Kaunas University of Technology

Faculty of Mechanical Engineering and Design

An Improvement of Quality Management and Production Processes in a Metal Manufacturing Company

Master's Final Degree Project

Pijus Poškus
Project author

Lect. Dr. Vaidas Bivainis
Supervisor

Kaunas, 2019

Kaunas University of Technology
Faculty of Mechanical Engineering and Design

An Improvement of Quality Management and Production Processes in a Metal Manufacturing Company

Master's Final Degree Project

Industrial Engineering and Management (6211EX018)

Pijus Poškus
Project author

Lect. dr. Vaidas Bivainis
Supervisor

Assoc. prof. dr. Rūta Rimašauskienė
Reviewer

Kaunas, 2019

Kaunas University of Technology

Faculty of Mechanical Engineering and Design

Pijus Poškus

An Improvement of Quality Management and Production Processes in a Metal Manufacturing Company

Declaration of Academic Integrity

I confirm that the final project of mine, Pijus Poškus, on the topic „An improvement of quality management and production processes in a metal manufacturing company" 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 plagiarised 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 project.

I fully and completely understand that any discovery of any manifestations/case/facts of dishonesty inevitably results in me incurring a penalty according to the procedure(s) effective at Kaunas University of Technology.

(name and surname filled in by hand) (signature)

Kaunas University of Technology

Faculty of Mechanical Engineering and Design

Task of the Master's final degree project

Given to the student – Pijus Poškus

1. Title of the project –

An Improvement of Quality Management and Production Processes in a Metal Manufacturing Company

(In English)

Kokybės vadybos ir gamybos procesų tobulinimas metalo apdirbimo įmonėje

(In Lithuanian)

2. Aim and tasks of the project –

Aim: To improve quality management and reduce wastes in a metal manufacturing company.

Tasks:

1. Prepare a universal acceptance sampling plan for different groups of customers.
2. Propose a new layout of machining centres for waste reduction of unnecessary operator's movement in a milling department.
3. Prepare Standard work procedure for part's milling operation.

3. Initial data of the project –

N/A

4. Main requirements and conditions –

Spaghetti map, Muther's grid, Pareto analysis, Systematic layout planning, time study, Standard work

Project author

(Name, Surname)	*(Signature)*	*(Date)*

Supervisor

(Name, Surname)	*(Signature)*	*(Date)*

Head of study field programs

(Name, Surname)	*(Signature)*	*(Date)*

Poškus, Pijus. An improvement of quality management and production processes in a metal manufacturing company. Master's Final Degree Project, supervisor lecturer dr. Vaidas Bivainis; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.

Study field and area (study field group): Production and Manufacturing Engineering (E10), Engineering Sciences (E).

Keywords: acceptance sampling plan, systematic layout planning, standard work, Lean, reduction of motion waste, metal manufacturing, improvement of quality management, improvement of production processes.

Kaunas, 2019. 56 pages.

Summary

In the time of acceleration of Industry 4.0 an improvement of quality management and production processes is vital for all companies, which want to remain in the market. The need of metal manufacturing company *ABF LT* was to improve quality and production processes, so this project is dedicated for improvement of these processes in this company and reduction of wastes. Three main problems were indicated in the start of this project: 1) Acceptance sampling procedure in the company can be improved; 2) A layout of the milling department is not adapted to the present situation; 3) Quality and production processes in the milling department for one of the oldest products must be improved. Decisions for the solving of these problems were: prepare an universal acceptance sampling plan, propose a new layout for the milling department for a reduction of motion waste and prepare Standard work for part‘s milling operations. An universal acceptance sampling plan was created by categorizing products by customer and accuracy of parts. For every group different Acceptable Quality Level (AQL) was assigned. A new layout for the milling department was created using Systematic Layout Planning (SLP) technique. This layout differs from other layouts created using SLP technique because it was created not analysing material flow, but analysing which combination of milling centres are vital and which milling centres have to be located nearby to reduce motion of operator. Standard work was written for part’s second milling operation where standard time for every process step exposes step’s execution time needed for an average operator. Research showed that an improvement of quality management and production processes in the company, which produce a big diversity of products, is quite complicated and lightly differs from theoretical solutions.

Poškus, Pijus. Kokybės vadybos ir gamybos procesų tobulinimas metalo apdirbimo įmonėje. Magistro baigiamasis projektas, vadovas lekt. dr. Vaidas Bivainis; Kauno technologijos universitetas, Mechanikos inžinerijos ir dizaino fakultetas.

Studijų kryptis ir sritis (studijų krypčių grupė): Gamybos inžinerija (E10), Inžinerijos mokslai (E).

Reikšminiai žodžiai: galutinės kontrolės planas, sisteminis išsidėstymo planavimas, standartinis darbas, Lean, judėjimo nuostolių sumažinimas, kokybės vadybos tobulinimas, gamybos procesų tobulinimas.

Kaunas, 2019. 56 p.

Santrauka

Ketvirtosios pramonės revoliucijos įsibėgėjimo metu, kokybės vadybos ir gamybos procesų tobulinimas yra gyvybiškai svarbus visoms įmonėms, kurios nori išlikti rinkoje. Metalo apdirbimo įmonė „ABF LT“ norėjo patobulinti kokybės ir gamybos procesus, todėl šis projektas skirtas šių procesų tobulinimui ir nuostolių sumažinimui. Trys pagrindinės problemos buvo nustatytos darbo pradžioje: 1) Galutinės kontrolės procedūra įmonėje gali būti patobulinta; 2) Frezavimo cecho išsidėstymas nėra pritaikytas dabartine situacijai; 3) Kokybės ir gamybos procesai frezavimo ceche vienam iš seniausių produktų gali būti patobulinti. Šių problemų sprendimai buvo tokie: parengti universalų galutinės kontrolės planą; pasiūlyti naują įrenginių išdėstymą frezavimo ceche, kad būtų sumažinti judėjimo nuostoliai; paruošti Standartinį darbą detalės frezavimo operacijai. Universalus galutinės kontrolės planas buvo sukurtas kategorizuojant produktus pagal klientą ir detalės tikslumą. Kiekvienai grupei buvo priskirti skirtingi Priimtinos kokybės lygiai (angl. AQL). Naujas frezavimo checho išsidėstymas buvo sukurtas naudojant Sisteminį išsidėstymo planavimą (angl. SLP). Šis išsidėstymas skiriasi nuo kitų išsidėstymų sukurtų naudojant Sisteminį išsidėstymo planavimą, todėl, kad buvo analizuojamas ne medžiagų srautas, bet analizuojama, kokios frezavimo centrų kombinacijos yra svarbiausios, ir kokie frezavimo centrai turi būti išdėstyti greta, kad būtų sumažinti operatoriaus judėjimo nuostoliai. Taip pat, detalės antrajai frezavimo operacijai buvo parašytas Standartinis darbas, kur standartinis laikas kiekvienam proceso žingsniui parodo, per kokį laiką vidutinis operatorius turėtų tą žingsnį atlikti. Tyrimas parodė, kad kokybės vadybos ir gamybos procesų tobulinimas kompanijoje, kurioje yra didelė gaminamų produktų įvairovė, yra pakankamai komplikuotas ir šiek tiek skiriasi nuo teorinių sprendimų.

Table of contents

List of figures

List of tables

Introduction

Industry 4.0 accelerates the improvement of production and quality processes. Companies must adopt changes because an inadaptation will lead to the loss of place in the market and bankrupt. The fourth industrial revolution is a great challenge for all companies because it requires a great investment and remodelling of all processes. A lot of small and medium-sized companies lack capital for an improvement of production processes, so they must find not so expensive way for improvement. These companies have to develop the quality of their products, reduce lead times and inventories, remove non-value adding activities, renew layouts of production departments. These activities can help to make companies more flexible for the present and challenges of Industry 4.0.

This study is focused on the medium-sized metal manufacturing company “ABF LT”. Working experience in this company showed some fields for improvement, what should be done in order to improve efficiency, productivity in production and quality processes.

Quality management in the company can be improved. The quality system in the company is working well, but sometimes the quality department is facing problems with acceptance sampling procedures. The company produces a lot of different parts for various customers and sometimes customers send only an order with a drawing and do not send information about sampling requirements, Acceptable Quality Level and etc. This situation makes a work of quality engineers and controllers difficult because they do not know how much of parts should be checked to fulfil the acceptance sampling procedure. A universal acceptance sampling plan for these cases will facilitate the work of the quality department and make the process of quality assurance more stable.

The layout of the milling department was created for the production needs, which were five years ago. The number of milling centres and production volumes were smaller five years ago, so the current layout is not adapted to the present needs. Quite often operators are working with three or four milling centres simultaneously. They have to move from one milling centre to another and often these milling centres are not located nearby. This movement of operators is a waste because the operator is spending time in motion and this makes a service of all centres very difficult.

A quality and production process in the milling department for one of the oldest products can be improved if Standard work will be written. This product has a good quality history, but there is some place for improvement. Operators make cleaning of the part after milling operation very differently, because of this sometimes they forget to clean some elements of part and this can lead to nonconformity. Also, the working tempo of operators is different, so Standard work will show the fastest, most efficient way of this work.

To sum up, implementation of the universal acceptance sampling plan, new layout in the milling department and Standard work in the company will distinctly improve quality management, reduce operator’s motion waste in the milling department, increase efficiency and productivity. Also, these improvements can become a keystone for improvement of other processes and departments and can be a start for implementation of Lean culture.

Aim of the work – analyse quality and productivity problems in selected metal manufacturing company and prepare solutions for problems solving.

Hypothesis: To improve quality management and the layout of the milling bar in a medium- sized metal manufacturing company.

Tasks of the work:

1. Propose a universal sampling plan for different groups of customers.
2. Prepare a new layout of machining centres for waste reduction of unnecessary operator's movement in milling bar.
3. Prepare Standard work for part's milling operation.

1. Analysis of the production processes problems

In this part of the work, information related to the task of the work will be analysed. Also, an analysis of information directly related to work's tasks will be stated in the problem description part.

1.1 Acceptance sampling

The problem of the sampling size is relevant till nowadays. Companies are trying to find the most effective sampling size for their products, which should ensure a quality for all lots. Choosing a large lot for inspection makes the inspection very expensive. Also, testing can be destructive or 100% inspection of a lot can take too long in some cases. Hence, the Lot Acceptance Sampling Plan (LASP) is developed as a method for checking a statistically reliable number of components that represent an incoming lot good enough. The procedure of acceptance sampling should be used in case of incoming large lots to determine whether to accept or reject a specific quantity of goods or materials because it ensures that customer's risk of receiving a bad lot is minimal, as well as supplier's risk of rejecting a good lot. (1) So, the sampling size should assure the quality but have to be time-saving and cheap. In the last five years, a lot of scientific articles were published in scientific journals, where new approaches of acceptance sampling plans are studied.

Muhammad Aslam et al. in their paper "Mixed Acceptance Sampling Plans for Product Inspection Using Process Capability Index" (2) write about mixed acceptance plans. Attribute and variable acceptance sampling plans are two major schemes used in the final inspection. In practice, both attribute and variable sampling plans simultaneously should be used on the same product. Aslam et al. analyse the design of the mixed sampling plans using the C_{pk} index.

MS Fallahnezhad and A Yousefi Babadi in the article "A new acceptance sampling plan using Bayesian approach in the presence of inspection errors" (3) write, that in acceptance sampling plans, the decisions on either accepting, rejecting the lot or inspecting is still a challenging problem. In this study Bayesian inference is used to update the probability distribution function of nonconforming proportion. In the end, authors are generalizing the model for a potential decision, which can be met in practice.

Ching-Ho Yen, Chia-Hao Chang and Muhammad Aslam in the article "Repetitive variable acceptance sampling plan for one-sided specification" (4) had studied a variable repetitive group sampling plan on one-sided process capability. Also, in the article is written, that Statistical Process Control is the main quality control tool in the present, but acceptance sampling plans are still unavoidable. Not all production companies have good quality assurance system, so acceptance sampling helps customer to verify quality before receiving a history of quality.

To sum up, an acceptance sampling plans are still very useful for companies, which do not have the ability to control all production with a Statistical Process Control. Acceptance sampling plan has to be adapted to the company's situation and should be reviewed and updated continuously.

1.2 The layout planning

Another, always actual problem in production companies, is the design of the manufacturing layout. According to many researchers, plant layout is one way to reduce the cost of manufacturing and increase productivity (5). Probably the most known tool for layout planning and creation is Systematic layout planning (SLP). Systematic layout planning is a tool used to lay out a workplace in a factory with a high frequency and logical relationships close to each other (6).

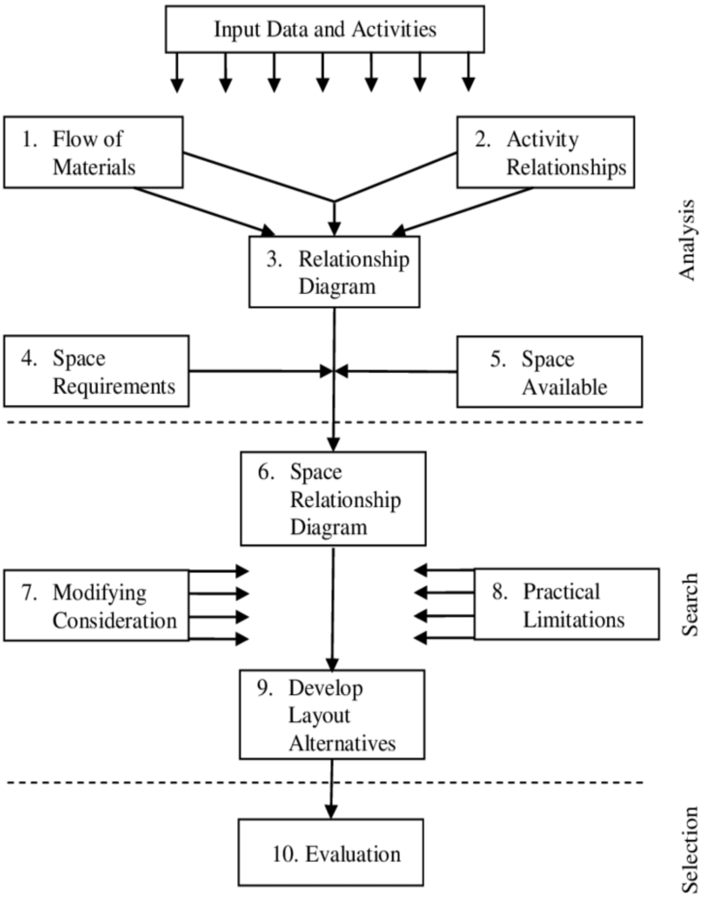


Fig. 1. Systematic layout planning procedure (7)

Fig.1 shows that in the ideal case Systematic layout planning consists of 3 actions: analysis, search and selection. A relationship diagram is created from Flow of materials and Activity relationship information. After analysis of Space requirements, Space relationship diagram is created. After final considerations, layout alternatives for the final evaluation can be proposed.

Nowadays, for a layout planning not only Systematic layout planning technique is used. Latest researches show that for a plant layout planning Graph-based theory, fuzzy logic and other tools can be used.

Yosra Ojaghi et al. in their paper “Production Layout Optimization for Small and Medium Scale Food Industry” (8) researched a new production layout for a meat processing company. In their research, they used three different layout planning techniques: Systematic layout planning (SLP), Graph-based theory (GBT), Pairwise Exchange Method (PEM). In results all techniques were compared, trying to find the best layout.

Syed Asad Ali Naqvi et al. in their article “Productivity improvement of a manufacturing facility using systematic layout planning” (9) use Systematic layout planning technique to improve better integration in a facility, which produces switch gears. Their research consists of 7 steps: 1) PRQST analysis; 2) activity relationships analysis; 3) flow of materials analysis; 4) relationship diagram; 5) Space requirements/available analysis; 6) layout alternatives practical constraints; 7) evaluation.

Parveen Sharma and Sandep Singhal in the paper "Implementation of fuzzy TOPSIS methodology in selection of procedural approach for facility layout planning" (10) marked out factors for a layout problem solving with Fuzzy logic: initial data required (IDR), use of charts (UC), use of graphs and diagrams (UGD), future expansion considered (FEC), constraints considered (CC), procedure implementation (PI), and material handling equipment selection consideration (MHC). They found that Muther's approach (Systematic layout planning) is the best suitable alternative for these factors.

Also, there are few layout planning software in the market. For example, "Proplanner Flow Planner" software is based on Richard Muther's Systematic Layout Planning (SLP) techniques. Diagram, chart, score, and compare alternative designs using relationships between activities as the key measure of layout efficiency. A software calculates layout scores and compares alternatives, with little data collection required. "Flow Planner" can be used as a precursor to a simulation study and may eliminate the need for a simulation study (11).

There are some techniques how to plan a layout for the plant, but SLP technique is the simplest, quickly understandable and effective. Software, like "Flow Planner", proposes layout using flow analysis and this is the easiest way to get the result. In other cases, when a production flow cannot be defined because of a huge amount of different parts, SLP done by hand should be the first choice.

1.3 Standard work

Lean methodology becomes more and more popular in the production field. Lean concerns a production system that is oriented on learning of organization through continuous improvements. It has its origins in the Toyota Production System and has been recognized as doing more with less. Originally, it was focused on the elimination of such wastes as defects of requiring rework, unnecessary processing steps, movement of materials or people, waiting time, excess inventory, and overproduction. Nowadays, it covers diverse aspects of the manufacturing starting from the initial stage of product life cycle such as product development, procurement, and manufacturing over to distribution (12). Companies think how to improve and adapt production processes to tendencies of Industry 4.0. Standard work is a Lean tool, which reduces variations of job performance, increases safety and makes the process more stable. In the latest scientific publications, this topic is not very popular because in the near past a lot of publications of Standard work were published. Nowadays, more actual questions are how to harmonize Standard work and creativity, how to measure waste and etc.

Annika Lantz, Niklas Hansen and Conny Antoni in the article "Participative work design in Lean production: A strategy for dissolving the paradox between standardized work and team proactivity by stimulating team learning?" (13) explore the design of job mechanism that increases team proactivity within a Lean production system. They write that standardization of work help to eliminate non-value adding activities, but also analyse how incompatibility between standard work and innovative teamwork can be eliminated.

Maciej Pieńkowski in his paper "Waste measurement techniques for Lean companies" (14) studied the problem of measuring waste in companies, which are implementing Lean Manufacturing concept. The author writes that waste measurement system will work properly only there, where Standard work is developed.

Sara Bragança and Eric Costa in the paper “An application of the Lean production tool standard work” (15) showing the importance and the applicability of Standard work. They write that Standard Work needs time and effort for the implementation and maintenance. However, developing and implementing it also changes the organizations’ culture. Standard work can immediately improve the company, by increasing productivity, quality, flexibility, stability and reducing lead times, variability. Standard work allows the operator to improve their creativity and entrepreneurship. In the start of implementation, operators can fell some loss of autonomy and flexibility, but after some time operators will understand the benefit of this tool and become more involved and disciplined. Also, because of Standard work, a higher degree of attention to the operations by management personnel will be achieved.

Scientific articles approve that Standard work is the foundation of Lean methodology. Without the implementation of Standard work other Lean tools simply will not work. Implementation of Standard work eliminates non-value adding activities, but in the higher level of Lean, the Standard work can interfere with creativity and learning in the company.

2. “ABF LT” description

“ABF LT”, JSC is a metal manufacturing company located in Mažeikiai, Lithuania. Company is medium sized company, because the number of employees is 58 (2019). *ABF LT* was established in 2009, at the place of the old electrotechnics factory. The company started to work with 15 employees and some machining centres. After some years the company achieved a high quality of products and services. Company is developing production capabilities every year. Production capabilities showed in Table 1.

Table 1. Production capabilities of “ABF LT”

Production capabilities			
Category	Name of CNC machine	Quantity	Main parameter
Milling CNC centres	YCM MV-106A	2	4 axis, 1120x600 mm worktable
	Hitachi Seiki VM40II/ VM50	4	3 axis, 760x406 mm and 1120x510 mm worktable
	Haas HS 1	1	4 axis, 406x400 mm worktable
	Toyoda PV 1	1	3 axis, 1050x650x700 mm worktable
	Dahlih DL-MCV 1020	1	3 axis, 1010x510x550 mm worktable
Turning CNC centres	YCM GT-250M	4	2 axis, Max. diameter: 270 mm, Max. length: 560 mm
	Mori Seiki SL-2	1	2 axis, Max. diameter: 700 mm, Max. length: 1200 mm
	Hitachi Seiki HT-25DM	1	4 axis, Max. diameter 700 mm, Max. length: 1200 mm.
	Emco Emcoturn 242	2	2 axis, Max. diameter: 210 mm, Max. length: 255 mm
	Nakamura Tome TW-20	2	3 axis, Max. diameter: 270 mm, Max. length: 192 mm
	Mazak Quick Turn 28	1	2 axis, Max. diameter: 310 mm, Max. length: 1010 mm
	Hyundai Kia SKT-21LM	1	3 axis, Max. diameter: 270 mm, Max. length: 530 mm
Aluminium die casting machines	UBE Kyosan NX350C	2	Clamping force: 350 t
	Weingarten GDK850	1	Clamping force: 850 t
Welding line	Beam Master Weld – BM48R2	1	2 welding lines, 3 robots, 2 rotors.

Table 1 shows, that “ABF LT” can provide a large variety of production services. There are nine CNC milling centre and twelve CNC turning centres. Also, “ABF LT” has three aluminium die casting machines, which ensure opportunity to receive big offers. Also, the company offers measurement and design services. Measurement equipment is presented in Table 2.

Table 2. Measurement equipment of "ABF LT"

Category	Name of measuring device	Quantity
Coordinate measurement machine	Tesa Derby (Manual CMM)	1
	Zeiss Prismo Vast (Automatic CMM)	1
Roughness measuring device	Mahr	1
Conturograph	Mahr	1
Spectrometer	Spectro	1
Electronical calipers	Garant, Mitutoyo, Mahr	30
Micrometers, angle meters, calibers, other equipment	Garant, Mahr, Mitutoyo and etc.	-

As shown in Table 2, "ABF LT" has a strong base of measuring devices. Company has two Coordinate measurement machines, spectrometer, conturograph and other devices, which are necessary for quality assurance. The measurement laboratory of "ABF LT" is one of the strongest metal manufacturing laboratories in the Northern Lithuania.

Companies spectre of products is very wide. The company produces various parts from steel, brass, plastic, non-ferrous metals, what can be manufactured by turning and milling. Also, "ABF LT" has 5 automatic die casting machines and this allows to die a wide spectre of parts from aluminium. In the field of the aluminium die casting "ABF LT" is one of the strongest companies in the Baltic States. It can be hard to describe a main field of products because "ABF LT" produce parts for the automotive industry, plumbing, electronics, food industry. Also, the company is producing parts for various other industries and have one own product – the fishing device for the Scandinavian market.

"ABF LT" 90% of production exports to Western Europe: Norway, Great Britain, Germany, Sweden and other European Union countries. The company use "Monitor" ERP program for production planning and control.

"ABF LT" is certificated to ISO 9001 requirements from the establishment of the company. Firstly, in 2009 the company was certified as a manufacturer of automobile's gas equipment and parts from metal. At the beginning of 2018 "ABF LT" was certified according ISO 9001:2015 by "Bureau Veritas". Company plans to be certified according to ISO 14001 for Environmental management. ISO 9001 is fully functioning in the company. There are nine processes of the quality management system: sales, procurement, design, production management, management of infrastructure, management of nonconformities, management of measuring devices, and management of the corrective actions.

Quality assurance in the company is performed by two quality engineers and masters of departments. Also, every operator is responsible for the quality of the product, what he is producing. The quality department is trying to improve a culture that every people in manufacturing departments should responsible for the quality. Not only for the quality of the product they produced but for all products.

For example, if the operator sees that other product, with which he does not have to work, is nonconforming, he has to inform managers.

Company has approved the scheme of the quality assurance process. The plan of quality assurance (production process of two operations) is presented in Fig.2.

Fig. 2. Quality assurance process for the part with two manufacturing operations

Fig. 2 shows that in the quality assurance process for the part with two manufacturing operations are included all directly with product working employees: quality engineers, masters of the departments, operators, quality controllers.

3. Methodology and description of problems

3.1 Root cause analysis

Long-term solutions for a problem can be found only then when reasons are identified. Best way to find reasons of the problem is to make Root cause analysis (RCA). One of the seven basic tools of quality - Ishikawa diagram (or Fishbone diagram) will be used for reasons of the problem finding. There are six groups in this Fishbone diagram: machines, methods, manpower, environment, measurements, materials. There are two fundamental problems which have to be analysed: long cycle times and unstable process of quality control. In the problem box, a dual problem is written. Reasons for long cycle time are highlighted in a yellow color, reasons for an unstable process of quality control – in red.

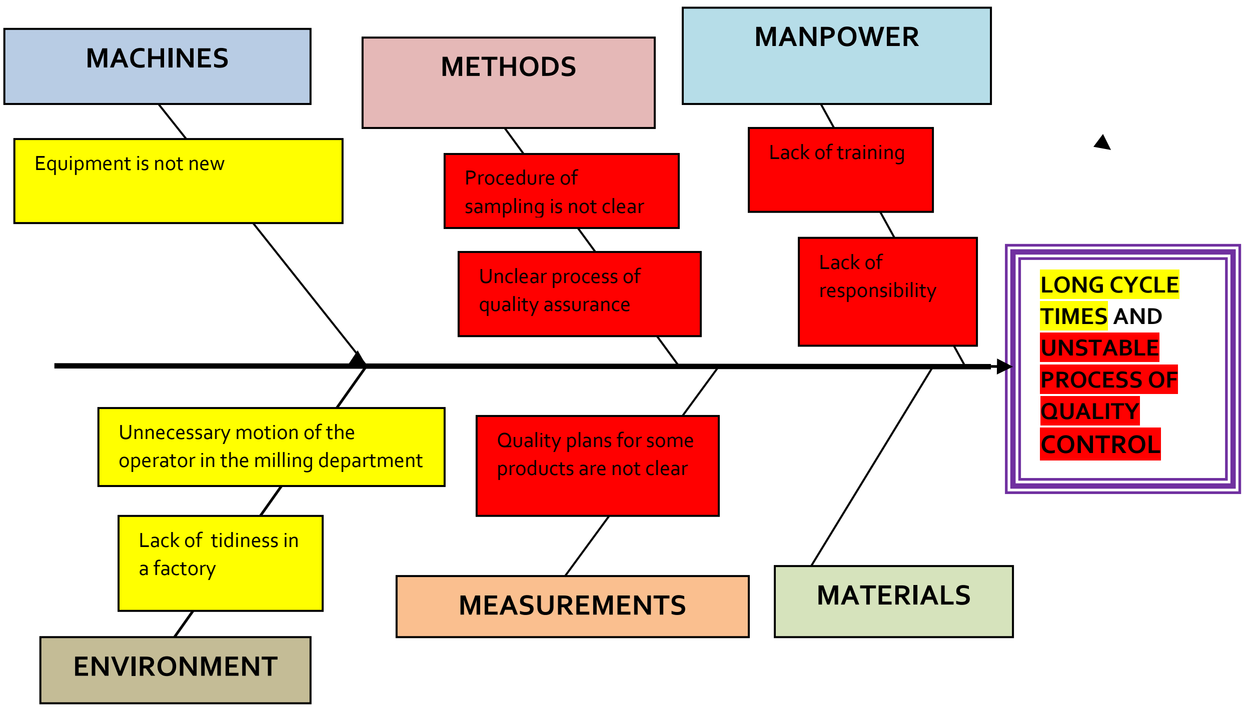


Fig. 3. Root cause analysis of the problem

Fig. 3 depicts RCA analysis for Long cycle time and unstable process of quality control problem. There are various root causes presented for both problems in RCA analysis: unnecessary motion of the operator in the milling department, lack of tidiness in a factory, quality plans for some products are not clear, lack of training and etc. After RCA, reasons of problems should be defined more precisely and abilities to eliminate problems evaluated. Because of this, a table of countermeasures (Table 3) is used to set priorities, which countermeasures can be implemented for the elimination of problems.

In Table 3 countermeasures to the root causes were stated and they have been rated considering the feasibility, effectiveness, and cost for implementation. Criteria for feasibility, effectiveness: (1-Very low, 2-Low, 3-Medium, 4-High, 5-Very high) and for cost: (1- Very High, 2-High, 3- Medium, 4-Low, 5-Very Low). Later in the work, highlighted countermeasures will be prepared for the elimination of problems. Evaluation of countermeasures was performed by CEO, production manager, quality manager, managers of the departments, commerce director.

Table 3. Countermeasures

	Root cause	Countermeasure	Feasibility	Effectiveness	Cost score	Overall score	Priority
Long cycle time	Unnecessary motion of the operator in the milling department	Make Gemba walk and change the layout	5	5	4	100	1
	Lack of tidiness in a factory	Use 5S	4	5	4	80	2
	Not the newest equipment	Renew equipment	3	5	1	15	2
Unstable process of quality control	Procedure of sampling is not clear	Make sampling procedure	5	5	5	125	1
	Quality plans for some products are not clear	Use LEAN standard work procedures	4	5	5	100	2
	Lack of training	Make the training	5	4	5	100	3
	Unclear process of quality assurance	Renew the process	4	4	5	80	4
	Lack of responsibility	Increase salary	5	5	2	50	5

According to Table 3, there are eight reasons of problems written in the Fishbone diagram and countermeasure table. All countermeasures are set in the table according to overall score. Overall score varies from 100 to 15 points. Some of the countermeasures are highlighted in green because these problems do not need big resources for implementing. For example, the increase of salary depends only from company owners, so nothing can be done with this by employees. Also, the purchasing of equipment demands big investment. Use of 5S to tidy the factory is the second priority in a long cycle time problem, but only the first priority will be analysed because only after a set of new layout 5S can be implemented.

3.2 Difficulties with an Acceptance sampling and inspection

The situation with sampling and inspection planning in “ABF LT” needs development. Quite often customers with an order send information how often parts should be checked in the process and how much of parts should be checked in the final inspection. Later, with batches of parts, they receive measurement protocols. Equally often, some companies do not send any information about inspection and acceptance sampling. This really complicates a work of the quality department, because there are no regulations, how often quality controllers should measure parts in the production time. Actually, the operator of the machining centre is responsible for the quality of his product, but their measurement results often cannot be indicated. This is because the amount of different positions is very big and it is almost impossible to make self-check plans for every position of the part. Normally, in this case, the quality department's engineers check the first sample at the start of operation and check other samples during production time depending on their work amount.

The final inspection usually does not measure internal dimensions. It is assumed that critical measurements and tolerances were maintained while in the process (16). In cases, when there is no information about inspection requirements from the customer, it is quite hard not to check everything in the final inspection, because it cannot be stated that all measurements were maintained in the process. Often in the second shift quality department is not working, so inspection works in the prevention mode when an operator and shift master measures output. Because of this final inspection with full measurements should be maintained. Also, almost all biggest customers want to have a measurement report for parts, so measurements of 3 or 5 parts for measurement report are done during final inspection time.

In the old company's practice, which came from the past, ≤5 % of parts from the batch should be randomly selected and checked in the final inspection. If there are one or more nonconforming parts, two times bigger amount of parts should be checked. If once again nonconformity is found, parts are stated as nonconforming. Lack of regulations makes final inspection very unclear. Though inspection is permanent every day but amounts of checked parts depend only from quality controllers or customer's requirements. Use of standard acceptance sampling procedures can facilitate the process of the final inspection when sampling requirements are not received.

Acceptance sampling is the process of evaluating a portion of the product in a lot for the purpose of accepting or rejecting the entire lot (17). The International Organization for Standardization (ISO) standard ISO 2859-1, as well as ANSI/ASQC Z1.4 and MIL-STD-105E, is a sampling system indexed by lot size ranges, inspection levels, and AQLs. To use this acceptance sampling system, an agreement is reached by the consumer and producer that a certain level of quality, the AQL, may be accepted most of the time, an inspection level is selected, and the appropriate lot size range is determined (18). In order to use these standards following information is needed (17):

- Acceptable Quality Level.
- Lot size.
- Type of sampling (single, double, or multiple)
- Inspection level.

Acceptable Quality Level is the maximum percent defective, or the maximum number of defects per can be considered satisfactory as a process average (16). Also, AQL can be stated as an amount of defects per 100 products.

The inspection level shows a relation between batch or lot size and the size of the sample. There are three main inspection levels – I, II, III. Level III involves the most inspection, which results in a higher level of assurance, more discrimination, and higher inspection costs. Also, there are four levels for special inspection. Special inspection levels can be used when small numbers of samples are used and big risk can be tolerated. There are three types of sampling (16):

1. *Single sampling.* The inspector pulls a sample of products based on the size of the batch/lot and the quality level required.
2. *Double sampling.* The inspector uses a smaller first sample, double sample permits the lot to be rejected or accepted using a smaller number of units, than in single sampling.
3. *Multiple sampling.* This type of sampling allows using another sample if the first two samples have not been sufficient to accept the batch.

All types of sampling have a normal, tightened or reduced inspection. Normal inspection is used, when there is no quality history. Reduced inspection can be used when a product's quality history was good. Tightened inspection is used when some batches were rejected and there is a need to maintain more parts.

3.3 Ineffective layout in the milling department

The basic objective of the layout decision is to ensure a smooth flow of work, material, people, and information through the system. The effective layout also (19):

1. Minimize material handling costs;
2. Utilize space efficiently;
3. Eliminate bottlenecks;
4. Reduce manufacturing cycle time;
5. Eliminate wasted or redundant movement;
6. Provide flexibility to adapt to changing technologies.

There are three types of basic layouts: process, product and fixed position layouts (20). "ABF LT" uses process layout because the company is divided into different manufacturing departments. Process layout, also known as functional layouts, group similar activities together in departments or work centres according to the process or function they perform. The advantage of this layout is flexibility and disadvantage is inefficiency (19).

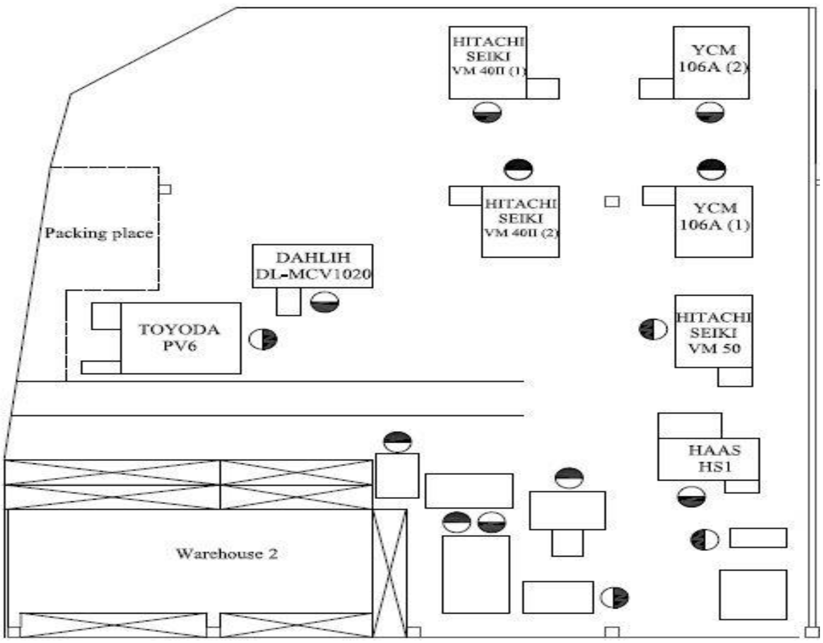


Fig. 4. The current layout of the milling department in "ABF LT"

The current layout in the milling department (Fig. 4) in "ABF LT" was created to maintain flexibility and improve efficiency in the department. Pairs of the milling centres, like YCM‘s 106A and Hitachi Seiki‘s VM40II were located one in front of the second because the idea was that one operator will work only with two milling centres simultaneously. In the beginning, the biggest load of work was designed to YCM‘s 106A and Hitachi Seiki‘s VM40II. Later, other milling centres, like Dahlih DL-MCV1020 and Hitachi Seiki VM50 received stable loading, then use of Toyoda PV6 and Haas HS1 fluctuates continuously.

In the present, often operators are working with three or four milling centres simultaneously. For example, the operator works with one pair of milling centres and also going to the third milling centre and returning back. This movement is undesirable because reduces the efficiency of milling centres. This situation arises because of the companies production profile. "ABF LT" mainly produces parts in size of batches and do not produce parts of the massive production. Sizes of orders are very different, so because of this, it is very hard to make production planning and to plan the operator‘s work without extra motion. Reduction of extra motion is one of the main factors for the increase of efficiency in the milling department.

Research should be started from the Gemba walk in the milling department. Gemba walk and a short time study will help to understand the situation better. A Gemba Walk is a technique used to observe and understand how work is being performed. Gemba is taken from the Japanese word gembutsu, meaning "real thing" or "real place," and a Gemba Walk has the following elements: observation (watching people perform work in-person); location (observing people at the actual location where work is performed); teaming (interacting with people performing the work). Gemba Walks provide an up-close, detailed view of behaviors in action and are a powerful tool for identifying process improvement opportunities and new ways to support the agile team. (21)

3.4 Need of Standard work for manufacturing processes

Standard work is the current most efficient working method that produces the best quality product. The reason standard work is important in the context of manpower improvements is that it identifies the most efficient methods and is the baseline for all improvements (22).

Standard work is a collection and implementation of the best practices known to that point. It includes what is mandatory to begin the procedure and the completed state of the same. Standard work is the sequential method for defining the best practices and ensuring that every operator is strictly following them to endow the value to the customers (23).

Without a Standard work it is impossible to improve work, because every operator is doing job in a different way. There are five steps for creating standard work (22):

1. Decide which processes require Standard work;
2. Observe the process.
3. Identify the work elements and the most efficient sequence.
4. Measure the element times for manual and machine elements (ten repetitions of each cycle are recommended.)
5. Fill out the standard operation sheet, inputting details, as necessary.

Fig. 5. View of the part “Axe”

Fig. 5 represents part “Axe”. Part “Axe” is a product, which “ABF LT” produces for 5 years. The quality level of the product is quite high, but improvement is needed. Machining operations of the part are programmed well, but there are a lot of variations in operator‘s manual work. After the last machining operation, when a part is machined, the operator has to clean a part from emulsion, burrs and to give the appearance of the product. These manual activities lead to unstable process because different operators perform the job differently and in the different pace.

The number of produced parts in one shift varies from 78-82 parts. Sometimes, this number varies because the operator is working with three or four milling centres, sometimes because of operator. As mentioned earlier, operators are doing manual operations differently, so this also leads to a variance of produced parts in a shift.

The main problem is that the company does not have a procedure for a part‘s cleaning operation. The geometry of a product is quite difficult: holes, chambers, radiuses, spherical and cylindrical surfaces, angled planes. Sometimes, because of lack of attention, operators forget to clean some surfaces or burrs. Standard work could help to eliminate different execution of cleaning operation and completely reduce faults in cleaning. Certainly, all operators should be trained, how to work according to Standard work and only after some time results will be seen.

4. Results

4.1 Universal sampling plan for all groups of customers

Standard acceptance sampling procedures can facilitate the process of the final inspection and make it easier. Also, a universal sampling plan for all groups of customers and standard acceptance sampling will help to maintain a quality of the product in processing time and make inspections more clear. Standard ISO 2859-1, as well known as ANSI/ASQC Z1.4 and MIL-STD-105E will be used as the main document of acceptance sampling. This plan will be used in cases, when a customer company will not send information about quality requirements, inspection frequency and acceptance sampling.

There are some contracts with customers, where are stated how many parts should be measured for the report of final inspection. Also, which documents should be prepared before the start of manufacturing. These customers with a batches of their product want to have these documents: final measurement report, ballooned drawing for measurement report, material certificate and part submission warrant. Other customers do not send any requirements for quality control or sampling, they just want to receive a good product.

As mentioned earlier, in order to make sampling plans Acceptable Quality Level (AQL) should be defined. Number of AQL should be written in a contract with a customer, but the manufacturer can use his own AQL number trying to offer a product with good quality. In “ABF LT” products can be divided into some special groups and AQL number, inspection level can be attributed for each one.

In a small–medium sized company biggest attention goes to customers with the biggest orders. It can not be stated that companies produce a bad quality product to smaller customers, but they are just trying to be flexible for bigger consumers: trying to implement their needs and deliver parts in the correct delivery time.

Customers in a metal manufacturing company “ABF LT” can be divided into some groups. With some of the customers is a long term relationship and sells for them generate the biggest percent of sales. Their quality requirements are high, but long relationship history and amount of sales state that AQL and other quality requirements for them should be strict. So, a long term customer, which generate a big percent of sales every year can be included in a group TOP. Also, new very important customers can be included in category TOP because their new products should be produced very well to receive orders in the future. Table 4 shows categories and criteria for customer groups.

Table 4. Categories of customers in “ABF LT”

Category	Criterias
Main customers (TOP)	TOP 6 of sales, new big projects
Not TOP customers	Constant orders, average level of sales
Other customers	Solitary orders, small sales, small accuracy

Categorizing of customers should be done by CEO of the company. According to the strategy of the company, clients can be moved to different groups. Other customers whose ordering from “ABF LT” are not so big, should be included in another category. This category can be called Not TOP customers. Requirements and AQL level for them are smaller than for TOP customer. As mentioned earlier, categorizing of customers should be done by CEO of the company. The third category should be created for customers who are ordering parts with small accuracy. AQL percent is biggest for this category because the tolerance field of dimensions is wide.

Categorizing of customers and sampling plan is showed in Table 5.

Table 5. Sampling plan for different groups of customers in "ABF LT"

Customer	Product	AQL	Inspection level, sampling plan	Sampling conditions
Main customers (TOP)	Old product	1,0	I level, single sampling	normal inspection
Main customers (TOP) or New customers	New product	0,65	I level, single sampling	normal inspection
Not TOP customers	Old product	1,5	I level, double sampling	normal inspection
Not TOP customers	New product	1,0	I level, double sampling	normal inspection
Other customers/small accuracy parts	Old product	4,0	I level, single sampling	normal inspection
Other customers/small accuracy parts	New product	2,5	I level, single sampling	normal inspection

Table 5 presents a sampling plan for various categories of products in "ABF LT", which can be used to set more clear regulations about a final control. AQL represents an permissible amount of defects per 100 products. As showed in the table, smaller AQL percent is for TOP customers, who are making the biggest profit for a company. After that goes other customers with an increase of AQL percent. The biggest AQL percent goes to customers, who are ordering products with a small accuracy. In all categories of products, AQL percent for a new product is smaller, than for product, who have been manufactured for a long time. Sampling conditions can be changed according to quality history. If there were some problems, inspection should be tightened or reduced if quality history is perfect.

Table I - Sample size code letters

Lot or batch size	Special inspection levels				General inspection levels		
	S-1	S-2	S-3	S-4	I	II	III
2 to 8	A	A	A	A	A	A	B
9 to 15	A	A	A	A	A	B	C
16 to 25	A	A	B	B	B	C	D
26 to 50	A	B	B	C	C	D	E
51 to 90	B	B	C	C	C	E	F
91 to 150	B	B	C	D	D	F	G
151 to 280	B	C	D	E	E	G	H
281 to 500	B	C	D	E	F	H	J
501 to 1200	C	C	E	F	G	J	K
1201 to 3200	C	D	E	G	H	K	L
3201 to 10000	C	D	F	G	J	L	M
10001 to 35001	C	D	F	H	K	M	N
35001 to 150000	D	E	G	J	L	N	P
150001 to 500000	D	E	G	J	M	P	Q
500001 and over	D	E	H	K	N	Q	R

Fig. 6. Sample size code letters (24)

Standard Sample size code letters, which are used according to mentioned standards, are shown in Fig. 6. Fig. 6 represents a table of sample size code letters. According to the sampling plan, where a lot size, inspection level used for the product is written, code letter can be found. After a code letter founding, table of single sampling plans for normal inspection should be analysed (Fig. 7).

Single Sampling Plans For Normal Inspection

Sample Size Code Letter	Sample Size	Acceptable Quality Levels (Normal Inspection)																					
		0.065		0.10		0.15		0.25		0.40		0.65		1.0		1.5		2.5		4.0		6.5	
		Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re	Ac	Re
A	2																			↓		0	1
B	3																	↓		0	1	↑	
C	5															↓		0	1	↑		↓	
D	8													↓		0	1	↑		↓		1	2
E	13											↓		0	1	↑		↓		1	2	2	3
F	20									↓		0	1	↑		↓		1	2	2	3	3	4
G	32							↓		0	1	↑		↓		1	2	2	3	3	4	5	6
H	50					↓		0	1	↑		↓		1	2	2	3	3	4	5	6	7	8
J	80			↓		0	1	↑		↓		1	2	2	3	3	4	5	6	7	8	10	11
K	125	↓		0	1	↑		↓		1	2	2	3	3	4	5	6	7	8	10	11	14	15
L	200	0	1	↑		↓		1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22
M	315	↑		↓		1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	↑	
N	500	↓		1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	↑			
P	800	1	2	2	3	3	4	5	6	7	8	10	11	14	15	21	22	↑					
Q	1250	2	3	3	4	5	6	7	8	10	11	14	15	21	22	↑							
R	2000	3	4	5	6	7	8	10	11	14	15	21	22	↑									

↑ Use Frist sampling plan above arrow, if sample size equals or exceeds lot or batch size, do 100 percent inspection.

↓ Use Frist sampling plan below arrow   Ac : Acceptance number   Re : Rejection number

Fig. 7. Single Sampling Plans For Normal Inspection (24)

Table in Fig. 7 lets to find how many defected parts can be in a batch or lot to state that this is confirmative. Actually, Acceptable Quality Level for every position of the product should be appointed.

Sampling plans for product groups can be changed due to production issues. Also, sampling conditions have to be adjusted to nonconformity level at the company and product's quality history. This sampling plan will easier work of the quality department and will let to better control procedures.

In the next section of the work creation of new layout for the milling department in "ABF LT" is presented.

4.2 Creation of new layout

If acceptance sampling plan for different groups of customers was related to an improvement of quality management, the creation of the new layout is an improvement of production processes. A new layout should be created for the reduction of motion waste and improvement of efficiency in the milling department. As mentioned earlier, the creation of the new layout should be started from Gemba walk with time study because these tools will approve or reject the statement that the layout of the milling department is not ergonomic.

4.2.1 Gemba walk and time study

Gemba walk started from registering with which combination of milling centres every operator is working. The layout of the department is shown in Fig. 4. There were three operators working in the shift. Operators were working with these milling centres:

1. First operator. Milling centre: YCM 106A (2);
2. Second operator. Milling centres YCM 106A (1) and Hitachi VM50;
3. Third operator. Milling centres: Hitachi VM40II (1) and Hitachi VM40 (2).

Summarily, a motion waste was identified. The second operator was working with YCM 106A (1) and Hitachi VM50 milling centres simultaneously. He had to make a route of 20 meters from one milling centre to another when the first operator was working only with YCM 106A (2). Normally, only one operator should be working with a pair of milling centres, in this case, YCM's 106A. In this situation, the first operator probably is not fully loaded with work, then the second one is making a motion waste. Work of the second operator was analysed deeper with a time study. Parts with which operators were working were not analysed.

Table 6. Machining and cycle times for parts No.1 and No. 2

	Part No. 1	Part No. 2
t_{mach}, s	15	27
t_{cycle}, s	36	72

In the investigated situation, the second operator is working with two milling centres simultaneously. Machining and cycle times (Table 6) were found in the production sheet. Measured walking time between YCM 106A (1) and Hitachi Seiki VM50 is 10 seconds. Machining and cycle times written in the production sheet coincided with an actual time. In this case, cycle time is a period of time needed to machine part, take it out, insert a new part into milling centre and start a new operation.

Table 7. Process data

	Part No. 1	Part No. 2
Start time, h:mm:ss	8:35:55	8:37:30
Production brake start, h:mm:ss	9:20:44	9:20:38
Production brake finish h:mm:ss	9:46:35	9:44:30
Finish time	10:00:57	10:02:52

Table 7 shows, that production of part No. 1 started 8:35:55 o'clock in the morning. Between 9:20:44 and 9:46:55 o'clock was a production break. 10:00:57 o'clock production of part No. 1 was finished. Production of part No. 2 started 8:37:30 o'clock and finished at 10:02:52. The total production time for 15 pieces of part No. 1 and 15 pieces of part No. 2 was 1:03:11 if brake time is taken away.

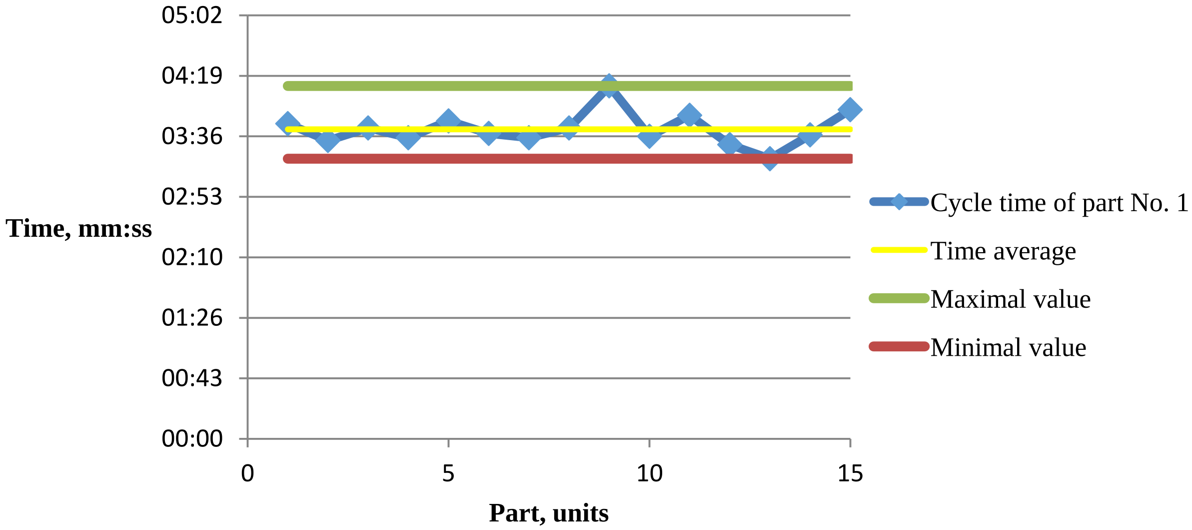


Fig. 8. Cycle time of part No. 1

The operator was working with two milling centres simultaneously: he inserted a new part into YCM 106A, cleaned a part that was taken out from this milling centre recently and went to Hitachi Seiki VM50 to take out a part, put a new part into a milling centre and to clean a product that was recently taken out. Because of this cycle times for both parts are longer. According to Fig. 8, the shortest time of the cycle was 3 minutes and 20 seconds. The longest cycle time – 04:12. The average time of the cycle – 03:41.

Fig. 9 shows cycle times for part No. 2. Because of work with two milling centres in one time, cycle times for part No. 2 are also longer, than in normal conditions. According to Fig. 9, maximal cycle time for part No. 2 was 4 minutes, minimal – 03:05 and average – 03:40.

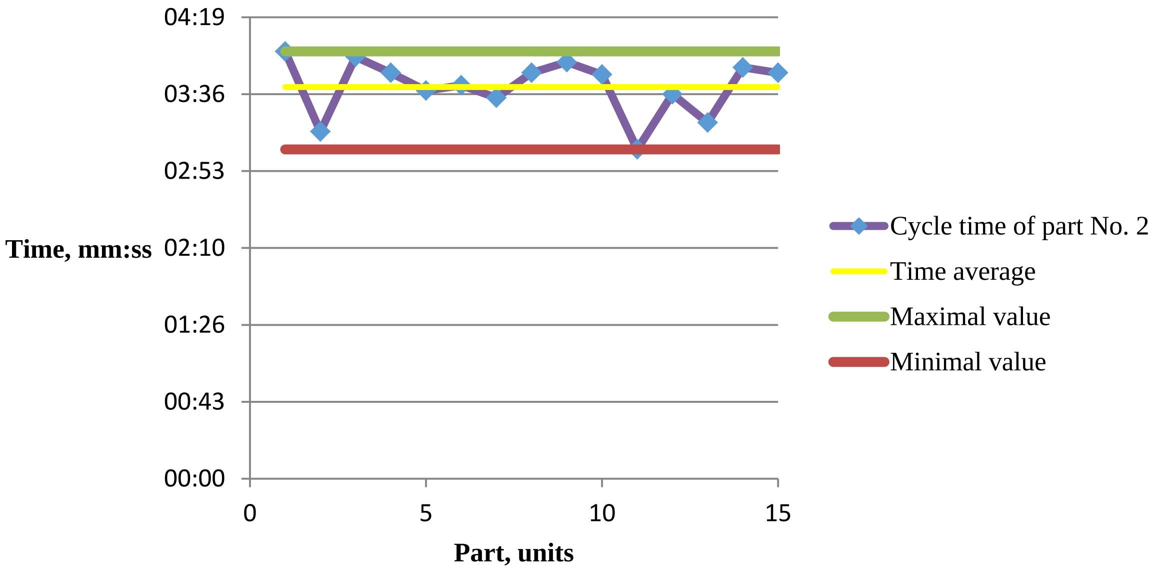


Fig. 9. Cycle time of part No. 2

Table 8. Cleaning time for parts No.1 and No. 2

No.	Part No. 1	Part No. 2
	Cleaning time, mm:ss	Cleaning time, mm:ss
1	00:40	01:39
2	00:55	01:12
3	00:37	01:39
4	00:52	01:17
5	01:05	01:16
6	00:56	01:10
7	00:59	01:18
8	00:58	01:18
9	01:04	01:42
10	00:46	01:24
11	00:57	01:28
12	00:47	01:17
13	00:53	01:01
14	00:53	01:18
15	01:07	01:22
Average cleaning time, mm:ss	00:54	01:21

Table 8 represents registered cleaning times for both parts. In this situation when machining times are short, the cleaning time is bigger than a machining time. Cleaning time varies severely for both parts. Average cleaning time for part No. 1 was 00:54, for part No. 2 – 01:21.

Table 9. Average time of the process

	Part No. 1	Part No. 2
Machining time, mm:ss	00:15	00:27
Cycle, mm:ss	00:36	1:12
Cleaning, mm:ss	00:54	01:21
Inserting part, mm:ss	00:11	00:38
Taking out part, mm;ss	00:10	00:07

When the average times of the process (Table 9) are known, other calculations can be done. From these parameters, the total time of production can be calculated when the operator is working with milling centres separately. It means, he produces and cleans 15 pieces of part No. 1 and then goes to Hitachi Seiki VM50 to produce part No. 2. In this case, an operator inserts a part into milling centre, after that he cleans a part which was taken out recently. Only then, when he finishes cleaning, he can take out part from milling centre and put a new one into the milling centre.

Table 10. Production time, when operator is working on milling centres seperately

	Pieces	Production time, mm:ss
Part No. 1	15	19:00
Part No. 2	15	31:57

	Pieces	Production time, mm:ss
Total time	30	50:57

Table 10 shows, that if an operator will work on one milling centre to produce 15 pieces of part No. 1, it will take 19:00. To make 15 pieces of part No. 2 – 31:57. The total time to make 15 pieces of part No.1 and 15 pieces of part No. 2 is 50:57.

A production time, when the operator is working simultaneously on two milling centres, can also be improved. In the current situation, the operator walking 10 seconds from one milling centre to another. This time can be reduced if Hitachi Seiki VM50 will be placed near YCM 106A(1). In this case, walking time and operator's route will be reduced. An operator's route if milling centres are located nearby is shown in Fig. 10.

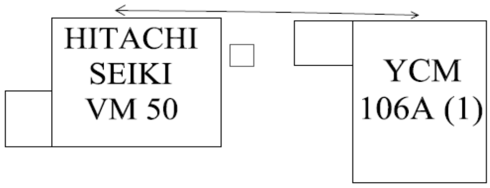


Fig. 10. Operator's movement when milling centres placed nearby

In the case presented in Fig. 10, the operator goes from one milling centre to another in 3 seconds.

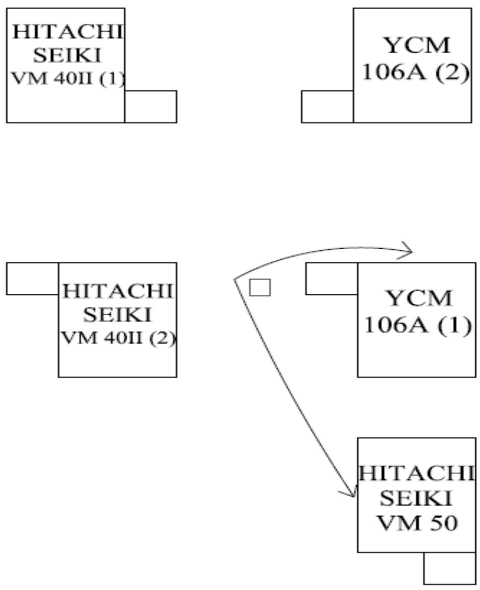


Fig. 11. Operator's route in original situation

From Spaghetti Map shown in Fig. 11, can be found, that operator in the original situation was going from one milling centre to another 30 times. So, 300 seconds (30×10) were needed.

$$t_{saved} = original\ time \quad - time\ after\ improvement \quad = 10 - 3 = 7 \text{ s} \quad (1)$$

From formula (1) measured, that 7 seconds will be saved in every walking from one milling centre to another. Total saved time will be:

$$t_{t.saved} = No. of\ walkings \times t_{saved} = 30 \times 7 = 210 \text{ s} \qquad (2)$$

If according formula (2) time saving will be 210 seconds, so the total time of production with two milling centres located nearby is:

$$t_{new} = t_{original} - t_{t.saved} = 3791 - 210 = 3581\ s = 59\ min\ 41\ s \qquad (3)$$

Table 11. Comparison of results

	Time, hh:mm:ss
Original situation / two milling centres working simultaneously	1:03:11
Milling centres working separately	00:50:57
Reduced distance between milling centres / two milling centres working simultaneously	00:59:41

Table 11 shows, that the original situation is the least efficient. Machining times for both parts are shorter than the cleaning time of parts, so part's cleaning takes a big amount of operator's time. Also, he has to travel 10 seconds from one machining centre to another.

If a milling centre Hitachi Seiki VM50 will be placed near YCM 106A(1), walking time will be reduced drastically. An operator will need 3 seconds to move between milling centres, but he will spend a big amount of time for cleaning parts. This improvement 3 minutes 30 seconds reduces production time.

The most efficient way to produce 15 pieces of part No. 1 and 15 pieces of part No. 2 is to work with milling centres separately. Firstly, produce parts No. 1 and after that produce parts No. 2. This variant of production will need 50 minutes and 57 seconds to produce parts.

As mentioned earlier, ABF LT mainly produces parts in size of batches and diversity of produced products is very wide. Because of this, it makes production planning difficult and it is very hard to effectively plan work for every operator. A better option for reduction of the operator‘s motion and increasement of efficiency is to find a new layout for a milling department because results of the research showed that milling centres are not located ergonomically.

4.2.2 Analysis of milling centres combinations

In Gemba walk and time study we executed, waste of motion was identified. Operators are walking a lot during their shift because often they work with two or three milling centres at the same time. The problem is that the current layout of milling centres (Fig. 11) is not adapted to the current situation.

Every shift operator is working with different milling centres at the same time, so without special research, it is not possible to understand the level of motion waste. Variety of machined products in a milling bar is very wide, so in this case, it is not worth to analyse manufacturing processes of all products. The easier way is to analyse which combinations of milling centres are used by operators mostly.

Table 12. Extract from a collected data

Date	Shift	Operator	YCM 106A (1)	YCM 106A (2)	Hitachi Seiki VM40II (1)	Hitachi Seiki VM40II (2)	Hitachi Seiki VM50	Haas HS1	Dahlih DL-MCV1020	Toyoda PV6
			Machining time in hours							
07/11	1st	Z	5,5	2	-	-				
		B	1,8				3,7	6		
		L			5,2	4,2				4,3
	2nd	J	2	7,7						
		E	4,1				3,6	2,8		
		Č								4,5
08/11	1st	B	5,8	2,8			1,8			
		K		2,4						
		Z		2,5			3,1		1,3	
		L			4,4	3,5				4,7
		V							2,8	
	2nd	J		7,4						
		E	6,2				3,2			
		Č								4,8

Data for the research were collected in November of 2018. There were 22 working days in November. Also, November was selected for data collection, because in this month a variety of orders were very big and this helped to show the manufacturing situation of the year. Table 12 shows an extract of the collected data. Also, Table 12 shows machining time of all milling centres in a shift and exposes combinations of milling centres with which an operator works at the same time in that shift.

In Fig. 12, Table 13 and other tables, abbrevations of milling centres names will be used.

Table 13. List of combinations by total machining time

No.	Combination of milling centres used by one operator in a shift	Total machining time in hours
1.	YCM1+YCM2	259,1
2.	HitachiVM40(1)+HitachiVM40(2)	121,4
3.	Dahlih	55,6
4.	YCM1+YCM2+HitachiVM40(2)	44,3
5.	Hitachi VM50+Haas	39,5
6.	Hitachi VM50+Dahlih	38,15
7.	Dahlih+Toyoda	35,5
8.	Hitachi VM40(1)+Hitachi VM40(2)+Toyoda	35,2

No.	Combination of milling centres used by one operator in a shift	Total machining time in hours
9.	YCM1+YCM2+Hitachi VM50	27,8
10.	YCM1+YCM2+Hitachi VM40(2)+Hitachi VM50	27,7
11.	Hitachi VM50+Toyoda	25,6
12.	YCM1+YCM2+Toyoda	24,4
13.	Hitachi VM50	24,1
14.	Hitachi VM40(1)+Hitachi VM40(2)+Dahlih+Toyoda	20,8
15.	Toyoda	20,1
16.	YCM1+YCM2+Dahlih	19,4
17.	YCM1+Hitachi VM50+Haas	19,2
18.	YCM2	18,1
19.	YCM1+Hitachi VM50	17,3
20.	Hitachi VM40(2)+Hitachi VM50	17,2
21.	YCM1+YCM2+Hitachi VM50+Toyoda	13
22.	Hitachi VM50+Dahlih+Toyoda	12,3
23.	Hitachi VM40(1)+Toyoda	11,6
24.	Haas+Dahlih	11
25.	Hitachi VM40(2)	10,9
26.	Haas+Toyoda	10
27.	Hitachi VM40(2)+Dahlih	9,8
28.	YCM1+Hitachi VM40(2)+Hitachi VM50	9,7
29.	YCM2+Hitachi VM40(1)+Hitachi VM40(2)	8,3
30.	YCM2+Hitachi VM50	8,2
31.	YCM2+Dahlih+Toyoda	8,1
32.	Haas	7,4
33.	YCM2+Hitachi VM50+Dahlih	6,9
34.	Hitachi VM40 (1)	6,7
Total		1024,35

Table 13 shows which combinations were used mostly in November. The six most used combinations are these:

1. YCM106A (1)+YCM106A (2);
2. HitachiVM40II(1)+HitachiVM40II(2);
3. Dahlih DL-MCV1020;
4. YCM106A (1)+YCM106A (2)+HitachiVM40 (2);
5. Hitachi VM50+Haas HS1;
6. Hitachi VM40(1)+Hitachi VM40(2)+Toyoda.

This shows that the two most used combinations consist of two milling centres. It means that operators are mostly working with two milling centres at the same time. Also, there is a combination of one, two and three milling centres in a top six combinations.

In total, there were 34 combinations used in November. Milling centres in the most used combinations are almost located nearby, so it is harder to improve the layout for these combinations, but there is a lot of opportunities for improvement for other combinations. For example, the operator's route in combination YCM1+YCM2+Toyoda is 42,6 m. The operator is working with two milling centres located nearby and to the third milling centre he has to walk more than 30 m. So, the operator's route in this type of combinations should be reduced significantly.

Table 14. List of combinations by operator‘s route

No.	Combination of milling centres	Operator's route, m
1.	YCM1+YCM2+Hitachi VM50+Toyoda	49,1
2.	YCM2+Hitachi VM50+Dahlih	47,9
3.	YCM1+YCM2+Toyoda	42,6
4.	YCM2+Dahlih+Toyoda	41,2
5.	YCM1+YCM2+Dahlih	37,0
6.	Hitachi VM40(1)+Hitachi VM40(2)+Toyoda	34,6
7.	Hitachi VM40(1)+Hitachi VM40(2)+Dahlih+Toyoda	32,7
8.	YCM1+Hitachi VM50+Haas	32,4
9.	Hitachi VM50+Toyoda	31,5
10.	Haas+Toyoda	30,0
11.	Hitaachi VM50+Dahlih+Toyoda	29,5
12.	YCM1+YCM2+Hitachi VM40(2)+Hitachi VM50	29,1
13.	Haas+Dahlih	28,4
14.	YCM1+Hitachi VM40(2)+Hitachi VM50	28,2
15.	Hitachi VM40(1)+Toyoda	27,7
16.	YCM1+YCM2+Hitachi VM50	25,6
17.	Hitachi VM50+Dahlih	23,3
18.	YCM2+Hitachi VM50	21,0
19.	Hitachi VM40(2)+Dahlih	17,9
20.	YCM2+Hitachi VM40(1)+Hitachi VM40(2)	17,2
21.	YCM1+Hitachi VM50	16,9
22.	Hitachi VM40(2)+Hitachi VM50	16,3
23.	Hitachi VM50+Haas	16,2
24.	YCM1+YCM2+HitachiVM40(2)	16,1
25.	HitachiVM40(1)+HitachiVM40(2)	7,4
26.	YCM1+YCM2	7,1
27.	Dahlih+Toyoda	7,0
28.	Dahlih	0,0
29.	Hitachi VM50	0,0
30.	Toyoda	0,0
31.	YCM2	0,0

No.	Combination of milling centres	Operator's route, m
32.	Hitachi VM40(2)	0,0
33.	Haas	0,0
34.	Hitachi VM40 (1)	0,0

Table 14 shows a list of combinations by the Operator‘s route. Operator‘s route is a distance, an operator has to walk from the first milling centre to second, third or fourth milling centre and to return to the starting point.

From Table 14 we can see that there were four combinations in November, where an operator had to walk more than 40 m from the first milling centre to others and return back. These combinations consist of four or three milling centres, so there is a possibility to locate milling centres nearby and to reduce the walking distance for the operator. On the other hand, Table 14 shows combinations only by walking distance and from this table it is not appropriate to decide which milling centres should be located nearby. So, the main factor should be machining time.

The Pareto analysis will help to understand which combinations are vital for our research. The Pareto analysis is a technique for focusing attention on the most important problem areas. Often referred to as the 80-20 rule, the Pareto concept states that approximately 80 percent of problems come from 20 percent of the items. In our case, 20% of combinations were working 80% of the total machining time. These 20% of milling centres are significant for the creation of the new layout.

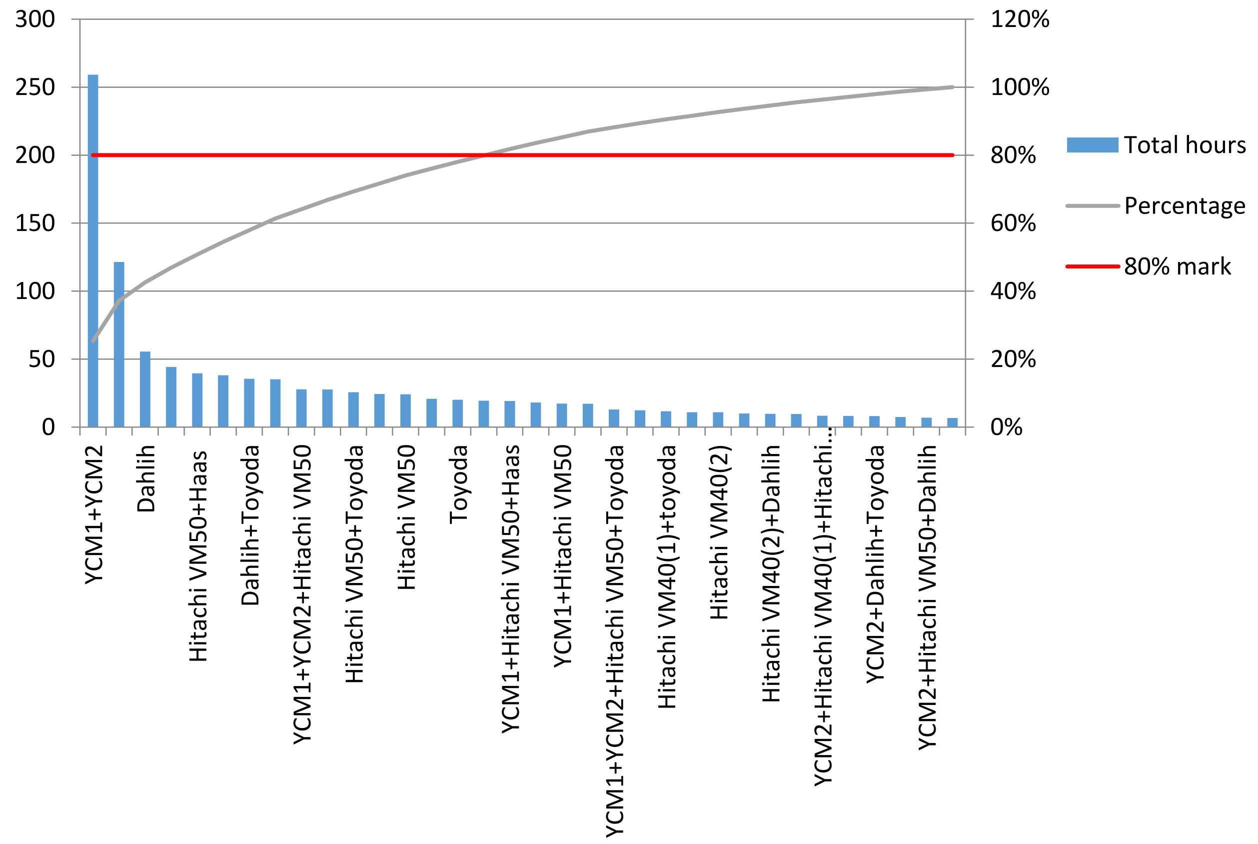


Fig. 12. Pareto chart of vital combinations

The Pareto diagram in Fig. 12 represents, which combinations have the biggest impact and should be analysed. All vital combinations with an operator‘s route and percentage from the total machining hours are presented in Table 15.

Table 15. Vital combinations of milling centres after Pareto chart

No.	Combination of milling centres	Percentage from total machining hours, %	Operator’s route, m
1.	YCM1+YCM2	25,29	7,1
2.	HitachiVM40(1)+HitachiVM40(2)	11,85	7,4
3.	Dahlih	5,43	0
4.	YCM1+YCM2+HitachiVM40(2)	4,32	16,1
5.	Hitachi VM50+Dahlih	3,72	23,3
6.	Dahlih+Toyoda	3,47	7,0
7.	Hitachi VM40(1)+Hitachi VM40(2)+Toyoda	3,44	34,6
8.	Hitachi VM50+Haas	3,86	16,2
9.	YCM1+YCM2+Hitachi VM50	2,71	25,6
10.	YCM1+YCM2+Hitachi VM40(2)+Hitachi VM50	2,70	29,1
11.	Hitachi VM50+Toyoda	2,50	31,5
12.	YCM1+YCM2+Toyoda	2,38	42,6
13.	Hitachi VM50	2,35	0
14.	HitachiVM40(1)+HitachiVM40(2)+Dahlih+Toyoda	2,03	32,7
15.	Toyoda	1,89	0
16.	YCM1+YCM2+Dahlih	1,89	37,0

4.2.3 Use of Systematic layout planning technique

For the creation of a new layout of the milling department, it is important to understand which pairs of milling centres are important and unimportant. Evaluation of important and unimportant pairs will help to understand, which milling centres can be located nearby in a new layout. Richard Muther developed a more general approach to the problem, which allows for subjective input from analysis or managers to indicate the relative importance of each combination of department pairs (20). That information is then summarized in a Muther’s grid. In our case, letter codes in Muther’s grid shows the importance of closeness for pairs of milling centres: A – absolute necessary, E – especially important, I – important, O – okay, U – unimportant, X, undesirable (19). In our research only three codes are used: A – for milling centres, which are working in a pair, E – for milling centres, which are working in the same combination of three or four milling centres, U – for milling centres, which are not connected to the same pairs or combinations. Muther’s grid for our case is shown in Fig. 13.

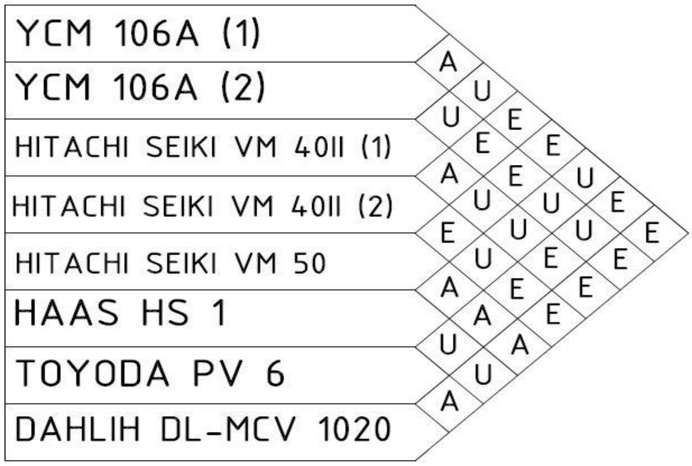


Fig. 13. Muther's grid

Fig. 13 shows, that six pairs were evaluated as absolutely necessary to be located next to each other:

1. YCM 106A (1) and YCM 106A (2);
2. Hitachi Seiki VM 40II (1) and Hitachi Seiki VM 40II (2);
3. Hitachi Seiki VM 50 and Haas HS 1;
4. Toyoda PV 6 and Dahlih DL-MCV 1020;
5. Hitachi Seiki VM 50 and Toyoda PV 6;
6. Hitachi Seiki VM 50 and Dahlih DL-MCV 1020.

A milling centre Hitachi Seiki VM 50 was mentioned three times in absolutely necessary pairs, so from this milling centre a creation of a new layout should be started. Next to Hitachi Seiki VM 50, Haas HS 1, Toyoda PV 6 and Dahlih DL-MCV 1020 milling centres are located because these milling centres formed pairs with Hitachi Seiki VM 50. On the other part of the layout, YCM 106A and Hitachi Seiki VM 40II milling centre are located, because most of the time YCM's 106A and Hitachi's are working in pairs. The best of created layouts, where Hitachi Seiki VM 50 is the central milling centre, is represented in Fig. 14.

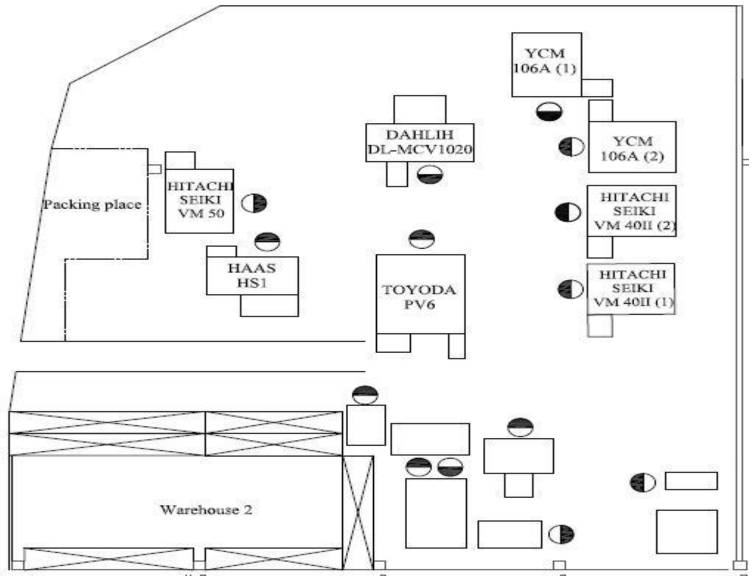


Fig. 14. Proposal of layout No. 1

The second proposal of the layout was prepared in a little bit different way. The creation of the layout started from Dahlih DL-MCV 1020 milling centre, connecting it with Haas HS 1, Toyoda PV6 and Hitachi Seiki VM 50. Like in proposal No. 1, YCM 106A and Hitachi Seiki VM40II were located next to each other. Proposal No. 2 is shown in Fig. 15.

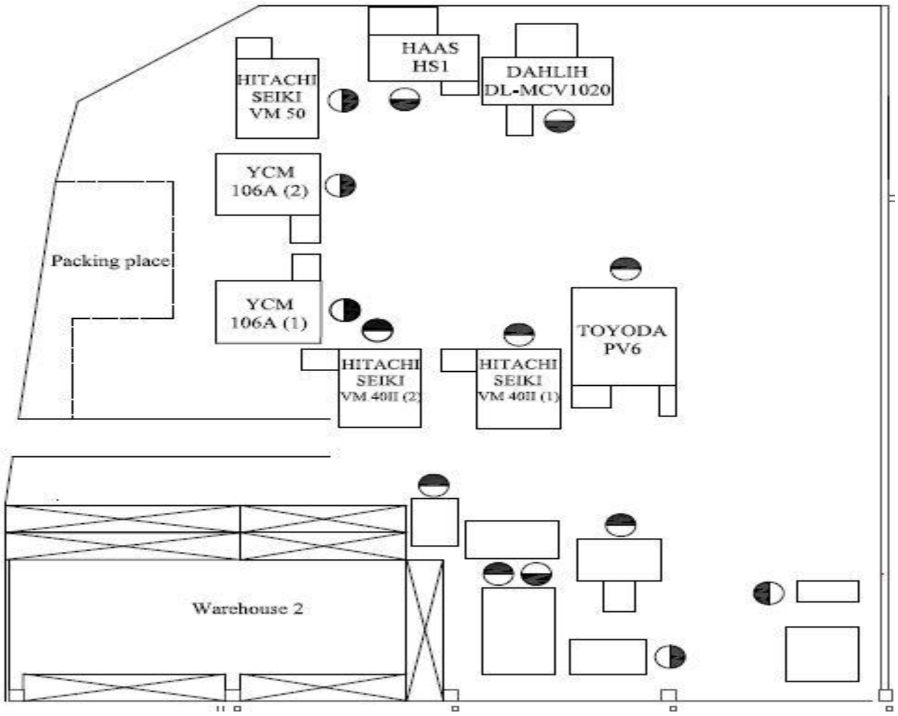


Fig. 15. Proposal of layout No. 2

Proposals No. 1 and No. 2 for layout improvement were selected from the best researched options. The main purpose of the creation of new layouts was to reduce movement waste for operators and to adapt the layout of the milling bar to the current situation. Comparison of operator's route among the current situation and proposals is shown in Table 16.

4.2.4 Comparison of results

Table 16. Comparison of operator‘s routes of the current layout and proposed layouts

No.	Combination of milling centres	Operator's route on the current layout, m	Operator's route in proposal No. 1, m	Operator's route in proposal No. 2, m	Difference between the current layout and proposal No.1, No.2, %
1.	YCM1+YCM2	7,1	5,3	9,4	-25,4; +32,4
2.	HitachiVM40(1)+HitachiVM40(2)	7,4	7,2	7,6	-2,7; +2,7
3.	Dahlih	0	0	0	0
4.	YCM1+YCM2+HitachiVM40(2)	16,1	11,2	13,6	-30,4;

No.	Combination of milling centres	Operator's route on the current layout, m	Operator's route in proposal No. 1, m	Operator's route in proposal No. 2, m	Difference between the current layout and proposal No.1, No.2, %
					-15,5
5.	Hitachi VM50+Dahlih	23,3	14,4	15,2	-38,2; -34,8
6.	Dahlih+Toyoda	7,0	8,4	14	+20,0; +100,0
7.	Hitachi VM40(1)+Hitachi VM40(2)+Toyoda	34,6	19	16,6	-45,1; -52,0
8.	Hitachi VM50+Haas	16,2	5,2	5,8	-67,9; -64,2
9.	YCM1+YCM2+Hitachi VM50	25,6	29,4	15,8	+14,8; -38,3
10.	YCM1+YCM2+Hitachi VM40(2)+Hitachi VM50	29,1	35,5	20	+22,0; -31,3
11.	Hitachi VM50+Toyoda	31,5	13,4	21,8	-57,5; -30,8
12.	YCM1+YCM2+Toyoda	42,6	20,1	27,8	-52,8; -34,7
13.	Hitachi VM50	0	0	0	0
14.	HitachiVM40(1)+HitachiVM40(2)+Dahlih+Toyoda	32,7	27,6	30,6	-15,6; -6,4
15.	Toyoda	0	0	0	0
16.	YCM1+YCM2+Dahlih	37,0	16,9	24,4	-54,3; -34,1
The total route:		310,2	203,6	222,6	-34,4; -28,2

Table 16 shows that the smallest sum of operator's route is in proposal No. 1. Fig. 16 shows that the total sum of operator's route on the current layout is 310,2 m., than in proposal No. 1 it is 203,6 m. It is 34,4% less than in the current layout. The total sum of operator's route in proposal No. 2 is 222,6 m., it is 28,2% less than in the current layout. Operator's route in proposal No. 1 for combinations Hitachi VM50+Haas HS 1, Hitachi VM50+Toyoda PV6, YCM 106A (1)+YCM 106A (2)+Toyoda PV6, YCM 106A (1)+YCM 106A (2)+Dahlih DL-MCV1020 are reduced more than two times. Fig. 17 shows a comparison of the used area in all layouts. The current layout occupies 230,6 m^2 area, proposed layout No. 1 – 176,6 m^2, proposed layout No. 2 – 166 m^2.

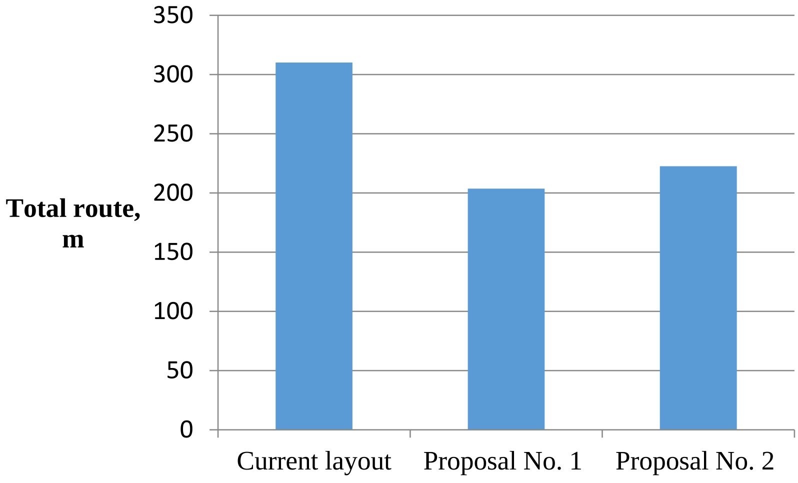


Fig. 16. Comparison of the total route

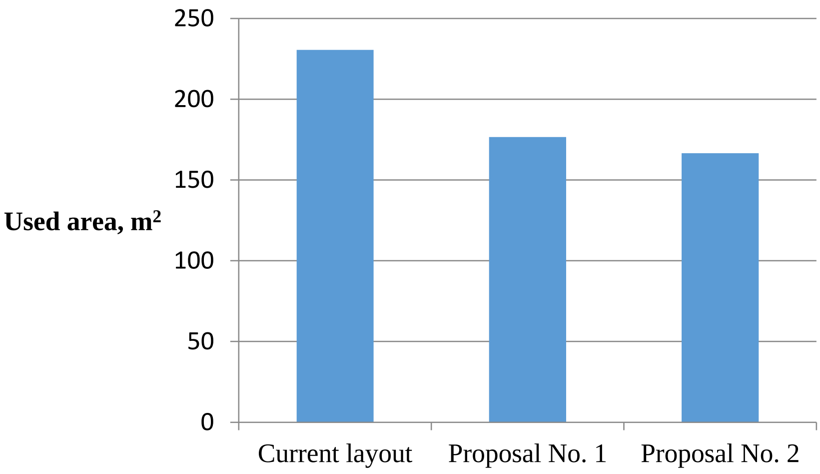


Fig. 17. Comparison of used area

Results of the research show that research was successful and proposal No. 1 can be implemented in production. Layout No. 1 is better than Layout No. 2 in the total route result, so because of this layout No. 2 is not the best option. Proposed layout No. 1 will significantly reduce the walking distance for operators. The total sum of operator's route for 16 combinations is 203,6 m. and it is 34,4% less than in the current layout. An occupied area in the layout No. 1 is 23,4% smaller than in the current layout. Also, a new layout will increase productivity and will not weary operator so much, because operator's route will be reduced significantly.

In the next section of the project creation of Standard work for a part "Axe" is presented.

4.4 Creation of Standard work

4.4.1 Observation and Standard time calculation

After the implementation of the new layout in the milling department other smaller improvements can be started, as an implementation of Standard work in manufacturing operations. The first product where Standard work should be implemented is part "Axe". As mentioned earlier, "Axe" is one of the oldest products but Standard work can help to improve 2nd milling operation of this product and make the process more stable.

Creation of Standard work procedure for 2nd milling operation of "Axe" started from the observation. All milling operation was divided into subgroups for the calculation of average time. Before the observation, were decided that sample size will be 10 cycles. One cycle consists of 11 subgroups. In the observation stopwatch, photo and video cameras were used.

Table 17. Observed time

Subgroup	Observed time, s										Average subgroup time, s
Putting a part into clamps	28	26	29	25	30	26	27	29	28	27	27,5
Fastening of bolts	13	15	16	14	17	13	17	13	12	14	14,4
Milling operation	660	660	660	660	660	660	660	660	660	660	660
Taking out a part	20	19	21	20	18	21	23	18	18	19	19,7
Putting a new part into clamps	27	25	26	29	30	25	27	28	26	27	27,0
Part's blowing off	3	4	3	3	5	4	4	3	3	5	3,4
Cleaning with a small knife	17	15	20	18	19	16	14	19	18	17	17,3
Making of chambers	20	23	18	21	22	18	18	22	21	17	20,0
Chambers in the intersection of plane and hole	6	9	6	7	8	8	7	6	6	8	7,1
Part's cleaning with a grinding sponge	24	18	23	25	23	19	19	25	22	26	22,4
Putting a part into the batch	6	7	7	5	8	7	6	6	8	6	6,6
The total operation time, s	826	821	829	827	840	817	822	829	822	826	825,4

Results of the observation are shown in Table 17. The observed time is not the actual time required to accomplish the work for the operator. It is normalized using the performance rating factor (25). The observed time should be used for a normal time calculation (formula 2).

$$normal\ time = observed\ time \times \frac{rating\ in\ percent}{100} \qquad (2)$$

Westinghouse performance rating table should be used for the evaluation of the worker's performance rating. Westinghouse performance rating consists of four factors: skill, effort, environmental condition, consistency (26). According to observation, the performance rating of the operator was evaluated:

1. Good skill, C1. +0,06;
2. Good effort, C1. +0,05;
3. Average condition, D. 0,00;
4. Average consistency, D. 0,00.

According to formula (2) normal times for all subgroups were calculated. Except for milling operation, because duration of the machining process is constant.

Table 18. Normal times for subgroups

Subgroup	Normal time
Putting a part into clamps	30,53
Fastening of bolts	15,98
Milling operation	Not calculated
Taking out a part	21,87
Putting a new part into clamps	29,97
Part's blowing off	3,77
Cleaning with a small knife	19,20
Making of chambers	22,20
Making a chamber in the intersection of plane and hole	7,88
Part's cleaning with a grinding sponge	24,86
Putting a part into the batch	7,33

Table 18 shows normal times for all subgroups of the cycle. Also, table 18 shows that a normal time is bigger than the observed time.

Standard time is calculated from the formula (3). As shown in formula (3), allowances are needed for the calculation. Allowances are recommended by International Labor Organization (ILO) (27). According to results of observation and ILO recommended allowances, for this cycle these allowances were assigned:

1. Basic fatigue allowance – 4%;
2. Standing allowance – 2%;
3. Monotony allowance – 1%;
4. Tedious – 2%

$$standard\ time = normal\ time \times \frac{100}{100 - allowance\ in\ \%} \quad (3)$$

According to Formula 3, standard times for subgroups were calculated. Table 19 shows results of standard time calculations for these subgroups.

Table 19. Standard times of subgroups

Subgroup	Standard time
Putting a part into clamps	33,58
Fastening of bolts	17,58
Milling operation	Not calculated
Taking out a part	24,05
Putting a new part into clamps	32,97
Part's blowing off	4,15
Cleaning with a small knife	21,12
Making of chambers	24,42
Making a chamber in the intersection of plane and hole	8,67
Part's cleaning with a grinding sponge	27,35
Putting a part into the batch	8,06

Standard times were rounded off and used in Standard work procedure for the evaluation of time. Duration of one cycle written in the Standard work procedure is 862 seconds. In this pace, the operator can do 41 part because the duration of working time in a shift is 27600 seconds.

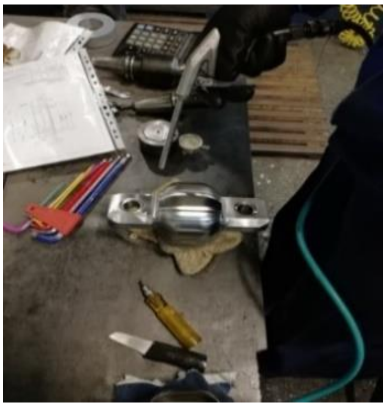
4.4.2 Standard work procedure

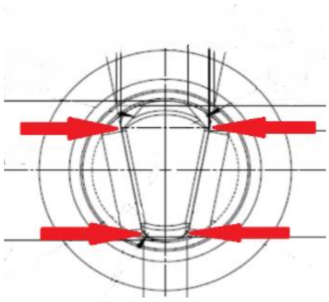
Standard work procedure for part's "Axe" 2nd milling operation is shown in Table 20.

Table 20. Standard work procedure

	Standard work procedure	*Instruction*	ABF 5.3-06
Name	**2nd milling operation of Axis**	*Version*	1
Equipment	YCM106A	*Valid*	2019-05-20
Goal	Correctly make parts cleaning after 2nd milling operation		
PPE	Gloves, glasses		
No.	Work sequence	Time, s	Comments/Photos
1.	**Putting a part into clamps** An operator is taking two parts and putting it into clamps	34	

	Standard work procedure	*Instruction*	ABF 5.3-06
Name	**2^{nd} milling operation of Axis**	*Version*	1
Equipment	YCM106A	*Valid*	2019-05-20
Goal	Correctly make parts cleaning after 2^{nd} milling operation		
PPE	Gloves, glasses		
No.	Work sequence	Time, s	Comments/Photos
2.	**Fastening of bolts** An operator is taking 30 mechanical wrench and fastening bolts for both clamps.	18	
3.	**Milling operation** An operator closes the safety doors and pushes START button. The milling operation starts. **Attention:** before the start up safety doors must be closed.	660	
4.	**Taking out a part** An operator is opening safety door, releasing bolts of the clamp, rotating clamping plane and taking out a part.	24	
5.	**Putting a part into clamps** An operator is taking two parts and putting it into clamps	33	

	Standard work procedure	*Instruction*	ABF 5.3-06
Name	**2nd milling operation of Axis**	*Version*	1
Equipment	YCM106A	*Valid*	2019-05-20
Goal	Correctly make parts cleaning after 2nd milling operation		
PPE	Gloves, glasses		
No.	Work sequence	Time, s	Comments/Photos
6.	**Part's blowing off** Firstly, an operator is cleaning part's surface with a cloth. Put a part on a work table and blow off the part with compressed air from emulsion and burrs.	4	
7.	**Cleaning with a small knife** An operator is taking a small knife and cleaning all intersections of sphere and plane. Also, he cleans all inner surfaces of holes.	21	 
8.	**Making of chamfers** An operator is taking a solid pin and making chamfers on both sides.	24	 

	Standard work procedure	*Instruction*	ABF 5.3-06
Name	**2nd milling operation of Axis**	*Version*	1
Equipment	YCM106A	*Valid*	2019-05-20
Goal	Correctly make parts cleaning after 2nd milling operation		
PPE	Gloves, glasses		
No.	Work sequence	Time, s	Comments/Photos
			
9.	**Making a chamfer in the intersection of the plane and hole** An operator is taking a solid pin and making chamfers in all intersections of the plane and hole. **Attention:** make this chamber carefully, because a quick move of solid pin can make scratches on the surface of plane.	9	
10.	**Part’s cleaning with a grinding sponge** Operator is taking a P120 grinding sponge and cleaning all planes. After that, he blows off the part with compressed air from burrs.	27	
11.	**Putting a part into the batch** Operator is putting a part to the batch.	8	
Total time		862 s	14 min. 22 s

Standard work procedure for the 2nd milling operation of “Axis” is the most efficient and safe way to make this operation. Standard work procedure shows how to make every step in operation and how much time every step needs. Time for every step of the procedure was calculated using ILO allowances and Westinghouse performance rating. An operator can check his pace according to time written in the Standard work procedure and to understand is he working efficiently or not. One cycle is equal to 862 seconds. In this pace, the operator can produce 41 part in a shift.

Conclusions and recommendations

The hypothesis is approved. An acceptance sampling plan and Standard work will have an evident impact for improvement of quality management if these proposals will be implemented. Also, the proposed layout for the milling bar is better than the current layout by an occupied area and the total operator's route and this will reduce the motion of operator. All these improvements will help to reduce cycle times and make the process of quality more stable.

1. A universal acceptance sampling plan for different groups of customers is prepared. In a sampling plan customers were categorized into three groups: main customers (TOP6 customers), not TOP customers (constant orders) and other customers (solitary orders). Every group was separated into two groups: old product and new product. Acceptance quality level (AQL) for new products is smaller than for old products: main customers/old products $AQL = 1$; main customers or new customer/new product $AQL = 0{,}65$; not TOP customer/old product $AQL = 1{,}5$; not TOP customers/new product $AQL = 1{,}0$; other customers/old product $AQL = 4{,}0$; other customer/new product $AQL = 2{,}5$. Sampling conditions for all groups in the start of use of sampling plan is normal inspection, inspection level – I level, sampling plan – single sampling. Categorizing of customers in acceptance sampling plan does not mean that for main customer company produces parts with a better quality, acceptance sampling plan clarifies sampling procedure for all products. Acceptance sampling plan has to be reviewed and renewed continuously according to a quality history of the products.
2. A new layout for the milling department is prepared. If the total sum of operator's route in the current layout is 310,2 m., than in the proposed layout it is 203,6 m. It is 34,4% less than in the current layout. Operator's route in a new layout for combinations of milling centres Hitachi VM50 and Haas HS1; Hitachi VM50 and Toyoda PV1; YCM 106A(1)&YCM 106A(2) &Toyoda PV1, YCM 106A(1)&YCM 106A(2)& Dahlih DL-MCV 1020 are reduced more than twice. Also, an occupied area in the proposed layout is 23,4% smaller than in the current layout.
3. Standard work instruction for part's "Axe" 2nd milling operation was written. Time for every step of the procedure was calculated using ILO allowances and Westinghouse performance rating. Duration of standard work is equal to 862 seconds. In this pace, operator can produce 41 parts in a shift.

After the implementation of universal acceptance sampling plan and Standard work, installation of the new layout in the milling department other works can be done for companies improvement. A layout of the turning department should be revised and improved. New Standard works for other products should be written and implemented for the improvement of efficiency and productivity. 5S projects can be done in a turning and milling department for a better workplace organization. Also, reasons for long cycle times and unstable process of quality control in Table 3 have to be revised and implemented or rejected.

List of references

1. BANOVAC, E., D. PAVLOVIC and N. VISTICA. Analyzing the Characteristics of Sampling by Attributes. *Proceedings of the 12th WSEAS International Conference on ROBOTICS, CONTROL and MANUFACTURING TECHNOLOGY (ROCOM'12).* 2012, pp. 158-163.

2. ASLAM, Muhammad et al. Mixed Acceptance Sampling Plans for Product Inspection Using Process Capability Index. *Quality Engineering.* 2014, Vol. 26, 4, pp. 450-459.

3. FALLAHNEZHAD, MS and A.Y BABADI. A new acceptance sampling plan using Bayesian approach in the presence of inspection errors. *Transactions of the Institute of Measurement and Control.* 2015, Vol. 37(9), pp. 1060–1073.

4. YEN, C-H., C-H. CHANG and M. ASLAM. Repetitive variable acceptance sampling plan for one-sided specification. *Journal of Statistical Computation and Simulation.* 2015, Vol. 85, 6, pp. 1102-1116.

5. SHEWALE, P.P., M.S SHETE and S.M SANE. Improvement in plant layout using Systematic layout planning (SLP) for increased productivity. *International Journal of Advanced Engineering Research and Studies.* 2012, Vol. 1, 3, pp. 259-261.

6. MUTHER, R. and L. HALES. *Systematic layout planning.* Marietta : MANAGEMENT & INDUSTRIAL RESEARCH PUBLICATIONS, 2015. ISBN 978-0-933684-06-5.

7. SUHARDINI, D., W. SEPTIANI and S. FAUZIAH. Design and Simulation Plant Layout Using Systematic Layout. *IOP Conference Series: Materials Science and Engineering.* 2017, Vol. 277, 1.

8. OJAGHI, O. et al. Production Layout Optimization for Small and Medium Scale Food Industry. *Procedia CIRP.* 2015, Vol. 26, pp. 247-251.

9. NAQVI, S.A.A et al. Productivity improvement of a manufacturing facility using systematic layout planning. *Cogent Engineering.* 2016, Vol. 3:1207296.

10. SHARMA, P. and S. SINGHAL. Implementation of fuzzy TOPSIS methodology in selection of procedural approach for facility layout planning. *The International Journal of Advanced Manufacturing Technology.* 2017, Vol. 88, 5-8, pp. 1485–1493.

11. Proplanner. *Flow planner.* [Online] [Cited: 17 April 2019.] https://www.proplanner.com/solutions/material-logistics-planning/flow-planner.

12. MRUGALSKA, B. and M.K WYRWICKA. Towards Lean Production in Industry 4.0. *Procedia Engineering.* 2017, Vol. 182, pp. 466-473.

13. LANTZ, A., N. HANSEN and C. ANTONI. Participative work design in lean production: A strategy for dissolving the paradox between standardized work and team proactivity by stimulating team learning? *Journal of Workplace Learning.* 2015, Vol. 27, 1, pp. 19-33.

14. PIENKOWSKI, M. Waste measurement technique for lean. *International Journal of Lean thinking.* 2014, Vol. 5, 1, pp. 1-14.

15. BRAGANCA, S. and E. COSTA. An application of the Lean production tool Standard work. *Jurnal Teknologi.* 2015, Vol. 76, 1, pp. 47-53.

16. HUTCHINS, G. *Introduction to Quality Management, Assurance, and Control.* New York : Macmillan Publishing Company, 1991. pp. 158, 172-173. ISBN 0-675-20869-3.

17. GRYNA, M. F. *Quality Planning & Analysis.* New York : McGraw-Hill Higher Education, 2001. p. 574. ISBN 0-07-039368-0.

18. WADSWORTH, M. H., S. K STEPHENS and A.B. GODFREY. *Modern Methods for Quality Control and Improvement.* New York : John Wiley & Sons, 2002. p. 557. ISBN 0471299731.

19. RUSEELL, S.R. and B.W TAYLOR III. *Operations management.* New Jersey : Prentice Hall, Inc., 1995. pp. 273-275. ISBN 0-13-849936-5.

20. STEVENSON, J. W. *Production/Operations management.* Boston : Irwin McGraw-Hill, 1999. pp. 268-271,502-503. ISBN 0073661120.

21. DALTON, Jeff. *Gemba Walks. In: Great Big Agile.* Berkeley, CA : Apress, 2019. ISBN 978-1-4842-4205-6.

22. Lane, G. *Made-To-Order Lean: Excelling in a High-Mix, Low-Volume Environment.* Boca Raton, FL : CRC Press Taylor&Francis Group, 2015. pp. 135-137. ISBN 13:978-1-4822-4323-9.

23. KULKARNI, P.P, S.S KSHIRE and K.V CHANDRATRE. Productivity improvement throught Lean deployment & work study methods. *International Journal of Research in Engineering and Technology*. 2014, Vol. 03, 02, pp. 429-434.

24. PRQC. *Quality resources.* [Online] [Cited: 04 04 2018.] https://proqc.com/quality-resources/ansi-sampling-tables-web-application-standard/.

25. HARTANI, L.P.S. WORK MEASUREMENT APPROACH TO DETERMINE STANDARD. *International Journal of Management and Applied Science.* 2016, Vol. 2, 10, pp. 192-195.

26. SALVENDY, G. *Handbook of industrial engineering: Technology and operations management.* New York : A Wiley-Interscience Publication, 2001. ISBN 0471-33057-4.

27. ILO Recommended Allowances . *NPTEL.* [Online] [Cited: 03 04 2019.] https://nptel.ac.in/courses/112107142/part1/table9_1.htm.

Appendices

Appendix 1. Used combinations of milling centres and machining times in the milling department in November

According to this data, the most used combinations of milling centres were calculated who let to prepare a proposal for a new layout in the milling department of "ABF LT".

Date	Shift	Operator	YCM 106A (1)	YCM 106A (2)	Hitachi Seiki VM40II (1)	Hitachi Seiki VM40II (2)	Hitachi Seiki VM50	Haas HS1	Dahlih DL-MCV1020	Toyoda PV6
			Machining time in hours							
02/11	1st	J	7,3	3,6						
		L			1,6	3,4				
		E					2,1	7,8		
		V								6,6
	2nd	Z	7,8	3,2		0,5				
		P		1,2	2,5	2				2,6
		B					1,7	7,6		
05/11	1st	Z	7,1	6,1						
		L			5,2	5,2				
		B					1,7	7,8		
		V								4,2
	2nd	J	7,8	6,5					5,1	
		E						7,8		2,2
06/11	1st	Z	4,9	4,5			1,5			
		L			3,8	3,1				4,2
		B					3	7,8		
		N							5,9	
	2nd	J	5,5	6,5						
		E						7,8	3,2	
07/11	1st	Z	5,5	2						
		B	1,8				3,7	6		
		L			5,2	4,2				4,3
	2nd	J	2	7,7						
		E	4,1				3,6	2,8		
		Č								4,5
08/11	1st	B	5,8	2,8			1,8			
		K		2,4						
		Z		2,5			3,1		1,3	

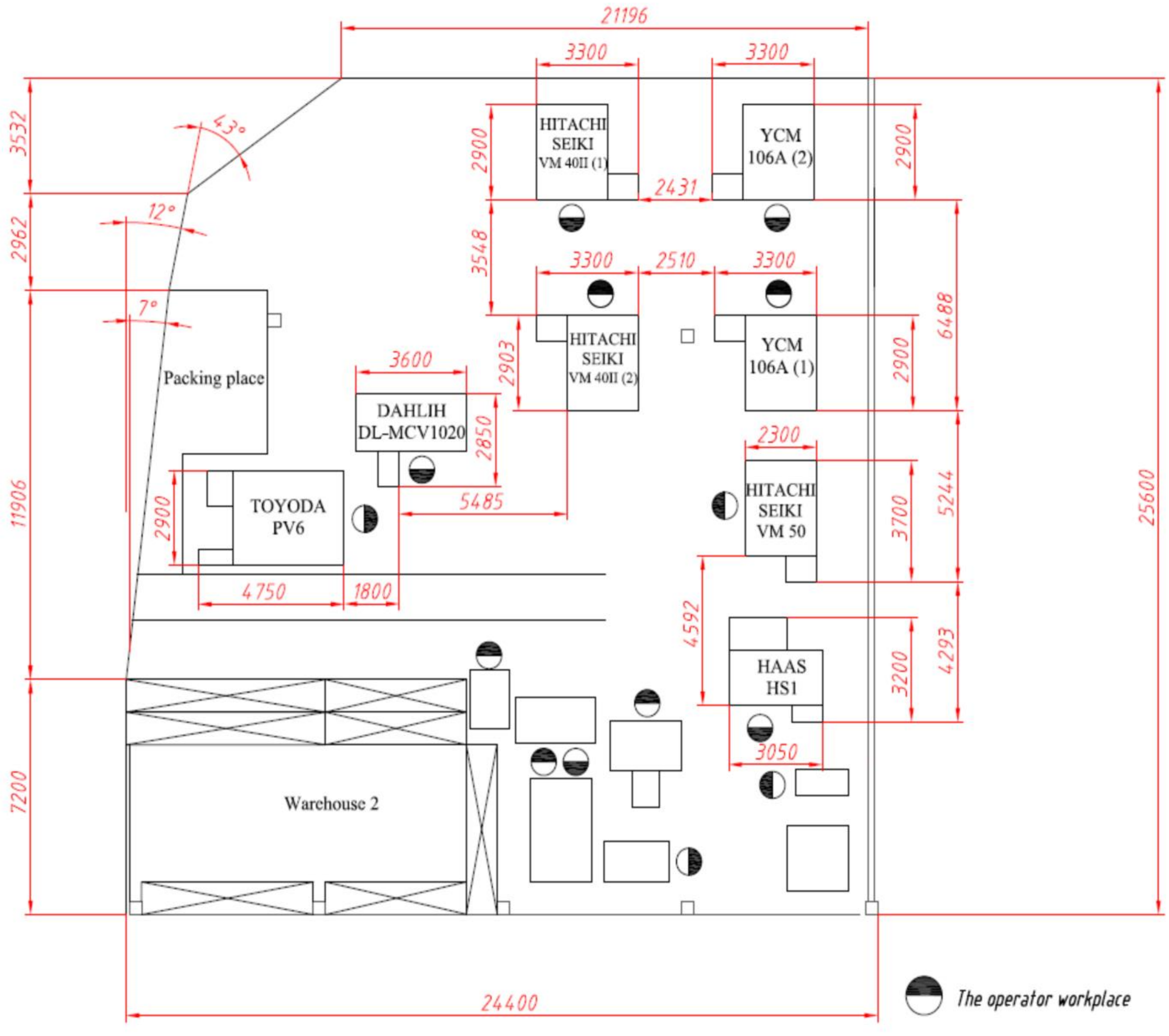
Date	Shift	Operator	YCM 106A (1)	YCM 106A (2)	Hitachi Seiki VM40II (1)	Hitachi Seiki VM40II (2)	Hitachi Seiki VM50	Haas HS1	Dahlih DL-MCV1020	Toyoda PV6
			Machining time in hours							
		L			4,4	3,5				4,7
		V							2,8	
	2nd	J		7,4						
		E	6,2				3,2			
		Č								4,8
09/11	1st	B	6,3				1,6			
		Z		8,3						
		L			4,2	3,3				4,6
		V							7,7	
	2nd	J		7,2			1			
		E	1,5				1	6,2		
		Č							2,5	5,5
12/11	1st	J	6	2						
		E						7,4		
		L			5,5	2,3				3,7
		V							4,7	
	2nd	B	4,1	1,5			0,9			
		Z					1,5		3,5	
13/11	1st	J					6,5			
		E	5,4	3,4						
		L			4,4					7,2
		V								
	2nd	B	5,5	3,6						
		Z					2,3			4,5
14/11	1st	E	3,3	4		0,2				
		J	2,5				6,2			
		L			3,1	2,6			4,6	0,5
	2nd	Z	7,3	4,3						1,2
		E			1					
		B							2,1	3,1
15/11	1st	E					5,9			1,4
		J	7,3	3,8						
		L			1,6	1,3			5,8	1,3
	2nd	Z	7,3	6,5						
		B					4,5			2,5
16/11	1st	E					7,7			

Date	Shift	Operator	YCM 106A (1)	YCM 106A (2)	Hitachi Seiki VM40II (1)	Hitachi Seiki VM40II (2)	Hitachi Seiki VM50	Haas HS1	Dahlih DL-MCV1020	Toyoda PV6
			Machining time in hours							
		J	5,1	4						2,5
	2nd	Z	7,4	4						
		B					1,1			4,2
		Y				3,5			6,3	
19/11	1st	B		0,5					6,9	0,7
		Z	7,8	3,5		1	1			
		Y			5,7					
	2nd	J	7,7	1,5						
		E				7,5	7,5			2,2
20/11	1st	B					1,3		6	5
		Z	6,5	3			1,5			2
		Y			5,5	5				
	2nd	J	7,2	7,4						
		E				6,7				
		S					3,25		1,7	
21/11	1st	B							5,9	2,5
		Z	6	5		5				
		Y			5,5	0,7				
	2nd	J	1,3	5		3				
		E				0,6	0,4			
		P							7,4	
22/11	1st	B					0,4		7,5	
		Z	2	6,5						
		Y				3				
	2nd	J	7,7			1	1			
		E				1,5				
		P							7,4	
23/11	1st	B					0,8		7,5	
		Z	7	4,3						
		Y			6,7	1				
	2nd	J	5,1	5,5						
		E				1,2				
		P							3,4	4,7
26/11	1st	J					3,5			
		P							4,7	1,1
		E			2,5	3,4				

Date	Shift	Operator	YCM 106A (1)	YCM 106A (2)	Hitachi Seiki VM40II (1)	Hitachi Seiki VM40II (2)	Hitachi Seiki VM50	Haas HS1	Dahlih DL-MCV1020	Toyoda PV6
			Machining time in hours							
	2nd	B							7,4	
		Z	7,9	2,1						
		Y			4,4	1,7				
27/11	1st	Z	6	5,7		1,5	1,2			
		P					2		7,4	
		E			4,4	1,1				
	2nd	J	2	7,7						
		Y			4,4	4,4				
		B							7,6	
28/11	1st	J	1,6	7,4						
		E			5	3,7				
		P							4,7	
	2nd	B	4,3	7						
		Z					6,4			
		Y			4	2,9				
29/11	1st	J	5,3	7						
		E			4,8	2,3				
		P					2		5	
	2nd	B	4,8	7						
		Z					4,5			2
		Č					2		3	
		Y			2,8	4				

Appendix 2. Scheme of a current layout of the milling department in "ABF LT"

Appendix 2 shows a scheme of the current layout of the milling department. This layout is ineffective because of this a proposal of a new layout was prepared.



	File name	Additional information	Material	Scale 1:240
Resp. department: Dep. of Prod.Engineer.	Technical reference	Document type		Document status: Training
Legal owner: KTU	Created by: Pijus Poškus	Title, Supplementary title: Layout of the milling department	P.P.000.001.01	
	Approved by: Lect.dr.Vaidas Bivainis		Rev. A; Date 2019-05-19	Lang. en; Sheet 1/1