 38% had some only in the beginning. Moreover, 52% of answered that a lack of information is the main difficulty to use Lean or TOC, 23% thinks the issues is a motivation of workers.

Suggestions

To begin with, every company should have permanent trainings about Lean and TOC. The better knowledge and deeper understanding will let employees know how to use those systems, may raise workers' motivation to use them, because productive company may mean better working conditions for them. What is more, productivity lets a company be more competitive. The more competitive, the more clients and orders.

For easer integration of Lean and TOC, enterprises must have integration models. Employees will know exact tools and exact order how to use them. It will ensure a constant companies' improvement and growth.

3. Productivity improvement model for metal-processing enterprises

3.1 Productivity improvement model

What is productivity? An efficient use of resources, labour, capital, materials, energy, information in the manufacturing of various products is defined as productivity. The aim is to create model which would help increase productivity or accomplish more with the same amount of resources. To reduce lead times, failures and production costs are the main points will be payed attention to.

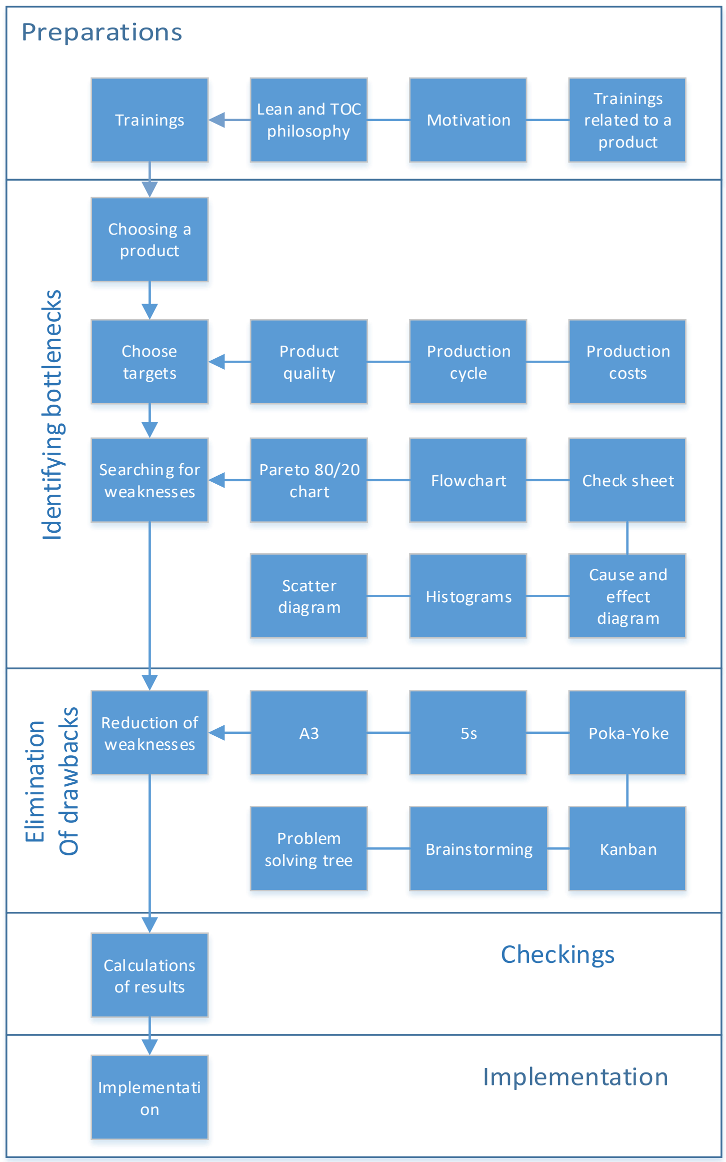

Fig. 27 Productivity improvement model

This model (Fig. 27) was created regarding analysis of another authors literature (chapter 2) and research of Lithuania industry trends (chapter 3). The principles of Lean ant TOC were used.

The model consists of five stages:

1. Preparations;
2. Identifying bottlenecks;
3. Elimination of drawbacks;
4. Checking;
5. Implementation.

Preparations

This is a stage where we shape a product team's attitude (Fig. 28). There are three main points to be touched, so three steps to do that.

Lean and TOC philosophy. Employees must be well familiar with the systems. Knowledge about tools and how to use them is mandatory for successful use of the model.

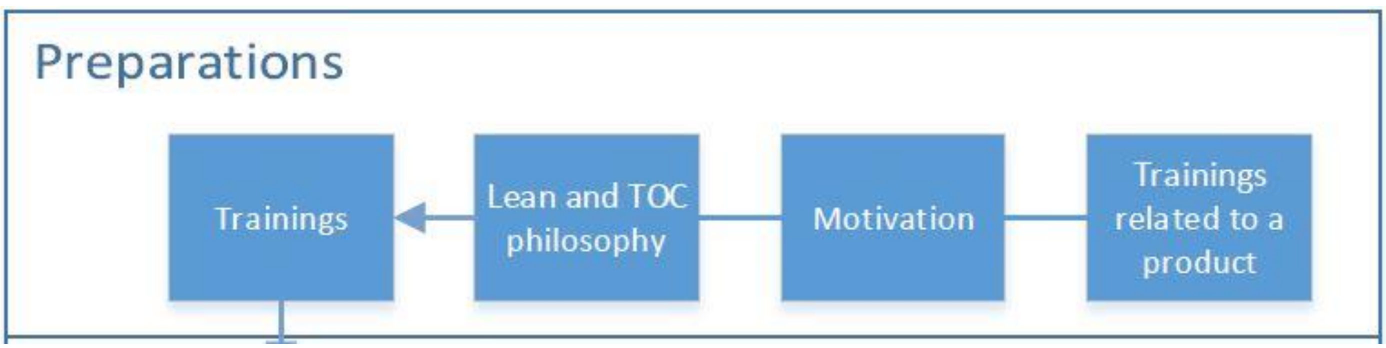

Fig. 28 First stage – preparations

Motivation. A product team has to be encouraged to solve problems themselves and find solutions to occurring failures. Additional motivational systems should be integrated. Rewards for employees' good work or ideas will keep them dedicated and focused. Providing rewards, both tangible and in the form of praise, can make employees happier. Happier employees often perform better at work.

Trainings related to a product. A product team should be familiar with the product they are working with and have knowledge about all the parts containing a product. For example, bearings. An employee should know how to select best price/quality ratio bearings which are the most suitable for a product.

Identifying bottlenecks

At this stage we try to find weaknesses of the chosen product (Fig. 29).

Choosing a product. There are few things we should evaluate before choosing the product. For how long has the product been producing in the company. The newer the product, the more operations and processes may be optimised. The complexity of the product, deeper analysis might show some hidden drawbacks. What is more, the product which tends to have most failures or brings insufficient profits should be ran through productivity raising model.

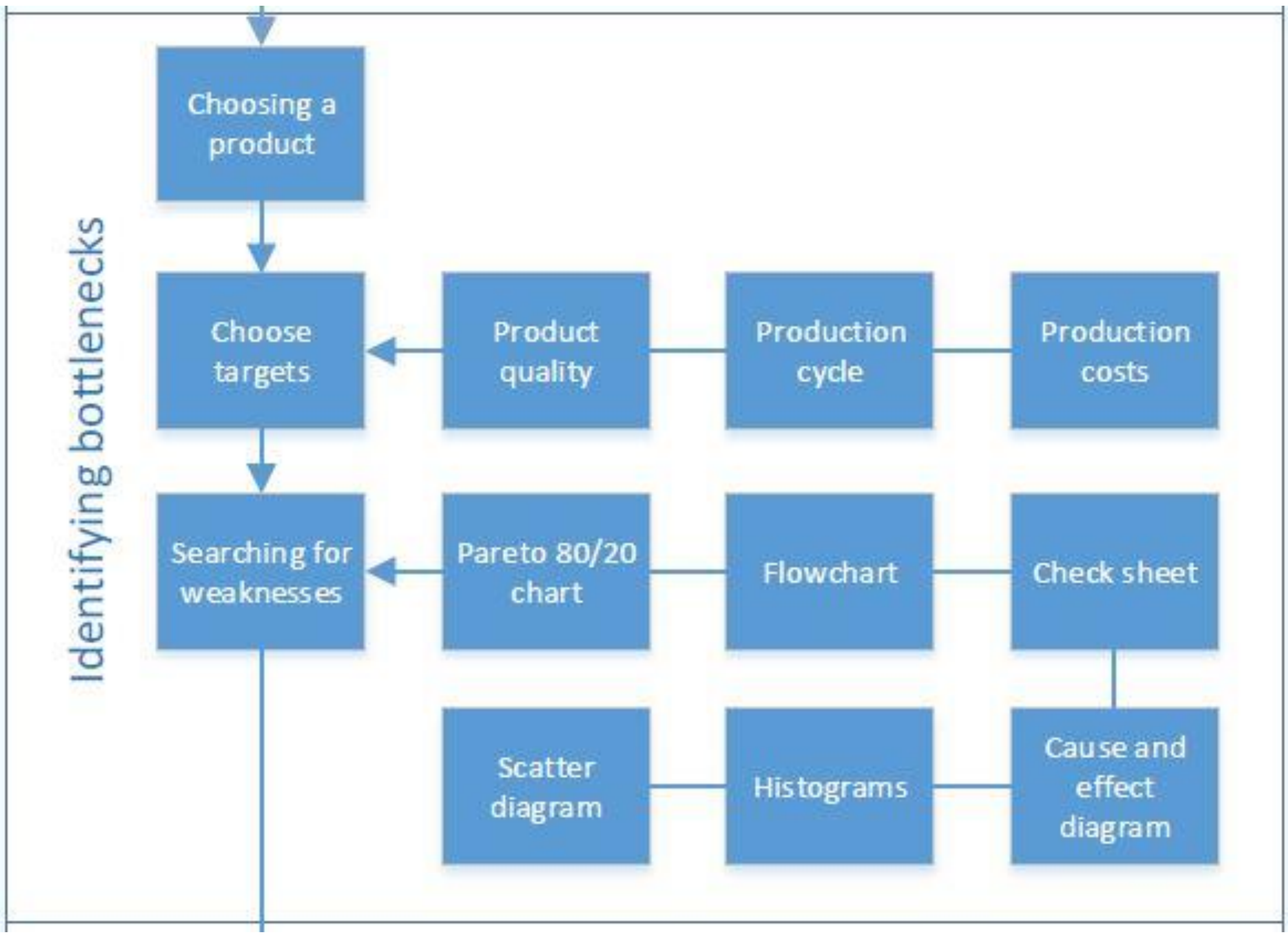

Fig. 29 Second stage – identifying bottlenecks

Choosing targets. The most usual targets are raising product quality or reducing production cycle/costs. Sometimes a target may involve all three operations mentioned.

Searching for weaknesses. This is where a deeper analysis starts. The main quality tools to identify a problem are mentioned: Pareto chart, flowchart, check sheet, scatter diagram, histograms, cause and effect diagram. Templates for these tools should be always ready to be filled with occurring problems or defects. 7 wastes in manufacturing, described in chapter 1.3, have to be considered.

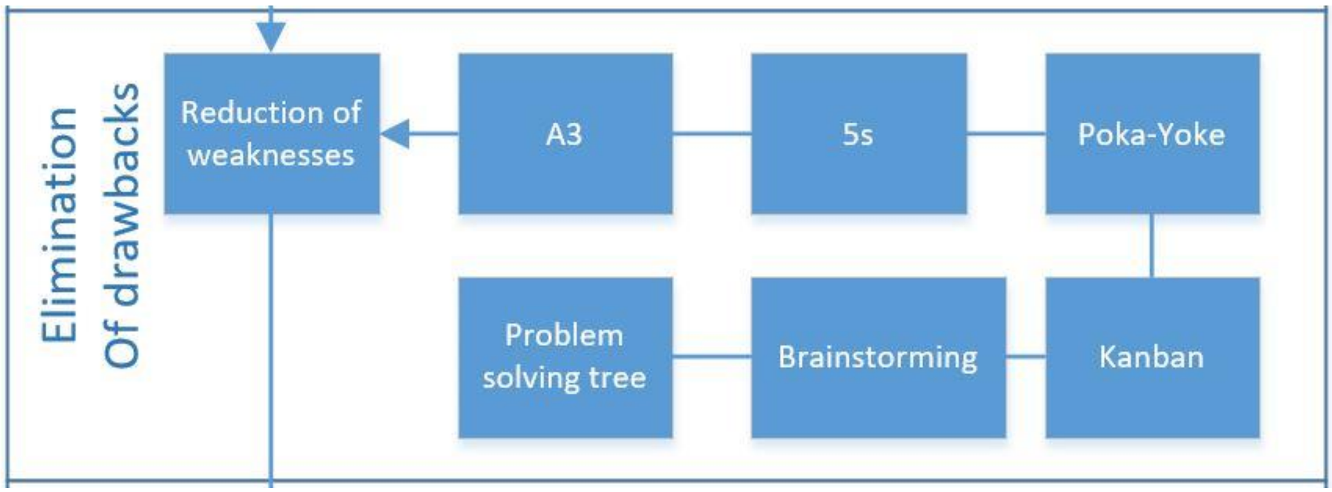

Fig. 30 Third stage – elimination of drawbacks

Elimination of drawbacks

Weaknesses and main problems are identified so the following steps to do is finding the right solutions (Fig. 30).

Reduction of weaknesses. There are many tools available for problem solving but some might be quite complex. I have chosen six which seemed the easiest and most understandable to do the job. The list is: A3, 5s, Poke-Yoke, problem solving tree, brainstorming, Kanban. Other tools are welcome to be used too.

Calculations of results

This is where we check solutions (Fig. 31). Calculations should be done to see actual benefit, for example, money we save after the changes, production cycle time reduction.

Implementation

If calculations meet expectations, decisions are integrated.

Fig. 31 Fourth and fifth stages – checking and implementation

3.2 Testing of developed model

Theory is not enough to affirm that productivity raising model (Fig. 27) is useful for a company to implement it. For this the model was put to a test in a real company. Outcomes will determine its usefulness.

The company chosen for an experiment is “Arginta Engineering”. “Arginta” is an enterprise where Lean has been implemented for quite a while.

“Raute” is one of the newest and the biggest clients of “Arginta Engineering”. So the model will be run on this company’s production. This is a technology company working in the wood industry worldwide. The main customers are the plywood and laminated veneer lumber industry. Conveyors are products “Arginta” is producing for “Raute” company.

Preparations

Lean and TOC philosophy. Every new employee in “Arginta Engineering” is introduced to Lean and TOC before starting working. There is a person which is responsible for Lean and TOC introduction. The lead-in is quite insufficient, because mostly just a philosophy of the systems is told. Everyone understands usefulness of Lean and TOC, however not enough information about tools and how to use them are given. Some notes about learning literature were told to a responsible person as he said he will make some changes regarding them. Moreover, there are books in the library (small library in “Arginta” for its own employees) about Lean and TOC systems and everyone willing to learn are more than welcome to do that.

Motivation. Like mentioned before, employees are encouraged to solve problems and share ideas with others during every week kaizen meetings. Additionally, there is a motivation system (Table 11) in the company, where people are rewarded with money for being active, sharing their thoughts, working without failures in their workplace. The reward size is decided by every departments head. The maximum reward size is 20% of monthly salary. The conditions mentioned below have its own rage, for example the maximum number of failures you can make to get full reward. Ranges are adjusted all the time, by number of employees getting 20% reward. When most of people gets the max size reward, conditions are risen. This way an enterprise ensures a continuous their employees improvement.

Table 11 Motivational reward system in “Arginta Engineering”

Conditions	up to 20%
Being active\sharing ideas\solving problems	up to 5%
Number of failures made	up to 5%
Number of failures made as a group	up to 5%
Finishing assigned tasks in time	up to 5%

Trainings related to product. As told “Raute” is a new client, so some trainings were organized to increase efficiency and avoid failures in production. Trainings organized for designers to avoid designing mistakes:

- Trainings about belts;
- Trainings about engines;
- Trainings about gears.

All these lectures were necessary for selecting the most suitable components for conveyors used in wood industry. This way huge amounts of money can be saved and failures avoided, when you buy what you need, not what is the best in the market.

As can be seen, the first stage of the model has been quite well implemented already. Some changes should be done regarding Lean and TOC trainings, as additional information about tools and how to use them.

Identifying bottlenecks

Choosing products. As it is clear already, “Raute” conveyors have been chosen. Reasons:

- The product is quite new, and most importantly designing and production takes place in “Arginta Engineering”. Possibly a lot of optimization can be done.
- Complexity. Deeper analysis may show some drawbacks.
- Company’s profitability highly depends on manufacturing of “Raute” products as they are one of the biggest clients.
- Some of components for conveyors have recurrent defects so they have to be eliminated.

Choosing targets. Three targets have been set:

- Increase quality. Quality of the conveyors are sufficient generally so the aim is to increase quality of individual components which tend to be produced defected. This way reproduction will be avoided – money and time saved.
- Reduce production cycles. It has been chosen to do that to increase company’s competitive advantage. Delivery times are one of the most important issues for clients.
- Reduce production costs to increase profits of the enterprise.

Searching for weaknesses. Using tools from the list, three drawbacks have been found:

- Weakness no. 1. One of the most defected part was right/left wall (Fig. 32). Using check sheet (Table 12) exact defects have been identified. As can be seen, a first problem is that thread are too close to welding beam and it gets damaged cause of the arisen heat. A second failure is that welders can’t keep tolerances between holes and alignment is lost after welding. High tolerances are necessary, because shaft is mounted through those holes.

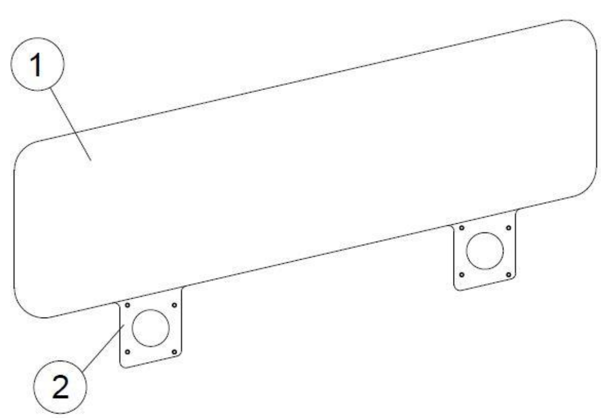

Fig. 32 Right/left wall: 1) part no. 1, 2) part no. 2

Table 12 Check sheet for most defected part

Defect type	No. Of defects	Total
Thread damaged after welding	////	4
Wrong alignment between holes	//	2

- Weakness no. 2. To improve company's competitive advantage, the Pareto diagram (Fig. 33) of most often delays has been done. As can be seen, usually an enterprise experience delays because of missing mounting elements like glues, bolts, nut. Another problem is delays because of defected components. Reproduction of those parts take time and money. Part shown in Fig. 32 is a great example.
- Weakness no. 3. To identify causes for high production costs a fishbone diagram has been made (Fig. 34). The main determined reason is old milling and turning machinery. First of all, it takes more time to make a part. Moreover, precision is insufficient so there is a higher chance for failure. Next, old equipment has just few features and more complex parts have to be produced with a help of subcontractors. It costs much more money and takes much more time than producing in place.

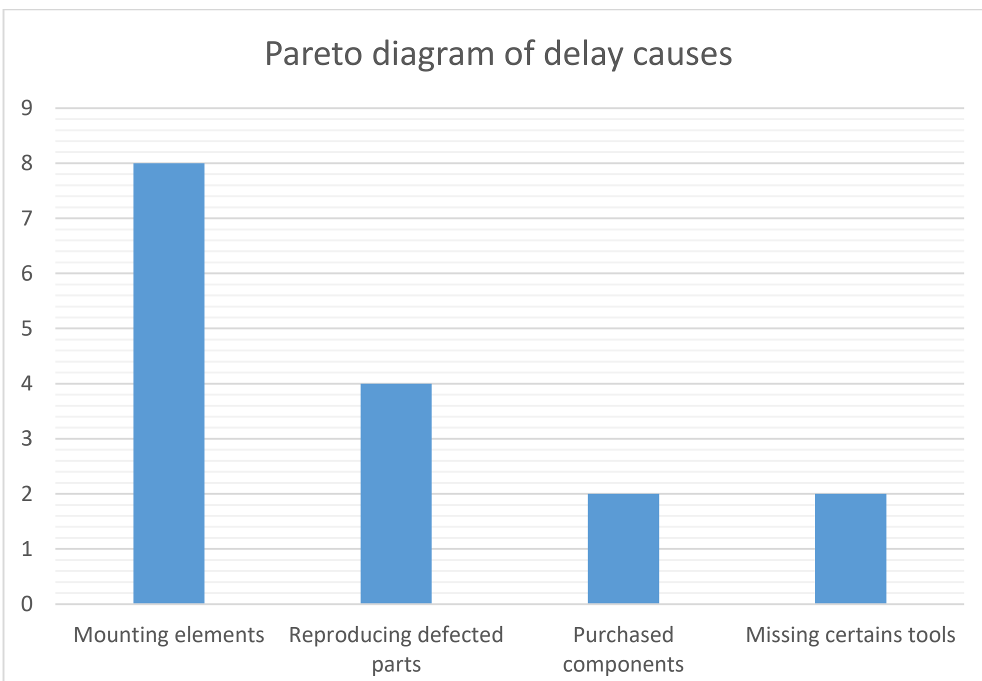

Fig. 33 Pareto diagram of delay causes

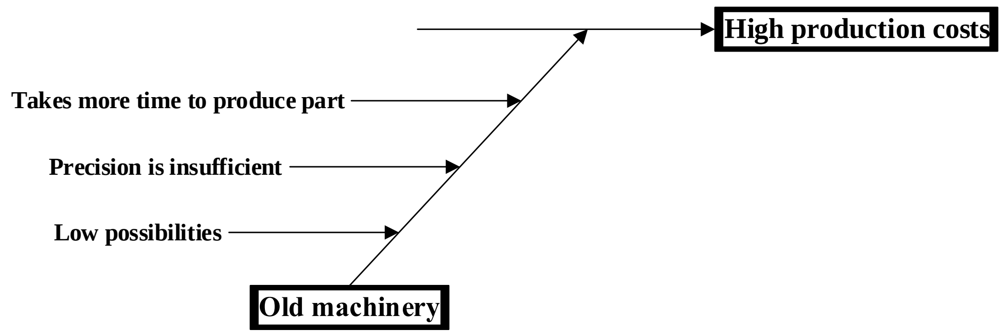

Fig. 34 Cause and effect diagram for high production cost

Elimination of drawbacks

Three weaknesses have been found. In this stage possible solutions will be proposed.

- Weakness no. 1. Defects have been discussed with technologists for possible changes and two ways have been suggested. First way is to thread holes after welding. Defects of damaged threads would be solved, but alignment between holes is still questionable. Another way is to cut the whole part as one and eliminate welding factor. Both of defects would be removed. However, welding has to be done while assembling the whole conveyor, so there is a chance this way would cause additional difficulties in assembly. After deeper analysis, which showed no possible problems to use part as a whole, a suggestion was accepted.
- Weakness no. 2. During every week kaizen meeting has been decided to implement Kanban to prevent delays when mounting elements finish. There will be a reserve of all bolts, glues, nut used for "Raute" conveyors. The idea is to buy elements for ten conveyors and every five produced products the Kanban has to be supplemented. This way delays will be eliminated.
- Weakness no. 3. A proposal is to renew some equipment in order to reduce production costs. Following a flowchart for renovation of production department (Fig. 35) has been decided whether "Arginta" needs to invest in new equipment. For deeper analysis A3 tool (Table 13) has been used.

Calculations

- Weakness no. 1. By changing the technology of a part (Fig. 32) not just defects were eliminated but production costs were reduced as well. Two technological routes are compared below in Table 14 and Table 15. As can be seen the price is reduced by 24€ (Fig. 36).

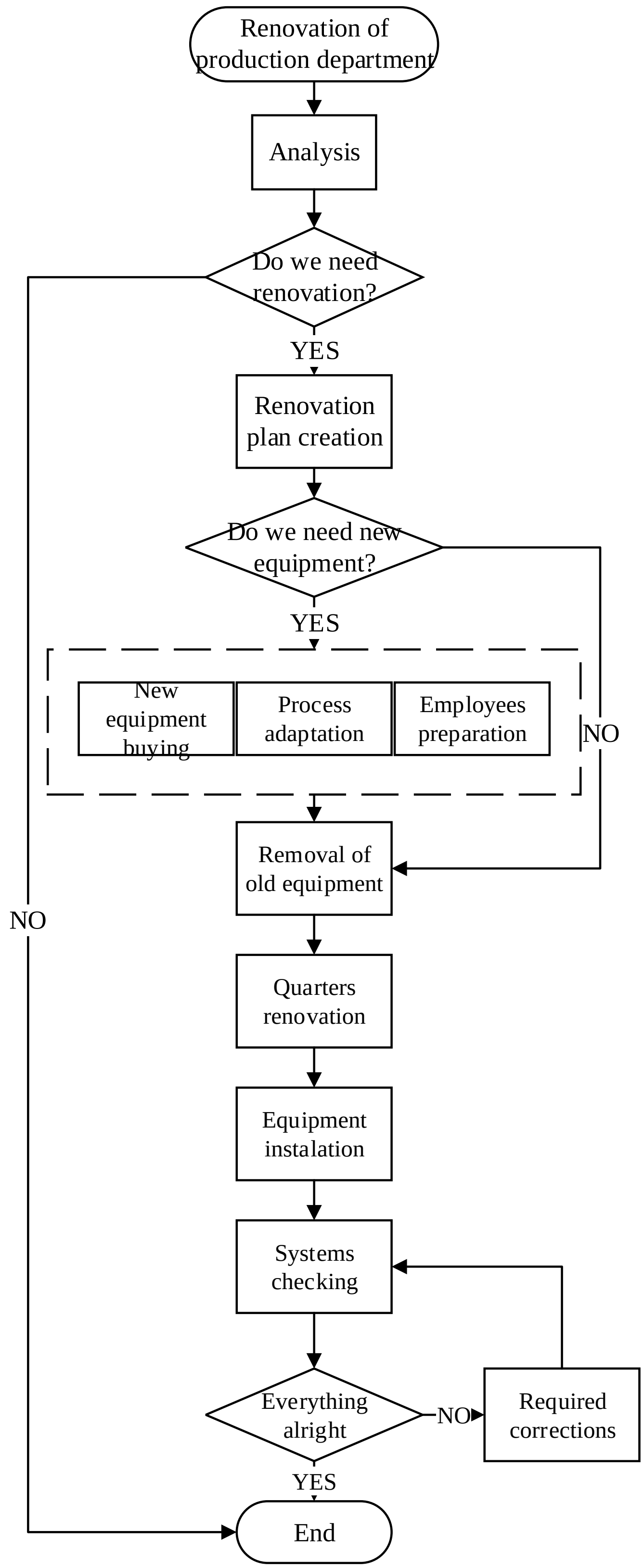

Fig. 35 Flowchart for renovation of production department

Table 13 A3 tool for new equipment analysis

<table>
<tr><td colspan="2">Project Title, Owner
Reduction of production costs, “Arginta Engineering”</td></tr>
<tr><td>Team
Preparation for production department</td><td>Do: Deploy countermeasures
1. Buy new CNC metal milling machine</td></tr>
<tr><td>Problem statement
Machinery is too old and it takes more times to produce parts. A quality is insufficient of some parts therefore some fixing might be needed. Old equipment does not have all necessary features, so some of parts have to be produced at subcontractors. The milling machine tend to break down.</td><td rowspan="2">Check: Effective confirmation Calculated how much money would be saved if subcontractor services were refused/ production time reduced/ defects and delays avoided. The results were positive, so decision was made to purchase new milling equipment.</td></tr>
<tr><td>Background/Current Conditions
Not enough parts are produced with milling machine per day. Some of the parts produced have to be fixed or even produced again More complex parts have to be produced at subcontractors. Delays occur because of perishable equipment.</td></tr>
<tr><td>Root causes
Cause and effect diagram tool was used to identify the problems in a company. The main aspect is too old milling machinery.</td><td>Act: Follow-up actions
1. Train workers to increase quality and effectiveness.</td></tr>
<tr><td>Goals
1. Reduce production costs
2. Avoid possible delays</td><td></td></tr>
</table>

Table 14 Technological route before changes

Part 1		Part 2		Right/left wall	
Cutting	105 €	Cutting	7 €	Welding	15 €
Completing	6 €	Drilling	3 €	Completing	3 €
		Completing	3 €		
Total price	**142.00 €**				

Table 15 Technological route after changes

Right/left wall	
Cutting	107 €
Drilling	5 €
Completing	6 €
Total price	**118.00 €**

Fig. 36 Comparison of prices

- Weakness no. 2. In Table 16 is calculated how much does Kanban costs to be implemented. The result is 428,3€ and every 5 conveyors Kanban has to be supplemented with 428,3€:2=214,15€ worth goods. The investment is considerably small compared to possible problems without it and gain we get with it. Delays will be avoided and company's competitiveness will be risen.

Table 16 Kanban implementation costs for ten conveyors

Kanban	Units	Price	
Bolt DIN961 M12x1,25x40	400	221.40 €	
Nut DIN6923 M12-8-Zn	400	103.24 €	
Washer DIN9021 M12-Zn	400	25.76 €	
Clues black	10	77.90 €	
Total	**1210**	**428.30 €**	

- Weakness no. 3. How much money will be saved using new milling machine (CNC metal milling machine OPTImill F80 [14]) has been calculated. It is expected that parts will be produced 15% faster, parts reproduced will be reduced from 6% to 1% and parts produced at subcontractors will be eliminated (8% of the parts are produced at subcontractors where the price is 15% higher than to produce in place). Milling to a company costs $b = 20€/\text{hour}$. A machine works $t = 320 hours/month$ and produces approximately 1100 parts including parts produced at subcontractors. This means that milling costs including subcontractors are:

$$a_1 = 20 \times 320 + \left(20 \times 320 \times 0.08(1 + 0.15)\right) = 6988.8€ \qquad (3.1)$$

Expected costs with new machinery for the same amount of parts:

$$a_2 = 20 \times 320 \times 0.85 - 20 \times 320 \times 0.85 \times 0.05 + 20 \times 320 \times 0.85 \times 0.08 = 5603.2€ \qquad (3.2)$$

How much money we would save per month producing approximately 1100 parts:

$$a = a_1 - a_2 = 6988.8 - 5603.2 = 1385.6€ \qquad (3.3)$$

A new CNC milling machines costs $b = 38087.3€$ [14]. How long will it take for machine to buy off? Safety coefficient $k = 1.5$.

$$t_2 = \frac{b}{a} \times 1.5 = \frac{38087.3}{1385.6} \times 1.5 = 41.23\ months\ or\ 3.43\ years \qquad (3.4)$$

As can be seen, this quite huge investment would buy off in 3.43 years and almost 20% could be saved every month.

Implementation

All suggestions and offers to three found weaknesses have been accepted. As calculations showed all changes are worth to be implemented.

3.3 Conclusions

The model to improve productivity at industrial enterprises has been developed and presented in this chapter. This model consists of five steps and every step has been described and explained. Those steps are:

1. Preparations;
2. Identifying bottlenecks;
3. Elimination of drawbacks;
4. Checking;
5. Implementations.

Finally, the model has been tested in areal company “Arginta Engineering”. Three weaknesses have been found. Solutions and calculations for those drawbacks have been done regarding theoretical model. All calculations proved the suggestions to be worth to be implemented.

Conclusions

1. Lean and TOC principles have been analysed. Philosophy of the systems has been described. Tools used for identifying defects in production has been given and explained how they work. Moreover, seven most usual wastes in manufacturing company have been described. Every descriptions includes examples how to eliminate particular waste. And finally tools for solving problems in a company have been listed. Every tool has been analysed and short notes how to use them were given.
2. In the second part, trends of overall industry and metal-processing sector have been analysed. Analysis has been done using data of Lithuanian Department of Statistics. The research has shown, that industry shows both positive and negative signs. Moreover, a questionnaire has been done and sent to three enterprises. Total 52 respondents were questioned. Results of the questionnaire has been analysed using correlation method.
3. In the last part, the developed productivity improvement model has been presented. The model has five implementation stages. Model has been made to be used in metal-processing sector. All the steps have been described with examples how to use the model. Every steps involves few tools, which are used to identify or solve problems. After analysis of theoretical model has been done, the model has been tested in a real company “Arginta Engineering”. Following the stages and the steps real situations have been given. Three examples have been analysed. Every example involved a specific weakness. All three drawbacks have been identified with different tools, and different tools have been used to solve those weaknesses. Suggestions were implemented after calculations had been done. Calculations showed that all solutions were positive and worth to be implemented in a company.

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Appendixes

1) Age
   - 20-30
   - 30-40
   - 40-50
   - 50<
2) Education
   - Secondary education
   - Vocational education
   - Higher education
   - University education
3) Do you know what is Lean or TOC?
   - Do not know
   - Something heard
   - Somewhat aware
   - Yes, I know
4) How do you know about Lean or TOC?
   - Books/ Internet
   - Training at work
   - Lectures at university
   - Other
5) Does your company implement Lean or TOC?
   - No
   - Plans to
   - Yes
   - Have implemented already
6) Does Lean or TOC raise production efficiency?
   - No
   - Probably no
   - Probably yes
   - Yes
7) What are the difficulties to implement Lean or TOC?
   - High cost

- Lack of information
- Employees attitude
- I don’t know

8) Are you being encouraged to solve problems and propose solutions?
   - Yes, I am
   - Nor being encouraged, nor being discouraged
   - No, I am not
   - I don’t know

9) Did you have any trainings about Lean or TOC?
   - None
   - Some, in the beginning
   - Several
   - All the time