Implementation of Lean Production Elements in Assembly Line at the Company Greiner Assistec, Ltd.

Bc. Renáta Horváthová

Master thesis
2013

Tomas Bata University in Zlín
Faculty of Management and Economics

Univerzita Tomáše Bati ve Zlíně
Fakulta managementu a ekonomiky
Ústav průmyslového inženýrství a informačních systémů
akademický rok: 2012/2013

ZADÁNÍ DIPLOMOVÉ PRÁCE

(PROJEKTU, UMĚLECKÉHO DÍLA, UMĚLECKÉHO VÝKONU)

Jméno a příjmení:	**Bc. Renáta Horváthová**
Osobní číslo:	**M11476**
Studijní program:	**N6208 Ekonomika a management**
Studijní obor:	**Průmyslové inženýrství**
Forma studia:	**prezenční**

Téma práce: **Zavádění prvků štíhlé výroby na montážní lince ve společnosti Greiner Assistec, s.r.o.**

Zásady pro vypracování:

Úvod

I. Teoretická část

- **Zpracujte literární rešerši k dané oblasti a formulujte teoretická východiska pro zpracování analytické a projektové části.**

II. Praktická část

- **Proveďte analýzu současného stavu montážní linky ve společnosti Greiner Assistec, s.r.o.**
- **Zhodnoťte výsledky analýzy a navrhněte ideový záměr pro řešení optimalizace montážní linky podle zásad štíhlé výroby.**
- **Vypracujte projektové řešení vybraných prvků ideového záměru a zhodnoťte z hlediska jejich proveditelnosti.**

Závěr

Rozsah diplomové práce: **cca 70 stran**

Rozsah příloh:

Forma zpracování diplomové práce: **tištěná/elektronická**

Seznam odborné literatury:

KEŘKOVSKÝ, Miloslav a Ondřej VALSA. Moderní přístupy k řízení výroby. 3., dopl. vyd. V Praze: C.H. Beck, 2012, xxi, 153 s. ISBN 978-80-7179-319-9.

KOŠTURIAK, Ján a Zbyněk FROLÍK. Štíhlý a inovativní podnik. Praha: Alfa Publishing, 2006, 237 s. ISBN 80-86851-38-9.

LIKER, Jeffrey K. The Toyota way: 14 management principles from the world's greatest manufacturer. New York: McGraw-Hill, c2004, xxii, 330 s. ISBN 0071392319.

MAŠÍN, Ivan. Výkladový slovník průmyslového inženýrství a štíhlé výroby. Vyd. 1. Liberec: Institut technologií a managementu, 2005, 106 s. ISBN 80-903533-1-2.

MAŠÍN, Ivan a Milan VYTLAČIL. Nové cesty k vyšší produktivitě: metody průmyslového inženýrství. 1. vyd. Liberec: Institut průmyslového inženýrství, 2000, 311 s. ISBN 80-902235-6-7.

Vedoucí diplomové práce: **Ing. Iva Dvořáková**

Ústav průmyslového inženýrství a informačních systémů

Datum zadání diplomové práce: **21. června 2013**

Termín odevzdání diplomové práce: **12. srpna 2013**

Ve Zlíně dne 21. června 2013

UNIVERZITA TOMÁŠE BATI VE ZLÍNĚ
Fakulta managementu a ekonomiky

L.S.

prof. Dr. Ing. Drahomíra Pavelková
děkanka

prof. Ing. Felicita Chromjaková, Ph.D.
ředitel ústavu

PROHLÁŠENÍ AUTORA DIPLOMOVÉ PRÁCE

Beru na vědomí, že:

- odevzdáním ~~bakalářské~~/diplomové práce souhlasím se zveřejněním své práce podle zákona č. 111/1998 Sb. o vysokých školách a o změně a doplnění dalších zákonů (zákon o vysokých školách), ve znění pozdějších právních předpisů, bez ohledu na výsledek obhajoby[1];

- ~~bakalářská~~/diplomová práce bude uložena v elektronické podobě v univerzitním informačním systému,

- na mou ~~bakalářskou~~/diplomovou práci se plně vztahuje zákon č. 121/2000 Sb. o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon) ve znění pozdějších právních předpisů, zejm. § 35 odst. 3[2];

- podle § 60[3] odst. 1 autorského zákona má UTB ve Zlíně právo na uzavření licenční smlouvy o užití školního díla v rozsahu § 12 odst. 4 autorského zákona;

---

[1] *zákon č. 111/1998 Sb. o vysokých školách a o změně a doplnění dalších zákonů (zákon o vysokých školách), ve znění pozdějších právních předpisů, § 47b Zveřejňování závěrečných prací:*

(1) Vysoká škola nevýdělečně zveřejňuje disertační, diplomové, bakalářské a rigorózní práce, u kterých proběhla obhajoba, včetně posudků oponentů a výsledku obhajoby prostřednictvím databáze kvalifikačních prací, kterou spravuje. Způsob zveřejnění stanoví vnitřní předpis vysoké školy.

(2) Disertační, diplomové, bakalářské a rigorózní práce odevzdané uchazečem k obhajobě musí být též nejméně pět pracovních dnů před konáním obhajoby zveřejněny k nahlížení veřejnosti v místě určeném vnitřním předpisem vysoké školy nebo není-li tak určeno, v místě pracoviště vysoké školy, kde se má konat obhajoba práce. Každý si může ze zveřejněné práce pořizovat na své náklady výpisy, opisy nebo rozmnoženiny.

(3) Platí, že odevzdáním práce autor souhlasí se zveřejněním své práce podle tohoto zákona, bez ohledu na výsledek obhajoby.

[2] *zákon č. 121/2000 Sb. o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon) ve znění pozdějších právních předpisů, § 35 odst. 3:*

(3) Do práva autorského také nezasahuje škola nebo školské či vzdělávací zařízení, užije-li nikoli za účelem přímého nebo nepřímého hospodářského nebo obchodního prospěchu k výuce nebo k vlastní potřebě dílo vytvořené žákem nebo studentem ke splnění školních nebo studijních povinností vyplývajících z jeho právního vztahu ke škole nebo školskému či vzdělávacího zařízení (školní dílo).

[3] *zákon č. 121/2000 Sb. o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon) ve znění pozdějších právních předpisů, § 60 Školní dílo:*

(1) Škola nebo školské či vzdělávací zařízení mají za obvyklých podmínek právo na uzavření licenční smlouvy o užití školního díla (§ 35 odst. 3). Odpírá-li autor takového díla udělit svolení bez vážného důvodu, mohou se tyto osoby domáhat nahrazení chybějícího projevu jeho vůle u soudu. Ustanovení § 35 odst. 3 zůstává nedotčeno.

- podle § 60[4] odst. 2 a 3 mohu užít své dílo – ~~bakalářskou~~/diplomovou práci - nebo poskytnout licenci k jejímu využití jen s předchozím písemným souhlasem Univerzity Tomáše Bati ve Zlíně, která je oprávněna v takovém případě ode mne požadovat přiměřený příspěvek na úhradu nákladů, které byly Univerzitou Tomáše Bati ve Zlíně na vytvoření díla vynaloženy (až do jejich skutečné výše);

- pokud bylo k vypracování ~~bakalářské~~/diplomové práce využito softwaru poskytnutého Univerzitou Tomáše Bati ve Zlíně nebo jinými subjekty pouze ke studijním a výzkumným účelům (tj. k nekomerčnímu využití), nelze výsledky bakalářské/diplomové práce využít ke komerčním účelům.

Prohlašuji, že:

- jsem ~~bakalářskou~~/diplomovou práci zpracoval/a samostatně a použité informační zdroje jsem citoval/a;

- odevzdaná verze ~~bakalářské~~/diplomové práce a verze elektronická nahraná do IS/STAG jsou totožné.

Ve Zlíně 3.6.2013 ....

---

[4] zákon č. 121/2000 Sb. o právu autorském, o právech souvisejících s právem autorským a o změně některých zákonů (autorský zákon) ve znění pozdějších právních předpisů, § 60 Školní dílo:

(2) Není-li sjednáno jinak, může autor školního díla své dílo užít či poskytnout jinému licenci, není-li to v rozporu s oprávněnými zájmy školy nebo školského či vzdělávacího zařízení.

(3) Škola nebo školské či vzdělávací zařízení jsou oprávněny požadovat, aby jim autor školního díla z výdělku jím dosaženého v souvislosti s užitím díla či poskytnutím licence podle odstavce 2 přiměřeně přispěl na úhradu nákladů, které na vytvoření díla vynaložily, a to podle okolností až do jejich skutečné výše; přitom se přihlédne k výši výdělku dosaženého školou nebo školským či vzdělávacím zařízením z užití školního díla podle odstavce 1.

ABSTRAKT

Cílem diplomové práce bylo optimalizovat montážní linku v repasovací hale společnosti Greiner Assistec, s.r.o.

Diplomová práce byla rozdělena na dvě části, teoretickou a praktickou. V teoretické části byly pomocí odborné literatury zpracovány informace z oblasti štíhlé výroby, metod měření času, jakožto i z oblasti montážních pracovišť a způsobů jejich optimalizace.

Praktická část se zabývá konkrétní situaci podniku řešenou na základě výsledků vstupní analýzy. Zaměřila jsem se především na balancování výroby dle taktu a cyklového času, zásobování jednotlivých pracovišť a možnosti reorganizace práce. V závěru práce byly vybrané optimalizace ověřeny pomocí simulačního program Plant Simulation.

Klíčová slova: montáž, štíhlá výroba, optimalizace procesu

ABSTRACT

The aim of Master thesis was to optimize repasing assembly line of Greiner Assistec Company.

The Master thesis is divided into two parts, theoretical and practical. In theoretical part I have elaborated main information about lean manufacturing, time measurement methods as well as basic data about assembly line and its optimization.

Practical part deals with particular situation in company based on entry analysis. I've focused on balancing production according to the cycle times, supplying individual workplaces and the possibilities of work reorganization. Line optimization proposal was at the end verified by process simulation software called Plant Simulation.

Keywords: assembly, lean production, process optimization

ACKNOWLEDGEMENTS

I would like to express my gratitude to my supervisor, Ms. Ing. Iva Dvořáková, whose expertise, understanding, patience and professional guidance led me to maintain correct direction when processing my Master thesis.

Very special thanks go out to Ms. Ing. Marie Fojtáchová and Mrs. Ing. Jitka Lišková from Greiner Assistec Company, whose motivating approach and encouragement helped mi to handle with the project.

I hereby declare that the print version of my Master's thesis and the electronic version of my thesis deposited in the IS/STAG system are identical.

"What makes life interesting are the challenges we face."

Paulo Coelho, *Like the Flowing River*

CONTENT

INTRODUCTION **7**
I. THEORY **9**
1 LEAN PRODUCTION **10**
1.1 LEAN COMPANY **10**
1.1.1 CREATION AND EVOLUTION 11
1.1.2 LEAN PRODUCTION ELEMENTS 13
1.2 VALUE STREAM MANAGEMENT **19**
1.2.1 VSM RISKS AND CONSTRAINTS 20
1.3 LEAN PRODUCTION IMPLEMENTATION **20**
1.4 THE TOYOTA LEAN MANAGEMENT CONCEPT **21**
2 WORK MEASUREMENT AND ANALYSIS **24**
2.1 WORK STUDIES **24**
2.2 METHOD STUDY **24**
2.2.1 PRINCIPLES OF MOTION ECONOMY 25
2.2.2 PROCESS ANALYSIS 26
2.2.3 CHECK-LISTS 27
2.2.4 ANALYSE USING PHOTOS AND VIDEOS 27
2.3 WORK MEASUREMENT **28**
2.3.1 STOPWATCH TIME STUDY 28
2.3.2 PREDETERMINED TIME STANDARD 29
3 INVENTORIES **31**
3.1 INVENTORY MANAGEMENT **31**
3.1.1 INVENTORY MANAGEMENT TYPES 31
3.2 JUST-IN-TIME **32**
3.2.1 PULL AND PUSH SYSTEM 33
3.2.2 KANBAN 34
4 MANUFACTURING PROCESS **37**
4.1 MANUFACTURING PROCESS TYPOLOGY **37**
4.2 ASSEMBLY **38**
4.2.1 ASSEMBLY SYSTEM AND ASSEMBLY LINE 38
4.2.2 FACTORS INFLUENCING ASSEMBLY SYSTEM 38
4.3 ASSEMBLY LINE OPTIMIZATION **39**
II. ANALYSIS **41**
5 GREINER GROUP **42**
5.1 GREINER ASSISTEC, LTD. **42**
5.2 PRODUCTION PROGRAM AND CUSTOMER PORTFOLIO **43**
5.3 INJECTION MOULDING **44**
5.4 ASSEMBLY **46**
5.5 SWOT ANALYSIS **47**

6 STARTING POINT ANALYSIS **49**
6.1 CHARGER **49**
6.2 FUSER **50**
6.2.1 CLEAN&SCREEN 51
6.2.2 REMAN ACTIVITY 52
6.2.3 ADVANCED PREPARATION I 53
6.2.4 VISUAL INSPECTION 53
6.2.5 ADVANCED PREPARATION II 55
6.2.6 PACKING 55
7 CURRENT STATE ANALYSIS **57**
7.1 DATA COLLECTION METHODOLOGY **57**
7.2 POSITIONS ANALYSIS **57**
7.2.1 CHARGER 58
7.2.2 CLEAN&SCREEN 59
7.2.3 REMAN PROCESS 61
7.2.4 ADVANCED PREPARATION I 61
7.2.5 ADVANCED PREPARATION II 62
7.2.6 VISUAL INSPECTION 63
7.2.7 PACKING 64
7.3 LAYOUT ANALYSIS **65**
8 OPTIMIZATION PROPOSAL **69**
8.1 CONDITIONS **69**
8.2 PROCESS ANALYSIS **70**
8.2.1 IMPROVED PROCESS ANALYSIS 71
8.3 WORK REORGANIZATION **72**
8.4 NEW LAYOUT PROPOSAL **76**
9 PROCESS SIMULATION **77**
9.1 BASIC SETTINGS **77**
9.2 GRADUAL RESULTS **81**
9.3 EFFICIENCY CHARTS **84**
10 RACKS STANDARDIZATION **85**
11 PROJECT EVALUATION **88**
12 ADDITIONAL IMPROVEMENT SUGGESTIONS **90**
12.1 POTENTIAL LINE LAYOUT AND 3D DESIGN **90**
12.2 POTENTIAL 3D WORKPLACES **90**
12.3 SUPPLY BY KANBAN **96**
CONCLUSION **97**
BIBLIOGRAPHY **98**
LIST OF ABBREVIATIONS **101**
LIST OF FIGURES **102**
LIST OF TABLES **104**

APPENDICES **105**
APPENDIX P I: MAYNARD OPERATION SEQUENCE TECHNIQUE TABLES **106**
APPENDIX P II: LOGICALFRAMEWORK **118**
APPENDIX P III: RIPRAN **120**
APPENDIX P IV: FUSER VALUE STREAM MAP **121**
APPENDIX P V: MOTION ANALYSIS **122**

INTRODUCTION

"Reason of the crisis is moral poverty.

Turning point of economic crisis? I do not believe in any turning points that happen just by themselves. The term that we got used to call economic crisis is just a different name for moral poverty. Moral poverty is the reason, economic crisis is just consequence.

There are many people that think it is possible to save the economical decline by money. I am threatened by the consequence of this mistake. In the situation where we are now, we do not need any brilliant twists or combinations. We need moral attitude towards people, work and public property.

Not to support bankruptcy, not to make debts, not to waste values for nothing, not to discriminate workers..... we need to do what helped us to grow after the war period and that is to work hard and to save and to make work and saving more effective, demanding and more honest rather than laziness and wasting.

You are right, it is necessary to overcome the crisis of trust, however with technical, financial or credit actions it will not happen. Trust is very personal and it can only be restored by moral perspective and personal examples."

Tomas Bata 1932

After several gruelling and degrading years, the economic crisis is slowly retreating and positive predictions are taking shape on the horizon. The hopes of people for more jobs and fulfilling lifestyle are increasing and vision of the better future is spreading all over the world. Small and medium-sized business is gaining momentum again, companies launch investments. This chain provides new partnerships as well as formation of new terms and conditions in business.

In the age when every single economy is recovering, it is fundamental for companies not only to solidly retain steady customers, but additionally reach new ones to increase produced value. As competition is getting bigger, companies determine key criterions to select the best partner for their favourable development and operation. In the case of supplier, the most common of these aspects are usually the ability to increase productivity and flexibility in meeting customer`s requirements.

Increasing the productivity and work efficiency is the major challenge of Industrial Engineering. The essential tool for achieving selected goals is downsizing the processes and reducing waste. However, it is necessary to realize, that the aim is not to replace people by machines, but also create conditions that enables people to become even more effective. Because, as Tomas Bata said, *"Buildings - they are just piles of brick and concrete. Machines - they are a lot of iron and steel. Only people can give life to it all."*

Processing my Master thesis I occupied a similar role. Company in which I completed my master project gained a long-term threefold increased contract from its customer. My task was to optimize the repasing lines, relocate activities provided by operators and create a motivating working environment. Proposed changes as well as applied improvements are contained in the following pages of my Master thesis.

I. THEORY

1 LEAN PRODUCTION

1.1 Lean Company

A lean company reduces waste and unneeded production activities when the value adding activities are performed properly. This kind of company is able to produce much more products than not lean competitors in the same time. So the value added to customers is higher and time consumption smaller. The lean company focuses just on the customers' need. There are four areas creating lean company shown in the picture below. (Handzová, 2009)

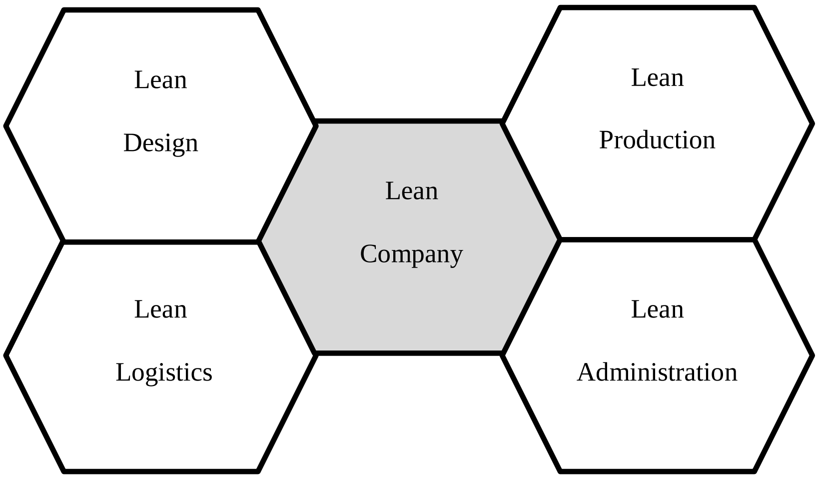


Figure 1: Lean Company

Lean Design is a philosophy focusing on the waste elimination already in the phase of process design. It takes into consideration a product design and its own producing procedure. Lean design advantages are then reflected in the costs, time consumption and quality. (API- Akademie produktivity a inovací , 2012)

Lean Administration is a very important part of the lean company, since the total lead time is a summary of administration work and production. Almost half of this time belongs to administration. The most common causes of this problem are:

- complicated internal communication;
- communication problems with suppliers and customers;
- fluctuating orders and different load of every department;
- not synchronized processes, unqualified employees;
- activities not adding value;
- equipment defects;

- unshared information; (Košturiak, 2012)

Lean Logistics is a process of planning, implementation and control of an effective/efficient product, information and services flow. The flow has an important impact on a company`s success and takes into consideration new trends as:

- mass customization;
- individual requirements;
- online sale; (Uhrová, 2012)

Lean production, also known as Toyota Production System, is a set of tools and principles, which are used for making production stable, flexible and standardized. These tools focus on the workplace, production lines, machines and workers. The lean production philosophy is based on shortening the time between a customer and a supplier (cycle time) and the elimination of waste, which occurs in production process. Its main meaning is to increase value defined by the customer by:

- flexible working teams;
- a low number of production levels in process;
- decentralization, every employee can stop the process after finding a problem;
- high responsibility for quality and production process; (Kyseľ, 2013; API- Akademie productivity a inovací)

Lean production is perceived as:

- a systematic review of whole value creation process and its optimization by Kaizen;
- solving problems by employees directly at the workplace;
- a creation of optimal value stream and cooperation among partners; (Tuček & Bobák, 2006, p. 18)

1.1.1 Creation and Evolution

After the Second World War American manufacturing man was considered to be an outstanding manufacturer whereas both Japan and Toyota Motor Company were in crisis. Therefore in 1950 Eiji Toyoda (his family founded Toyota Motor Company in 1937) together with other professionals visited Ford company in Detroit to study every aspect of this world`s biggest and most efficient manufacturing system, though mass production would never be working in Japan. Japanese were to turn away from inferior production to a sophisticate and a properly (from the perspective of engineering) prepared production system focused on the best quality. Buying licenses, improving them and training students and professionals abroad led to spectacular engineering boom in Japan. Automotive industry was expanding thanks to putting emphasis on higher export.

At the same time American balance of payments retrograded. Americans had to face many reproaches. The way of manufacturing hasn't changed for a long time, production system wasn`t modernized, most of the effort was directed to financial sector, which doesn`t make value, just transfers it.

Table 1: Difference between American and Japanese management (EuroEkonóm.sk, 2012)

Japanese management	**American management**
collectivism	individualism
lifetime employment	job rotation
promotion depends on age	promotion depends on skills
holistic interest in human as employee	segment interest
ringi system[1]	top down system
salary system depends on age	salary system depends on skills
centralization	decentralization
collective decision making	individual decision making
many small changes	a few fundamental changes

That`s the point in which Japanese production overran American in forward standard, flexibility to customer, high rated quality, low expenditure and acceptable price. In the last decades Japanese automobile factories changed the models twice as fast as American factories. The most important person in this evolution was Taichi Ohno. Since 1960s he has

[1] Japanese management principle, in which each employee has a right and obligation to submit an improving proposal in a company and in this way support team work.

innovated Toyota`s production facilities, established Operation Management Consulting Division to support lean thinking in Toyota company and its suppliers. (Pascal, 2002, pp. 1-11; Jirásek, 1998, pp. 40-50)

1.1.2 Lean Production Elements

A utilization of the lean production elements enables a flexible reaction to customers' needs and competitive advantage too. These elements are interconnected and influence each other. (Košturiak & Frolík, 2006, p. 23)

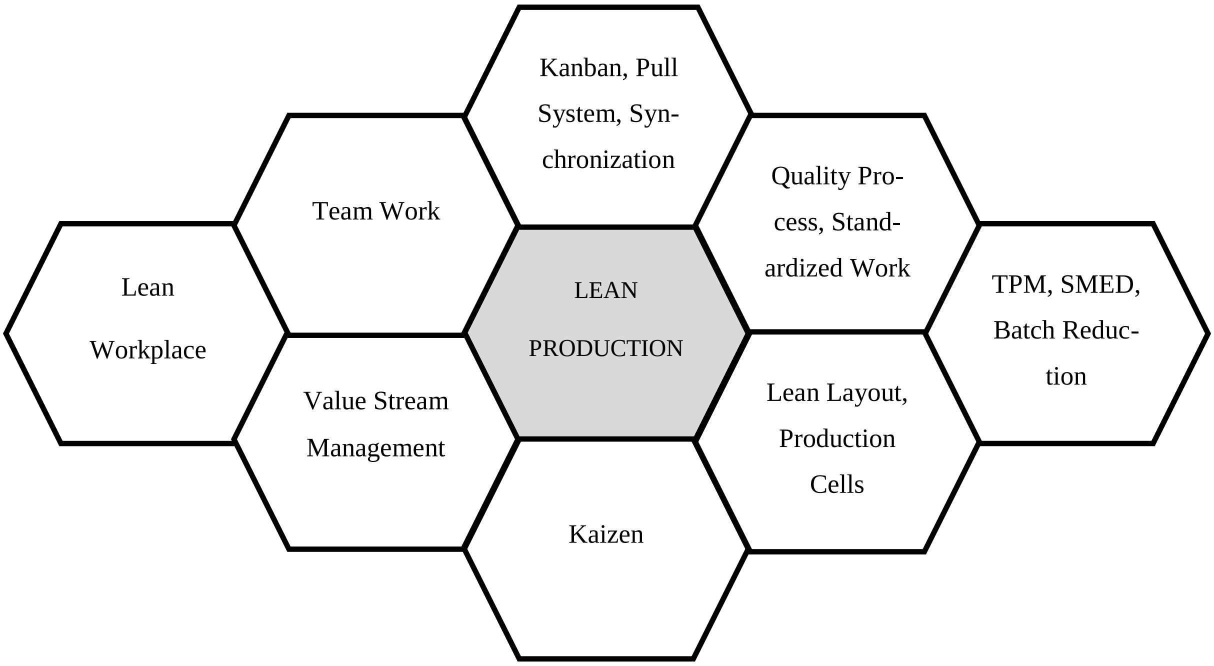


Figure 2: Lean Production elements (Košturiak & Frolík, 2006, p. 23)

Lean Workplace

The core of a lean production is a lean workplace. Workplace design influences employees' movements, time consumption, norms, production capacity and other factors. Therefore there are principles and methods which should be implemented in the lean workplace and followed to support the lean production. (Košturiak & Frolík, 2006, p. 24)

5S

5S method defines basic rules/principles of the lean workplace. Letter "S" represents 5 Japanese as well as English words:

- seiri / sort- the first step is to define tools and material which are regularly used and needed for the activities at the workplace, all other items should be placed at the earmarked store;
- seiton / set in order- arranging tools and material, define a standard place for each tool in the way that the most frequently used tools are close to operator to eliminate unnecessary movements;
- seiso / shinning- the workplace and tools must stay strictly clean all the time, at the end of a shift everything should be sorted to its standard place;
- seiketsu / standardize- apply and develop previous steps, make employees observe them, eliminate time devoted for searching;
- shitsuke / sustain- maintain and review standards, transfer this new principles to truism; (Dennis, 2002, pp. 29-36; Košturiak & Frolík, 2006, p. 24; Tuček and Bobák, 2006, p. 117)

Visualization

Visualization is an important element of all lean processes not just a lean workplace. People perceive almost 80% of information visually. That`s why this old way of communication and information sharing is still routinely used. Visualization provides such information as process time, abnormalities, required quality, productivity, efficiency and describes standard process flow. Usually used facilities to visualize information are information tables, screen documentation, work flow documents with pictures, etc. (Košturiak & Frolík, 2006, p. 25; Tuček & Bobák, 2006, p. 286)

Team Work, Kaizen

Good function of the lean elements is based on accurate team work. Most of the wastes in a company occur because of incorrect communication among people. A Team is defined as a group of people who complement each other with their skills and abilities have the same goal and work together to reach it. There are many barriers appearing on the way to reach the target. For people it is natural to think about the problems and try to solve or improve them. Continual improvement is a synonym for kaizen (kai = change, zen = good). Kaizen represents a regular improvement of personal, family, work and social life. Kaizen supports the profit increase, improves the workplace principles and needs, and makes people accept changes easily as they suggest the improvements too. In a way of proper motivation this system makes employees thinking about the problems and workplace improvement as well as the ways of decreasing the cost. For the proper kaizen impact and its good function, there are many other methods, principles which should be applied in a company and which are covered by the kaizen method. The system of all elements supporting kaizen is called the kaizen umbrella. (Košturiak & Frolík, 2006, p. 25; Tuček & Bobák, 2006, pp. 266-274)

Figure 3: Kaizen umbrella (Tuček & Bobák, 2006, p. 270)

Lean Layout

A lean layout describes a line with an optimal material flow, material stocks, and area straightforward operators` movements, etc. A design of the line should accept JIT principle and enables maximum productivity, short cycle time, high quality and effective team work and communication. A precise line layout creates conditions for:

- a team's responsibility for the process;
- a job rotation;
- a job enrichment and a job enlargement;
- an one piece flow;
- a low cost automation;

An important part of a line design is balancing, which consist of dividing on-going activities among all the operators for creating balanced material flow. (Košturiak and Frolík, 2006, pp. 25-26; Tuček & Bobák, 2006, p. 228; API- Akademie produktivity a inovací , 2012)

Total Productive Maintenance

A Total Productive Maintenance is usually connected with SMED (Single Minute Exchange of Die) to shorten changeover time. The aim of TPM method is to increase equipment productivity by reduction of the waste time. TPM includes these points:

- TPM tends to maximize machine efficiency
- TPM is a companywide system involving productive maintenance, planned maintenance, predictive maintenance as well as maintenance improvement
- TPM must be supported by managers, technicians, operators, maintenance men
- TPM involves each single employee
- The basic of TPM is to subsidy preventive and productive maintenance by team work (Mašín & Vytlačil, 2000, p. 237-240)

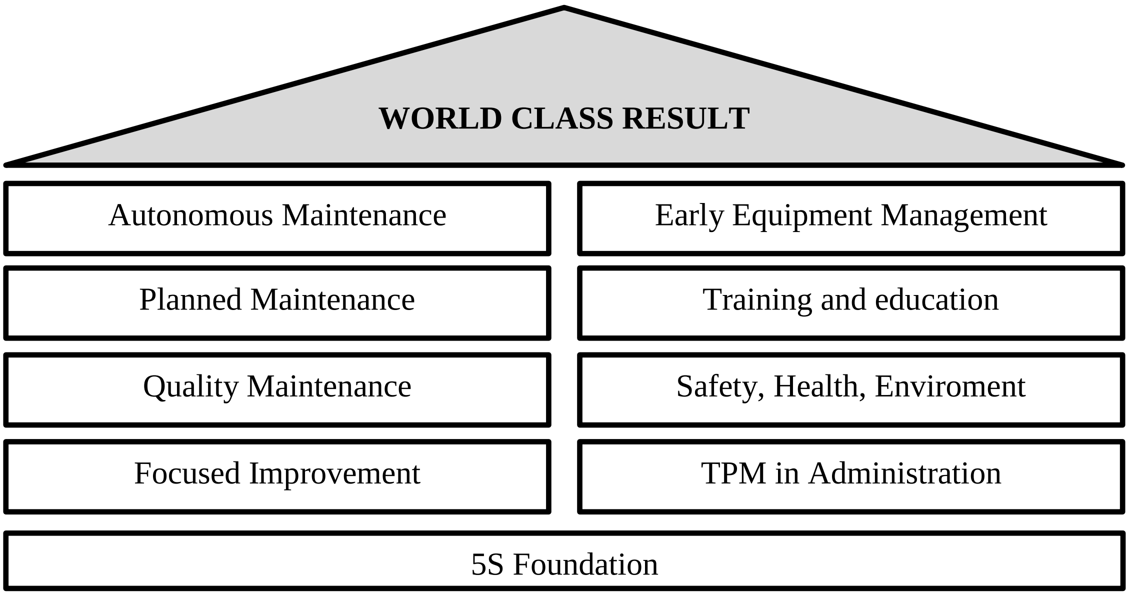


Figure 4: TPM pillars [custom processing]

SMED

Single-Minute Exchange of Die is simply understood as a tool changeover in the time 1-9 minutes. This method was created by Shigeo Shingo in 1985. The main idea of SMED is to reduce waste linked with the manufacturing process requiring changeovers.

A changeover time is the time between the last good product of an old production and the first good product of a new production. There are 5 steps to changeover equipment:

- preparation- standard place for tools;
- dismantle and assembly- dismantle of the equipment parts after the old production is finished, assembly of the new parts before the new production is started;
- control setup- calibration, measurements, efficiency;
- ability to changeover machine at the first time;
- changeover improvements; (Boledovič, 2007)

Quality Process and Standardized Work

"Quality is meeting and exceeding customer needs and expectations" (Kolarik, c1999, p. 5)

Quality is one of the most important elements, if quality is not working properly, no other element is working. Quality is not just about norms, visual inspection or product measurements. Primarily the concept of quality is based on immediate problem/defect detection, reaction, source searching and a removal. To avoid defects caused by different work of each operator, workplaces should contain a protocol of standardized work steps, examples of abnormalities and procedures to remove these abnormalities. Quality management is not just a single process but is closely connected with productivity. Our products are judged by external customer in four dimensions:

- physical;
- economic;
- timeliness;
- customer service;

Every dimension represents interconnection, not the separate productivity or quality. The concept of this interdependence is known as TQM.

The total quality management is a managerial systematic approach aiming at continual increase of value for customer, supported by systematic improvement of working procedures and systems. TQM involves all system management, not just single or separated processes. TQM is the way of thinking about the goals, organization, people and processes. It has a remarkable impact on a company`s results as well as the employees` behaviour and attitudes. TQM covers the problematic issues, for example ethics, culture, self-access. (Kolarik, 1999, pp. 5-6; Kormanec, 2007)

Synchronized Processes and Balanced Streams

The synchronized processes and balanced streams are very condition in reaching lean production. Companies should produce just the products required by a customer. Production must fulfil the requirements about the quality, amount and the delivery time. The aim of a balanced product stream is to reduce the area needed for inventories and make the production system transparent. It is based on the pull system using kanban and EPEI. (Košturiak & Frolík, 2006, p. 27)

- EPEI means Every Part Every Interval- the best option is every day, the interval should eliminate chaos occurred because of irregular changeovers. If a machine is changed over every other day, then EPEI is two days. This interval should be the shortest to fulfil every order, avoid inventories, smaller production batches and shorten changeover time. (Mašín, 2004, p. 48), (Duggan Associates- Lean training and implementation experts, 2013)

An accurate implementation of lean production elements for building a lean workplace leads to the elimination of waste, unbalance and overload.

Waste

MUDA represents waste, everything what doesn`t add value and for what customer is not willing to pay. In general there are these types of waste:

- overproduction- producing more or earlier than is needed;
- delay- employees waiting for another tool, process, machine;
- motion- extra motion, which doesn`t add value;
- transportation- excess movements or manipulation;
- inventory- more than is needed for project execution;
- correction- poor quality, reworking, retesting, re-inspection;
- over-processing- activities beyond the defined specification;
- intellect- not using employees full intellectual contribution;

MURA means unevenness, fluctuation in work. Usually the main reason is a fluctuating production plan and can be eliminated by heijunka, production levelling or mixing models.

MURI "hard to do" represents activities which are difficult to make because of an incorrect workplace design, ergonomics mistakes, inadequate tools, etc. (Dennis, 2002, pp. 20-25; Košturiak & Frolík, 2006, p. 29)

1.2 Value Stream Management

A value stream represents all the processes (adding value, non-adding value) supporting the transformation of a raw material to the final product. Consequently the difference between the functional characteristics of a product and the costs used for its formation, constitute the product value.

All items not adding value to the transformation process are usually systematically reviewed. This investigation is named the "*value analysis*" and it leads to the elimination of non-adding value activities in a view of the required quality and performance.

On the other hand, increasing the value for customer is the task of a "*value management*". To reach this target, there is a set of methodologies and tools focusing on innovation and maximization of value. The value management is based on a bilateral relation between the customers' need and objects' features. De facto the object (product, process, motion, etc.) is the centre of a value management`s interest. (Výkladový slovník průmyslového inženýrství, 2005)

A value stream management (VSM) is a lean management tool used for creating a realistic picture of process flow. It is the best way to identify the waste in the process. The advantages of VSM are:

- a door-to-door production flow picture includes shipment to the customer and delivery of supplied material;
- a creation of the future state;
- a visualization of multi process flow;
- revealing the source of the waste;
- VSM is a common interdepartmental language to discuss manufacturing processes;
- the only tool reflecting the linkage between material and information flow;
- searching for the potential sources (lean concepts and techniques) which are used to avoid "cherry picking"; (Chromjaková & Rajnoha, 2011, pp. 46-53; Košturiak & Frolík, 2006, pp. 43-49; Rother & Shook, 1999, pp. 13-14)

Benefits of Value Stream Management

The VSM benefits are principally visible in the reduction of waste, specifically reduction of process time, space reduction, simplification of the management system, production batches reduction, process synchronization, and clarification of the process flow. (Košturiak & Frolík, 2006, p. 46; Mašín, 2003, pp. 15-16)

1.2.1 VSM Risks and Constraints

A value stream map mostly uncovers at least one constraint. This workplace is called bottleneck and unfavourably influences all manufacturing process. The activities concentrating on bottleneck removal are trying to:

- maximize the flow rate;
- minimize the inventories;
- minimize the operational costs;

In general, we recognize five basic steps to remove bottleneck:

1. identify the constraints;
2. suggest the ways of the best bottleneck utilization;
3. all activities are subordinate to the decision about bottleneck;
4. searching the possibilities of constraint removal;
5. return to point 1; (Košturiak & Frolík, 2006, p. 46; Mašín, 2003, pp. 18-20)

1.3 Lean Production Implementation

Current economic situation is very complex and variable. For companies it is important to increase competitiveness, flexibility, responsiveness and to decrease cost, employee fluctuation and waste. The mostly recommended way is to implement the lean production, which enables to develop the company, gain higher productivity and efficiency without significant investments. Lean implementation is based on the following steps:

- The right composition of realization team, team should be built with regards to personal characteristics, position in a team, position in a production process and finally skills and knowledge. According to these conditions, realization team includes:
    - a visionary coming up with new ideas
    - two analysts responsible for mathematic part of the project, its risks and emerging problems;

  - seven- ten practitioners, who are able to realize all the commands;

  The task is to concentrate on the source of waste in the process and its removal. General rule says that up to 95% of process activities are not adding value. The effort should be directed not just at activities adding value and their improvement but on the contrary the activities not adding value and their elimination.

- The second step of the lean production implementation is Value Stream Mapping, which shows the overall picture of the process, material and information stream activities, abnormalities. The result of VSM represents Value Added Index indicating the proportion of value adding activities to non-value adding activities. VSM should be followed by Value Stream Design, illustrating the future state of the process.
- Thanks to these steps the lean production implementation solves the following problems:
  - lack of cleanliness and order;
  - poor maintenance;
  - incorrect communication;
  - long changeover times;
  - push production system;
  - substandard work procedure;
  - inappropriate layouts with long distance among workplaces,
  - etc. (Strachota, 2007)

1.4 The Toyota Lean Management Concept

The lean concept wrought by Toyota Company should be the target of all institutions applying lean elements in the system. The concept involves 14 management principles all together creating remarkable results in a company. Toyota rules are divided into the four major groups.

- Long-term philosophy
  1. *Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals.* Formulate a mission common for the whole company. Create the value for customers/ economy and take responsibility for your activities.
- The right process will produce the right results

2. *Create a continuous process flow to bring problems to the surface*. The idea of continuous flow must be a part of the company`s culture. All the processes must be running nonstop to reach high added value.
3. *Use pull system to avoid overproduction*. Restock the material just in time and due to this principle reduce the inventories. React sensitively when customer`s order changes.
4. *Level out the workload*. Use heijunka to balance workload in every process. Remove production plan unbalance.
5. *Build a culture of stopping to fix problems, to get quality right the first time.* Use all available means to reach the best quality, implement them into the machines and improve the system of visible control. Make the idea of stopping machine to prevent poor quality a part of the culture.
6. *Standardized tasks and processes are the foundation for continuous improvement and employee empowerment.* Combine experiences of your employees to create the best work standard. Use this standard to maintain predictability and regular time rhythm of the processes.
7. *Use visual inspection so no problems are hidden.* Support visual inspection by using basic signs improving problems recognition. Eliminate facilities distracting operators.
8. *Use only reliable, thoroughly tested technology that serves your people and processes.* Use new technologies to support people, not to replace them. Test the technology before its integration to the process and refuse / change it in case of disturbing process stability.

- Add value to the organization by developing

9. *Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.* Choose leaders from internal business environment. The leader must be the proprietor of the company's philosophy.
10. *Develop exceptional people and teams who follow your company`s philosophy.* Spread company`s values and opinions. Teach people how to work in inter-department teams to increase quality and productivity.
11. *Respect your extended network of partners and suppliers by challenging them and helping them improve.* Stimulate your partners towards development and growth. Think of them as the company`s expanding part.

- Continuously solving root problems drives organizational learning

    12. *Go and see for yourself to thoroughly understand the situation*. For decision-making use just the real data. Never decide before your own familiarity with the problem`s root.
    13. *Make decision slowly by consensus, thoroughly considering all options, implement decisions rapidly*. Mostly used method for decision/making is called Nemawashi. Nemawashi represents the way of discussion about the problem and potential solutions with everyone who is affected.
    14. *Become a learning organization through relentless reflection and continuous improvement.* Lean process enables people to recognize even the smallest abnormalities and wastes. Make people contemplating, avoid employees' fluctuation and built an effective promotion system. (Liker, 2004)

2 WORK MEASUREMENT AND ANALYSIS

2.1 Work studies

Work study is considered to be a classical discipline of industrial engineering. It is based on systematic work procedure analysis. The goal is to improve efficiency of machine capacity planning and to define a time norm for each single operation.

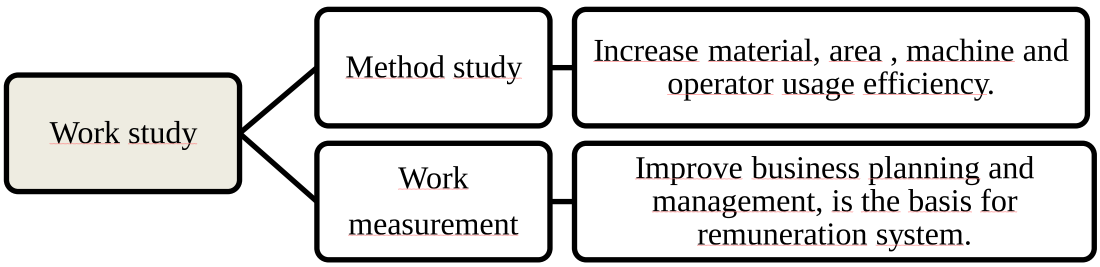


Figure 5: Work study partition [custom processing]

Benefits of work study:

- reduced manufacturing costs;
- improved work flow;
- increased productivity;
- increased operational efficiency;
- improved work place layout;
- better manpower and capacity planning;
- fair wages to employees;
- reduced material handling costs;
- better working conditions to employees; (Lhotský, 2005, pp. 53-60)

2.2 Method study

The study of working methods collects information about working processes, analyses them and detects waste in the processes. This study focuses on finding the best way how to work.

"Method study is the systematic recording and critical examination of existing and proposed ways of doing work as a means of developing and applying easier and more effective methods and reducing costs." (RayWild, Essentials of operation management, p. 111)

Benefits of method studies:

- an improved work place layout;
- an improved work place equipment;
- an improved working procedure;
- a better manpower and capacity usage;
- an improved working environment;
- an improved product construction;

Steps creating the method study:

1. CHOOSE an operation which should be studied.
2. RECORD all relevant facts.
3. ANALYZE the current way of performing the operation.
4. SUGGEST a more effective way of operation performance.
5. EVALUATE different alternatives improving method.
6. DEFINE a new method.
7. IMPLEMENT the new method make it standardized.
8. CONTROL the new standard method.

There are four basic groups of recording tools for method studies described below. (Lhotský, 2005, p. 62)

2.2.1 Principles of motion economy

Analysis of Therbilgs

Each activity is possible to be described by one of 17 motions. These motions are divided into effective and non-effective. Work created just by effective motions is productive. Non-effective therbilgs don`t add value and that`s why they should be eliminated or removed. (API- Akademie productivity a inovací)

Cyclograms and chronocyclograms

Cyclogram: small lights are tacked at the moving body parts. By shooting occurred motions, lighting lines arise. Looking at the developed film the lines shows the movements of arms at one working cycle.

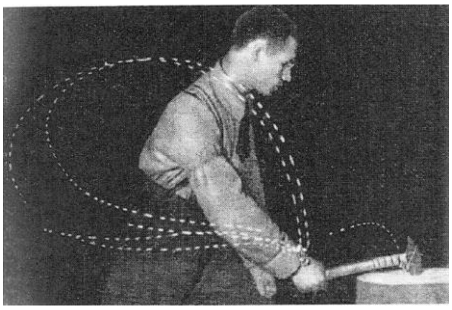


Figure 6: Chronocyclogram

Chronocyclograms: represent the same principle as cyclograms. The difference is in small lights which are blinking. Looking at the developed film we can also notice the speed of each movement. Longer lines represent higher speed of the movement. (API- Akademie productivity a inovací)

Spaghetti diagrams

All worker`s motions are drawn in a work place layout. Spaghetti diagram enables to find length of workers motion and the most frequent areas visited by worker. The diagram is usually used in factories assembling big products or in the case of operator working at more machines at the same time, etc. (API- Akademie productivity a inovací)

2.2.2 Process analysis

A process analysis presents a chronological sequence of steps that explain how something is done, how something happens. It is a graphical explanation of separate activities with specific symbols. Process analysis offers couple of results:

- the time required by process;
- the distance which is made by product until it is finished;
- the time of waiting;
- the time for which a company has still enough inventories;

There are four types of process analysis:

- a product process analysis;
- a person process analysis;
- a human-machine process analysis;
- a process analysis for administration; (API- Akademie productivity a inovací)

2.2.3 Check-lists

PQCDSM Check-list: is effective tool for uncovering problems in the process.

Table 2: PQCDSM Check-list (API- Akademie productivity a inovací)

	PQCDSM Control questions
Productivity	Will be the production increased or decreased in the future? Will be the productivity changed?
Quality	Is quality decreasing? Is the scrap rate increasing? Are our consumers dissatisfied?
Cost	Are costs increasing?
Delivery	Do late deliveries occur? Is it possible to shorten manufacturing time?
Safety	Do safety problems occur? Is the number of injuries high?
Morale	Is work ethic high? Do the interpersonal conflicts exist?

5W1H Check-list is used to minimize the possibility to omit following criteria:

Table 3: 5W1H Check-list (API- Akademie productivity a inovací)

	5W1H Questions
Task	WHAT
Person	WHO
Purpose	WHY
Place	WHERE
Sequence	WHEN
Way	HOW

2.2.4 Analyse using photos and videos

Video recording: perfectly records all kinds of operator`s motion, its length and speed as well as time consumption of every single activity. It enables to analyse every movement and method used for performing work.

Photo: is descriptive and clear, usually is used for working process documentation. (API-Akademie productivity a inovací)

2.3 Work measurement

Work measurement represents a method created for determination of the time needed for specific work activity. The application of this method leads to creation of time norms. Work measurement techniques are the basis for work process rationalisation. There are three basic techniques of time measurement:

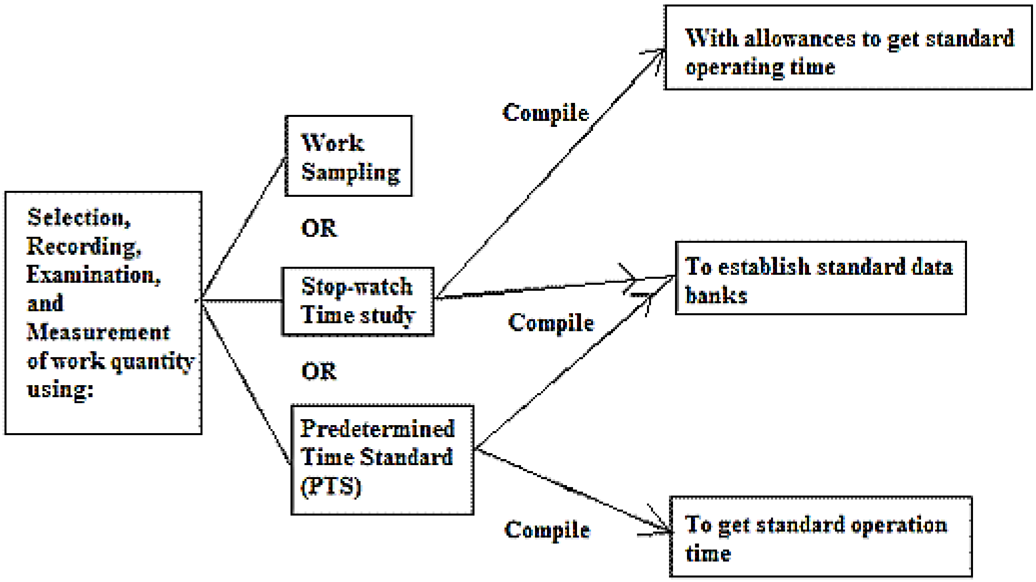


Figure 7: Work measurement division

Work measurement steps:

- CHOOSE the activity, that should be measured;
- DEFINE work procedure for the activity;
- DIVIDE the activity on basic elements;
- MEASURE the time needed for the activity;
- DETERMINE standard time;
- APPLY determined standard time on measured activity;
- STANDARDIZE time consummation for defined work procedure; (Lhotský, 2005, p. 64)

2.3.1 Stopwatch Time study

Stopwatch Time Study is a way of measuring work. It is easy to learn and carry out these measurements. Most importantly, it is cheap with no other investment than labour. Stop-watch time study is timely and challenging in execution. Making it properly, you will get accurate time values and that is why it is still being used by a majority of garment making factories today.

- Continuous chronometry method is a timing technique; the stopwatch is allowed to run for the entire job; method results present a complete record for the entire observation period including all delays and foreign elements (external things to the process that delay the work from moving forward); continuous method requires clerical work;
- Snapback chronometry method is another timing technique; usually used to record duration of each work element process; this technique requires resetting the stopwatch after each breakpoint; no clerical work is needed to subtract from previous observations; enables directly to read and to record observed time; (Lhotský, 2005, pp. 66-67)

2.3.2 Predetermined Time Standard

A predetermined time system consists of a set of time data and a systematic procedure. This set analyses and subdivides any manual or human task into motions, body movements, or other elements of human performance, and assigns to each the appropriate time value. There are many different systems of predetermined time standard, MTM (Methods Time Measurement), UMS (Universal Maintenance Standard), USD (Unified Standard Data), UAS (Universelles Analysier System), MOST (Maynard Operation Sequence Technique). The most common methods are defined bellow.

MOST: this concept was created by Kjell Zandin from Sweden. MOST is based on idea that work is just energy expenditure to achieve the goal. In other words, work is a relocation of substance. There are special patterns defining the relocation type. These patterns are called sequences and are the basic unit of the MOST concept. (Krišťák, 2007)

Table 4: MOST division (Krišťák, 2007)

MOST	Operation duration	Time of measurement	Time of analysis
Mini MOST	2-10 seconds		
Basic MOST	10s- 10 min	1 hour	10 hours
Mega MOST	> 2 min	1 hour	3-5 hours

Sequences used in MOST:

- General move- pattern ABGABPA, in which:
  - A = Action Distance (mainly horizontal)
  - B = Body Motion (mainly vertical)
  - G = Gain Control
  - P = Placement
- Controlled move- pattern ABGMXIA with three different parameters:
  - M = Move Controlled
  - X = Process Time
  - I = Alignment
- Tool Use- pattern ABGABP*ABPA
  - * represent used tool
- Manual crane- special sequence with the pattern ATLKFVLVPTA

The basic unit used in MOST as well as in MTM concept is called TMU = Time Measurement Unit and represents:

- 1 TMU = 0,0006 minutes;
- 1 TMU = 0,036 seconds; (Mašín, 2003, pp. 30-40)

3 INVENTORIES

3.1 Inventory Management

An inventory management task is to balance the product flow in supply chain, to reach a high service level and a required price at once. For each company it is costly to sustain continual level of inventory. Inventories bind the capital and it is possible to invalidate them. So why is it so important and dispensable?

- Security/ certainty- to head off unexpected order, physical security secured by stored object when supplies are uncertain or unreliable;
- Linkage between offer and demand as inventories for introduction of new production, work in process or final products prepared for expedition;
- Expected demand- increased demand in case of seasonal good or amount discounts;
- Special services for subscriber- cyclical inventories of final product, operational reserve for unexpected demand; (Emmet, 2008, p. 43; Synek & Kislingerová, 2010, p. 15)

Companies often contend with the excessive inventories. Redundant reserve level decreases profitability in two ways:

- reduces net income by inventory costs;
- increases total assets by the capital bound in inventory;

To reach what the lowest possible inventory cost is the responsibility of logistics. (Drahotský & Řezníček, 2003, p. 16)

3.1.1 Inventory Management types

To have optimal inventory costs we should follow three basic indicators:

- Uncoupling inventory point- is a criterion for an inventory management and an allocation of needed assets. This point divides material flow into two parts. The first one is managed according to forecast and following plans, the other one is managed by customers ‘order. It enables to control the amount of committed current assets in stock; (Chromjaková & Rajnoha, 2011, pp. 86-88)
- ABC method splits manufactured products into three groups according to a proportion on corporate turnover and a fraction of total product sold:

- A represents 10-15% of inventory used to produce 70-80% of total production
- B group includes 10-15% of inventory producing 20-25% of total production

- C means 68-80% of inventory needed for 10-15% of total production, which is from economical point of view unimportant but support the production and cannot be removed. (Synek & Kislingerová, 2010, p. 15)

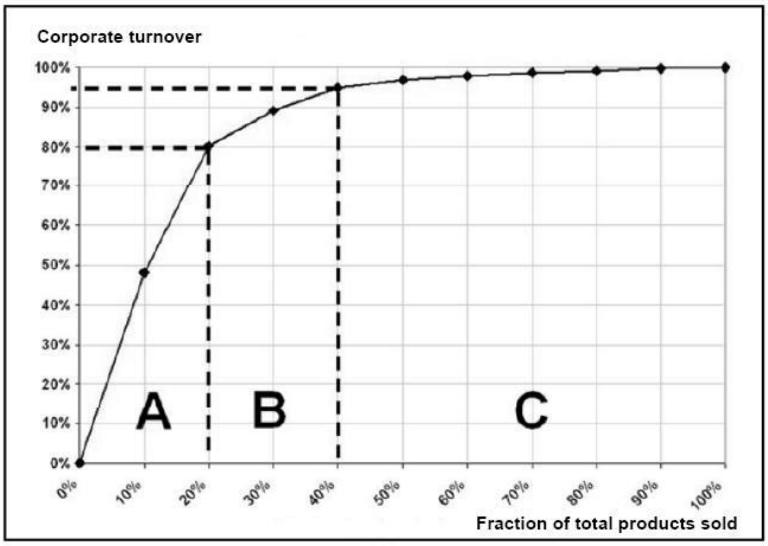


Figure 8: ABC analysis

- Inventory turnover provides information about the inventory management efficiency. The data are based on a total consumption per period and an average consumption. The resulting information means the number of inventory turnover in time and the financial turnover as well. (Chromjaková & Rajnoha, 2011, p. 88)

3.2 Just-in-Time

The Just-in-Time method was firstly integrated in Japanese company Toyota. JIT idea is based on producing the right item at the right time in the right quantity. It represents an integrated managerial activity eliminating all kinds of waste. The basic characteristics of JIT include:

- pull system;
- Kanban;
- poka-yoke;
- flexible and balanced manufacturing system;

- one piece flow;
- SMED;
- TPM;

Most of these characteristics are already described in the first chapter. That`s why the following part is dedicated to pull system, kanban and related topics. (Mašín, 2004, pp. 22-25)

3.2.1 Pull and Push System

Pull system is one of optimized material flow principles. It means that the goods or services are not produced until the following workplace makes an order for them. The idea of "*I will bring what is already produced*" was changed into "*I will take what I need*". (Mašín & Vytlačil, 2000, pp. 263-264)

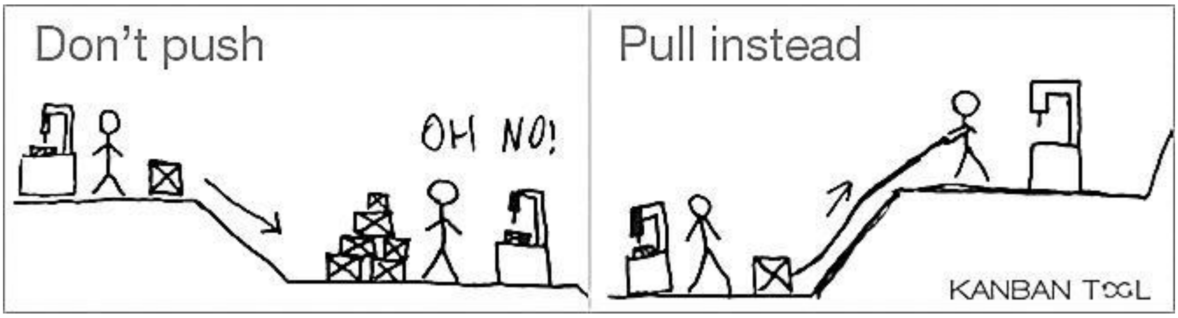


Figure 9: Pull and push system (Košturiak and Frolík, 2006)

Advantages of pull system:

- minimized raw material and component inventories;
- 100% quality;
- a minimized decoupling inventory;
- shorter lead time;
- zero defect system;
- a minimized inventory of finished goods; (Tuček & Bobák, 2006, p. 203)

Push system produces according to the production plan even when there are no orders. Semi-finished products are pushed to the following work place immediately after the production process and cause big decoupling inventories. (Tuček & Bobák, 2006, p. 204)

Advantages of push system:

- a reliable database system;

- developed technical norms;
- feedback process- results;
- an integrated planning system;

Disadvantages of push system:

- time and financially demanding implementation
- decision-making support is insufficient;
- deterministic data set up;
- inflexible to order changes; (Tuček and Bobák, 2006, pp. 213-214)

3.2.2 Kanban

Kanban is a flexible self-regulating Japanese system of production management. Information tool is a kanban having the function of an order or a dispatch note. (Košturiak & Frolík, 2006, pp. 174-175)

Kanban system is working if a supplier-customer chain exists in production process. Information-material circle is represented by order (kanban card) given to a supplier. Afterwards an order is given back to customer (material even with related kanban card). (Keřkovský & Valsa, 2012, p. 86)

Kanban facilities:

- Kanban card- represents an order for external or internal purchaser; it is information in a form of an empty place, light, ball, upside-down crate, etc.
- Kanban table- an area where internal supplier takes the information from internal purchaser;
- Kanban box- a box for kanban cards or internal purchaser demands;

Kanban rules:

- following process is allowed to subscribe products from previous process just in accordance with the kanban card;
- it is inadmissible to allocate components to the process without kanban card;
- assume inequality products from previous process is unacceptable;
- pallets including components can be moved only together with the related kanban card;

- number of kanban cards must be in compliance with the final production need; (Košturiak & Frolík, 2006, p. 175)

Heijunka box is a tool used for production balancing and continuous production flow. It proves the basic information about what to produce, when and what amount. Thanks to steady work load and stable production mix, heijunka supports the waste removal. Heijunka box was developed by Toyota professionals. Horizontal line is dedicated to each production item, vertical line represents identical time intervals, for example 20 minutes. Each pigeonhole involves a certain amount of kanban cards carrying information about how many articles of a product must be produced in a certain time interval.

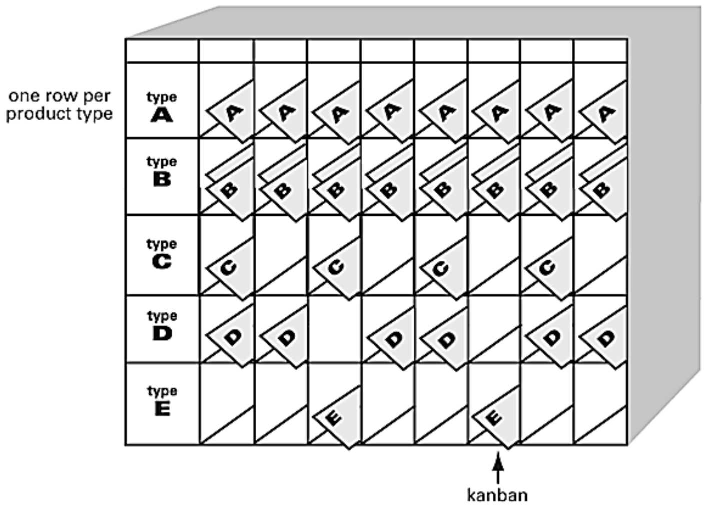


Figure 10: Heijunka box (Dennis, 2002)

Irregular orders cause four main problems:

- Customer orders are unpredictable and company must be flexible to adapt production plan to the customer demand;
- Risk of big unmarketable products inventories;
- Production factors utilization is irregular;
- Uneven demand going against the production stream;

Advantages of balanced production plan:

- lower risk of unmarketable products;
- production flexibility, accepting customer demand and producing when it is suitable for the company;
- Balanced utilization of equipment and workers;

- smooth process and suppliers demand going against the production stream; (Dennis, 2002, pp. 74-80)

Supermarket

Closely connected with the kanban system is also a usage of a supermarket store. A supermarket is based on kanban cards and represents new form of an inventory. Basically it substitutes conventional stores. Except the kanban system, the supermarket acts as a pull system tool as well. The supermarket is considered to be an inventory of finished goods or material with the exactly defined amount of the items. It is usually used when implementation of a one piece flow is not possible. Material hold in supermarket can be removed only in pursuance of kanban card. (API- Akademie productivity a inovací, 2012)

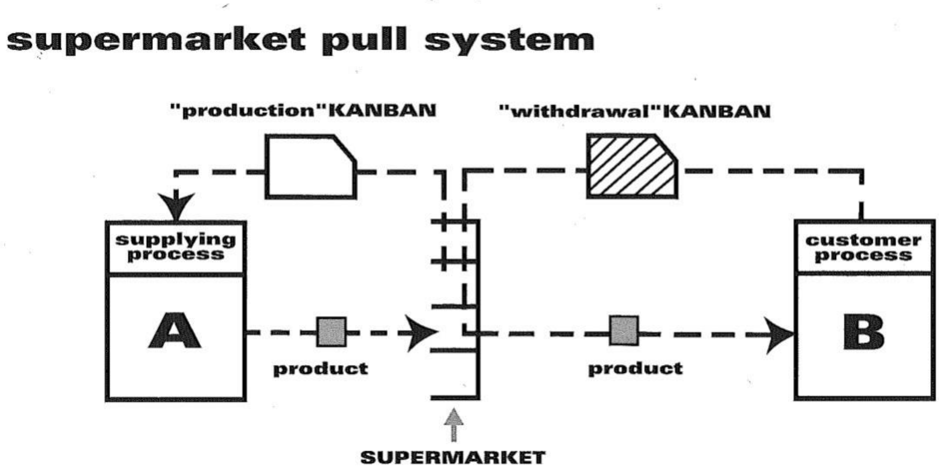


Figure 11: Supermarket pull system (Dennis, 2002)

Milk runner

Milk runner is a person using the supermarket for the material cartage. There are precisely defined logistics ways and time intervals used by milk runner. Material is unloaded at an accurately determined place. On the way back to the store empty transport articles are picked up. Mostly used handling or transport facilities are the so called toy trains. (Výkladový slovník průmyslového inženýrství a štíhlé výroby, 2005)

4 MANUFACTURING PROCESS

Production system is perceived as a set of industrial engineering methods, management tools and lean manufacturing methods enabling to reach business goals. Production system is a way to realize production, process of transformation inputs to outputs.

Manufacturing process is understood as a set of activities implemented on a raw material or semi-finished goods with the focus to transform them to the finished goods. (Tuček & Bobák, 2006, pp. 12-13)

4.1 Manufacturing process typology

According to the different process fluency, continuity and regularity there are three basic ***manufacturing process forms***:

- stream form- a workplace's layout is based on the technological procedure, regularity and operation synchronization; manufacturing process is repeated regularly in the same time intervals; typical example of this form is an automobile assembly line; the line is specialized on low amount of products;
- group form- is characterized by a wide range of final products and none of these products has an operative production share; similar production equipment is clustered together, is easily rebuilt and thus flexible to the customer order;
- phase form- is using an universal technology equipment for irregular or single and unique orders; a workplace's layout is organized in a technology way; (Tuček & Bobák, 2006, pp. 41-45)

Production programme typology is based on the types of production programme management:

- production according to the orders- the entire production process or at least its part is performed due to specific customer requirements;
- make to stock-is usually used when it is possible to predict future demand, but the product features and parameters are defined by producer;
- production controlled by inventory- the production process is launched when the inventories reach minimum allowed level; (Tuček & Bobák, 2006, pp. 45-46)

4.2 Assembly

"Assembly is a group of subassemblies and/or parts joined together by machine or labour constitutes an assembly." (Výkladový slovník průmyslového inženýrství a štíhé výroby, 2005)

4.2.1 Assembly system and assembly line

Assembly system always focuses on a special product group and according to this group it has the following features:

- material- assembly tools and equipment, assembled parts and complexes;
- dispositive- design, planning and assembly management;
- operative- assembly staff, assembly operations arrangement;

Table 5: Assembly typology due to mechanization and automatization aspects

Characteristics	**Assembly type**			
	Manual	Mechanized	Flexible Automatic	Fast Automatic
Power source	Human	Engine	Engine	Engine
Tool command	Human	Human	Machine	Machine
Process management	Human	Human	Flexible management	Fast management
Control	Human	Human	Human, sensor	Sensor

4.2.2 Factors influencing assembly system

- Product construction- reliability, aim, shapes, dimension;
- Labour- number of operators, remuneration system, qualification, working environment, performance, morale;
- Assembly techniques- number of assembly machines and their reliability, used techniques, level of automatization and mechanization;
- Assembly management- work-sharing, cooperation possibilities, coordination of production activities, batch size;
- Contract conditions- assembly terms, number of products due to contract, level of production preparedness, current and future annual production; (ZČU- Katedra Technologie Obrábění- Základy montáže, pp. 1, 5, 8)

4.3 Assembly line optimization

The following part gathers 10 rules for a successful assembly line optimization.

- GOLDEN RULE: To create an atmosphere supporting enthusiasm for change- people who will be affected by the changes worry. These people must be involved in the whole project and cooperate on improvements.
- Step 1: Main product selection- the product represents 70% of time consumption according to the ABC analysis or Pareto rule.
- Step 2: Customer tact calculation: Customer tact is an interval in which a customer subscribes to the products or services. According to the customer tact it is possible to set the rhythm of product flow from one operation to another.
- Step 3: Familiarization with the product assembly process- is based on recognition of activities which are consecutive one after the other. This step can be enlarged by defining the risk places. It allows repartitioning of operations.
- Step 4: Detection of each operation time consumption- using stopwatch method or predetermined time method.
- Step 5: Determination of line capacity- discerning whether the machine and the manual process times fulfil the capacity table. This information is supplemented by facts about noncyclic activities, occurrence of losses caused by scraps and the number of small disturbances.
- Step 6: Number of needed operator calculation- this number provides information for balancing the line
- Step 7: Assembly line shape and organization of operations- lean concept prefers U-shape due to short distances, no communication barriers, the line starts and ends at the main communication channel, operator activities don`t cross mutually.
- Step 8: Tools, material and equipment emplacement- having regard to optimal distances to achieve effective work flow. A lot of anthropometric data and ergonomics knowledge should be used.
- Step 9: Work procedure standardization- work procedure is a document with clearly described activities and required results which eliminate non-effective production variants.

- Step 10: Visualization and shop floor management- monitoring outputs in regular intervals on a table and comparing with the expected outputs. In case of variation the reason should be recorded as well.
- Final advice: “Measure twice cut once.” (API- Akademie productivity a inovací, 2012)

II. ANALYSIS

5 GREINER GROUP

Greiner Group was established in Germany in 1868 and in Austria in 1899. The company is in 100% family ownership. It combines the know-how of a network organization with the high innovation capacities and the flexibility of its legally independent company units. Greiner Group includes 5 subgroups in the foam and plastic area:

- Greiner Packaging International
- Greiner Bio-One
- Greiner Foam International
- Greiner Tool. Tec
- Greiner Technology &Innovation

Currently Greiner Group provides jobs to almost 7500 employees in overall 123 locations (manufacturing & sales) around the world. In 2010 the company reached consolidated turnover of 1.132 Mio. €.

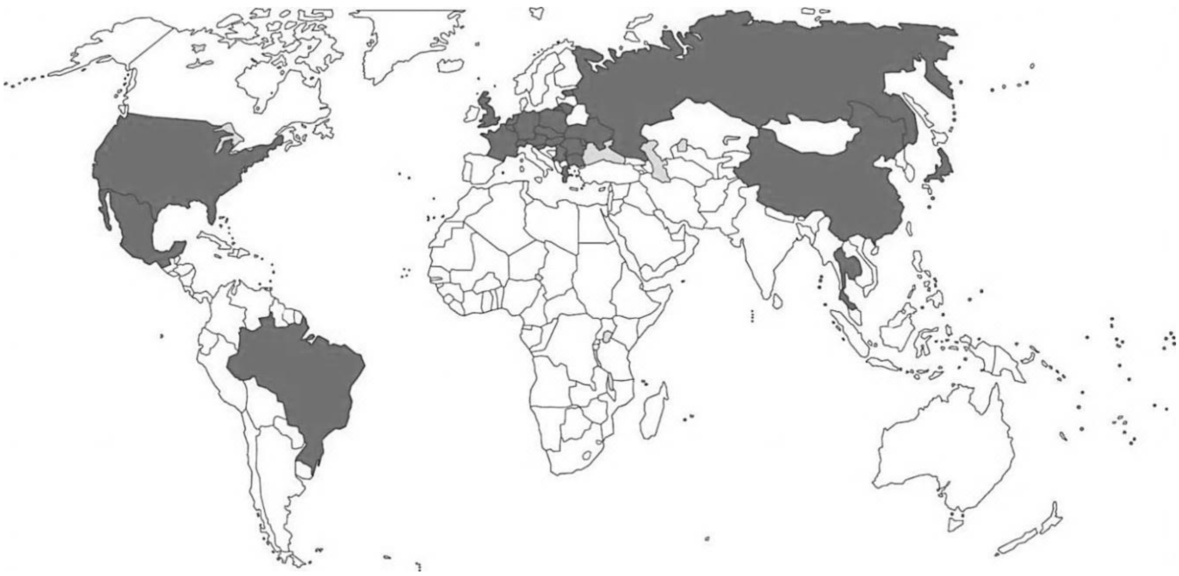


Figure 12: Map of worldwide activities of Greiner Group

5.1 Greiner Assistec, Ltd.

Greiner Assistec has been incorporated in Greiner Packaging International as an individual division in 2009. The company was registered in the Commercial register on 11.11.2009 as a limited company. Company`s executive, Mr. Ing. Martin Červenka, MBA is acting for the company individually. The basic capital is the amount of 200 000 CZK while the shareholders have become:

1. Greiner Packaging International GmbH with the contribution of 20.000CZK and the business share of 10%
2. Greiner Packaging Slušovice Ltd. with the contribution of 180.000CZK and the business share of 90%.

Currently the division employs almost 300 people from Czech Republic and Slovakia.

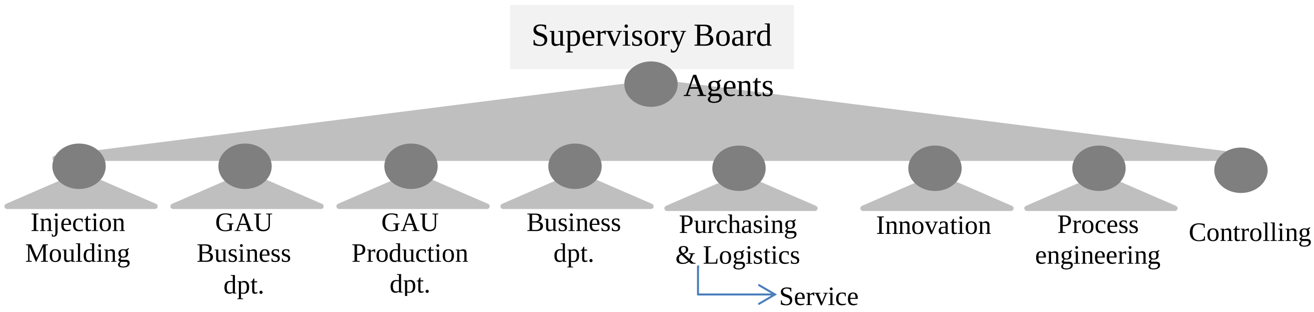


Figure 13: Organizational structure

5.2 Production program and customer portfolio

The name of the company "Assistec" is created by specific English words **As**sembling – **S**ystems – **I**n **S**ourcing – **Tec**hnologies. By using wide variety of technology they create fascinating solutions in the field of plastic components production and complex assemblies. They have become expert in the field of their business.

Greiner Assistec has an opportunity to use following available technologies:

- Injection moulding
- Gas injection moulding
- 2K injection moulding
- In mould labelling
- Near future technology - MuCell
- Assembly (design of assembly lines)
- Ultrasonic welding
- Tampo print
- Packaging & Filling
- Logistics

Greiner Assistec Slusovice focuses on two main activities:

- Injection Moulding (Assistec I);
- Assembly (Assistec II);

Production portfolio includes:

- toys (sand pails, covers, boxes);
- technical units for copy machines;
- technical units for automotive industry;

The key customers of the company are LEGO and XEROX. But they are not the only. Among company`s customers belong SHIMANO, CANON, BRANO GROUP, CONTINENTAL, MANN + HUMMEL, PHILIPS, SWAROVSKI, HILTI, STIHL and MAKITA as well.

Figure 14: Product portfolio

5.3 Injection moulding

The injection hall consists of 36 Engel, Krauss Maffei or Netstal injection moulding machines. The machines are placed in two separated halls. The injection moulding machines are mostly used for production of LEGO and XEROX products. The machines are distinguished according to its clamping force. Greiner Assistec uses machines with clamping force from 25 to 700 tons operated by robotic arm and operators (0,25 - 1 operator according to the type of product).

Figure 15: Injection moulding machine

The inputs for the machine are plastic granules. Their big advantage is lower price than powder material even despite longer drying process than powder ones. Following the order, each machine can be set up. Setting up signifies the exchange of movable and stationary part of form. The set up time is usually between 1-3 hours pursuant to the machine type and required change. It is possible to produce the same product at maximum 4 different machines (due to various sampling force). In the case of excessive order, company has doubled amount of mostly used forms, the product can be injected at two standalone machines.

Each machine has given its occupancy rate. In accordance with the rate, the number of operators is assigned. Mass of the machines is associated with occupancy of 0,25 operator or 0,33 operator. It follows that 3-4 machines are operated by the same operator. Some machines produce components which must be merged together, that` s why one operator must operate the machine throughout the whole shift.

There are three recycling types used in the company:

- Immediate recycling right at the injection moulding machine;
- Special crusher intended for a larger volume;
- Recycling secured by a special customer for bulkier components which are not possible to be recycled at the Greiner Assistec.

The production activity also includes occurrence of scrap. Injection moulding is characterized by frequent products repaint. Despite constant cleaning of colour stack, repainting leaves stains at the new products which become scrap. The company is still trying to cope with this problem.

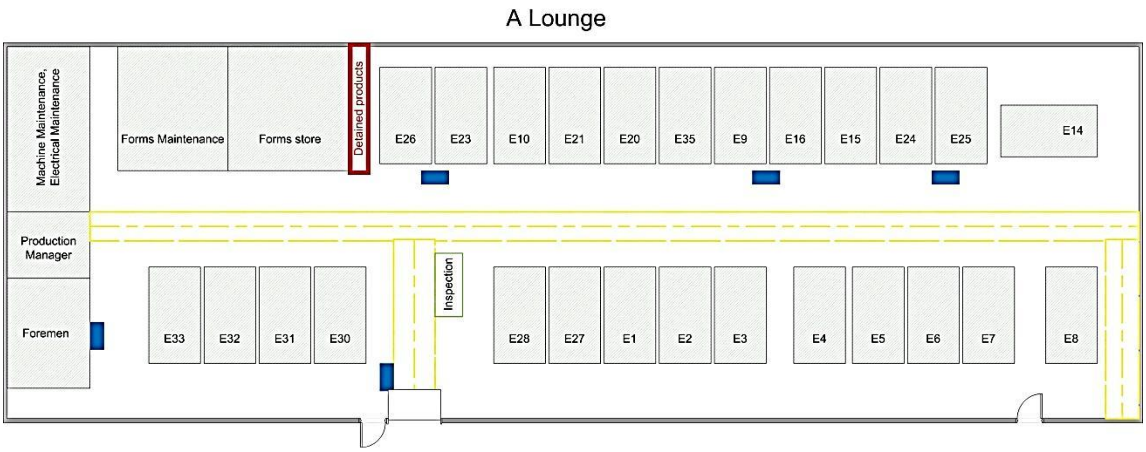


Figure 16: Injection moulding A Lounge layout

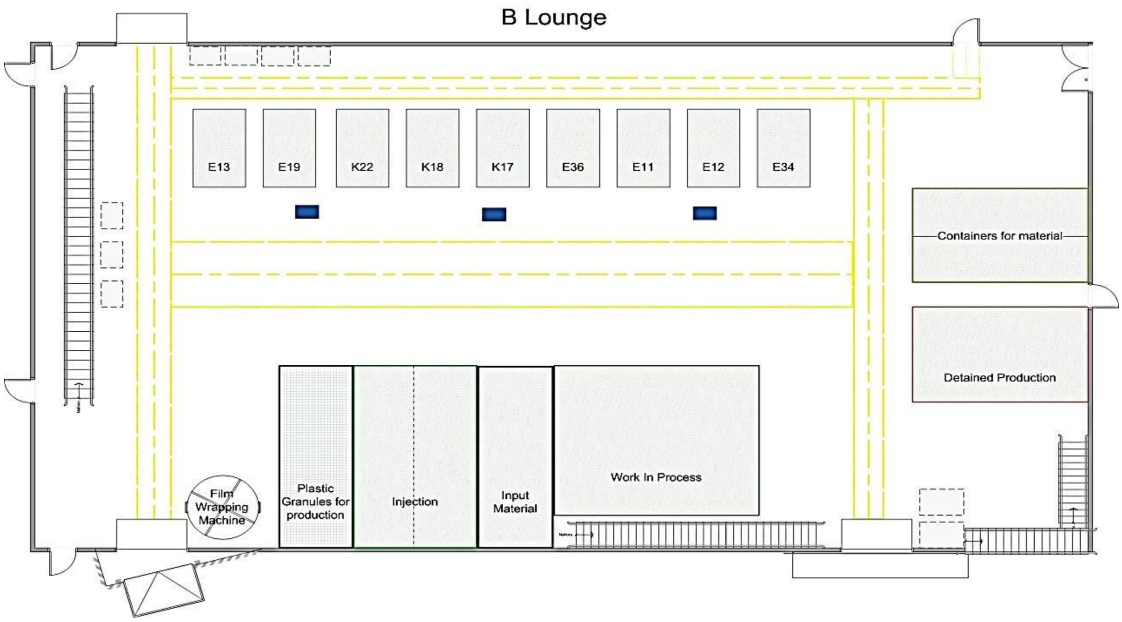


Figure 17: Injection moulding B Lounge layout

5.4 Assembly

Currently the assembly hall is almost solely devoted to the XEROX Company. The gist of these projects is usually assembling of different module types. The deployment of actual projects and their short characteristics are shown below.

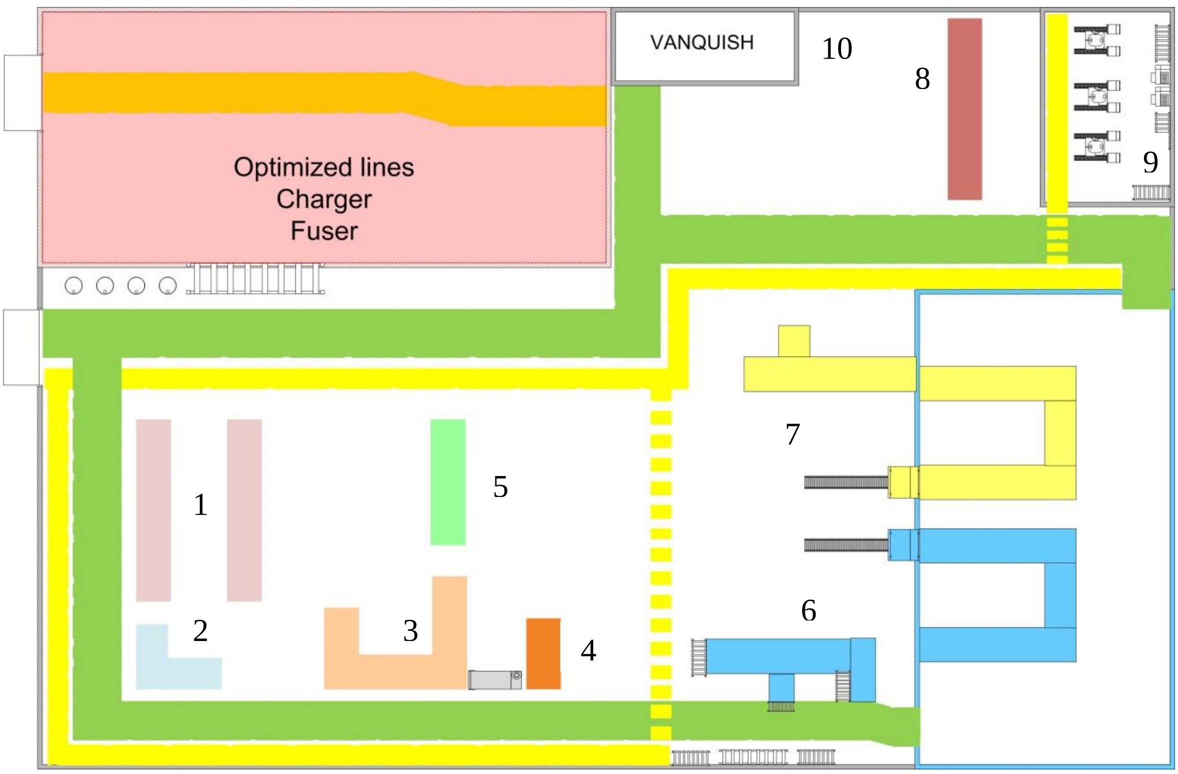


Figure 18: Assembly hall layout

The assembly hall consists of several separate lines. Overall, the current projects cover 5 different customers.

- Project 1: consist of two identical, parallel lines, the project customer is XEROX and the project name Oakmont Waste Toner;
- Project 2: is dedicated to FUHJIN Company, there are two project alternating at the line, DC12 and Elan
- Project 3: is ordered by HILTI and focuses on Motoreckel and Flow Indicator assembly, these projects rotate each other on the line as well;
- Project 4: a small line belongs to MAKITA Company and Water sets are assembled here;
- Project 5: is devoted to DSC products (fireboxes) produced for TYCO;
- Project 6: belongs to group of XEROX projects, the line goes through Yellow chamber with a special light for assembly of three Xerox module types, Oakmont, Northwood, CRU;
- Project 7: is similar to previous project, including Yellow chamber in the process too, there are 3 projects running at the line, Imperia, Copeland and Spode;
- Project 8: is another in a series of XEROX projects, including just one steady assembly called Oakmont Waste Toner Reman;
- Project 9: is a Tampoprint line mostly machined HILTI products;
- Project 10: is a newly build line called Vanquish;
- Separately marked is the Blass Module area, including Fuser and Charger project, which are the subject of the master thesis;

5.5 SWOT analysis

To analyse internal and external environment of the company I made a SWOT analysis. For each area I chose the most important factors influencing company`s development. All the factors are marked by a number determining its importance within the group (1= the most important).

Among strengths of the company belong quality material, high production capacity, agency employees, long-lasting contracts with customers and quality products produced thanks modern technologies. I consider quality products the most important strength of the company. Quality is what customers always require and are able to pay for. Good reputation of the company thanks to the quality products is spreading fast and helps to gain new contracts.

I find insufficient use of SAP the most significant weakness. Company is missing an important module concerning about the production planning. Because of this absence there is occurrence of problems in internal communication, problems about material delivery system, non-dried material causing visual poor quality, etc.

Opportunities are related all together. For company it is important to obtain new customers and new contracts. To reach this aim, new companies should enter the region or GA should enter new markets. The easiest way is to be registered on the plastic portals, which groups together firms in this field.

The biggest threat for company is in general changing legislation and related increasing of taxes or business barriers. It is necessary to adapt to the changing conditions while maintaining competitive prices, quality and processes.

Table 6: SWOT Analysis

STRENGHTS	Ranking	**WEAKNESSES**	Ranking
quality material	2	insufficient use of SAP	1
high production capacity	6	high scrap rates	2
utilization of agency employees	5	long set up time	5
long-lasting contracts with important customers	3	unused production capacity	4
quality products	1	frequent fluctuation of employees in some positions	3
modern technologies	4		
OPPORTUNITIES	Ranking	**THREATS**	Ranking
using portals about plastic and rubber	3	competing companies	3
new contracts, new customers	1	increasing taxes	2
new companies (potential customers) in region	2	legislative regulations	1

6 STARTING POINT ANALYSIS

The diploma project is situated in the remanufacturing area which is a part of assembly hall (Assistec II). The representative product has been chosen in pursuance of increased customer`s order and relocation of the line from separate hall to the assembly hall. Remanufacturing area involves two parallel running projects, Charger and Fuser.

6.1 Charger

Charger focuses on unique type of Xerox module including just one independent workplace with the only worker per shift. The norm is set on 16 modules per shift. There are roughly 400 modules processed per month. Due to customer requirement this number will be tripled.

The charger operator firstly unpacks the module, the cardboard boxes and polystyrene parts are sorted according to the later usage. Followed by the reman process, module is repased. The reman process includes exchange of rollers and springs, in the case of damaged parts, these must be exchanged as well.

Afterwards the module is tested by a special tester and used for printing copies. The copies are inspected visually. Finally the module is wrapped in a plastic, laid into the polystyrene filling and packed together with the booklet and the substitute filter to a cardboard box. Full pallet consists of 32 modules and goes directly to the expedition store.

In the picture below there is charger workplace disposition and its activity disposition.

Figure 19: Charger workplace

6.2 Fuser

Fuser is a project for XEROX Company, covering repasing activity of 4 similar module types (Alchemy AB, Leander, Alchemy C, Sorcery), where Alchemy AB and Leander is almost identical and Alchemy C with Sorcery is almost identical too.

Since 1.1.2013 the fuser line has been repositioned from separated building to the decoupled specific area of the assembly hall. Significantly the highest percentage of the repasing activity is related to Alchemy AB modules. The current norm is set on 104 modules per shift. The task is to increase norm up to 130 modules. This line is composed of 6 unique workplaces:

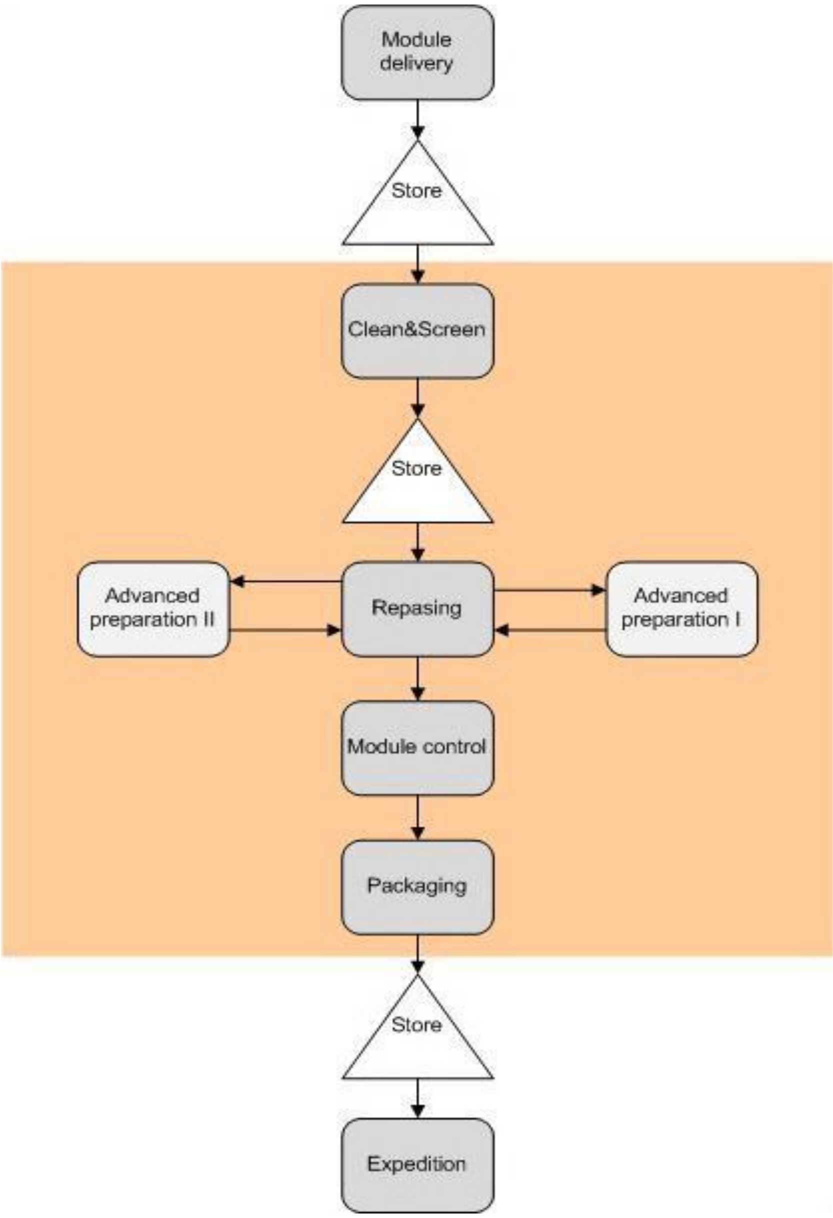


Figure 20: Flowchart of the whole Fuser module process

The fuser line operates just morning shifts. There is the only operator for each position. They are possible to replace each other in the case of absence principally thanks the Clean&Screen position, which capacity is not fully used.

6.2.1 Clean&Screen

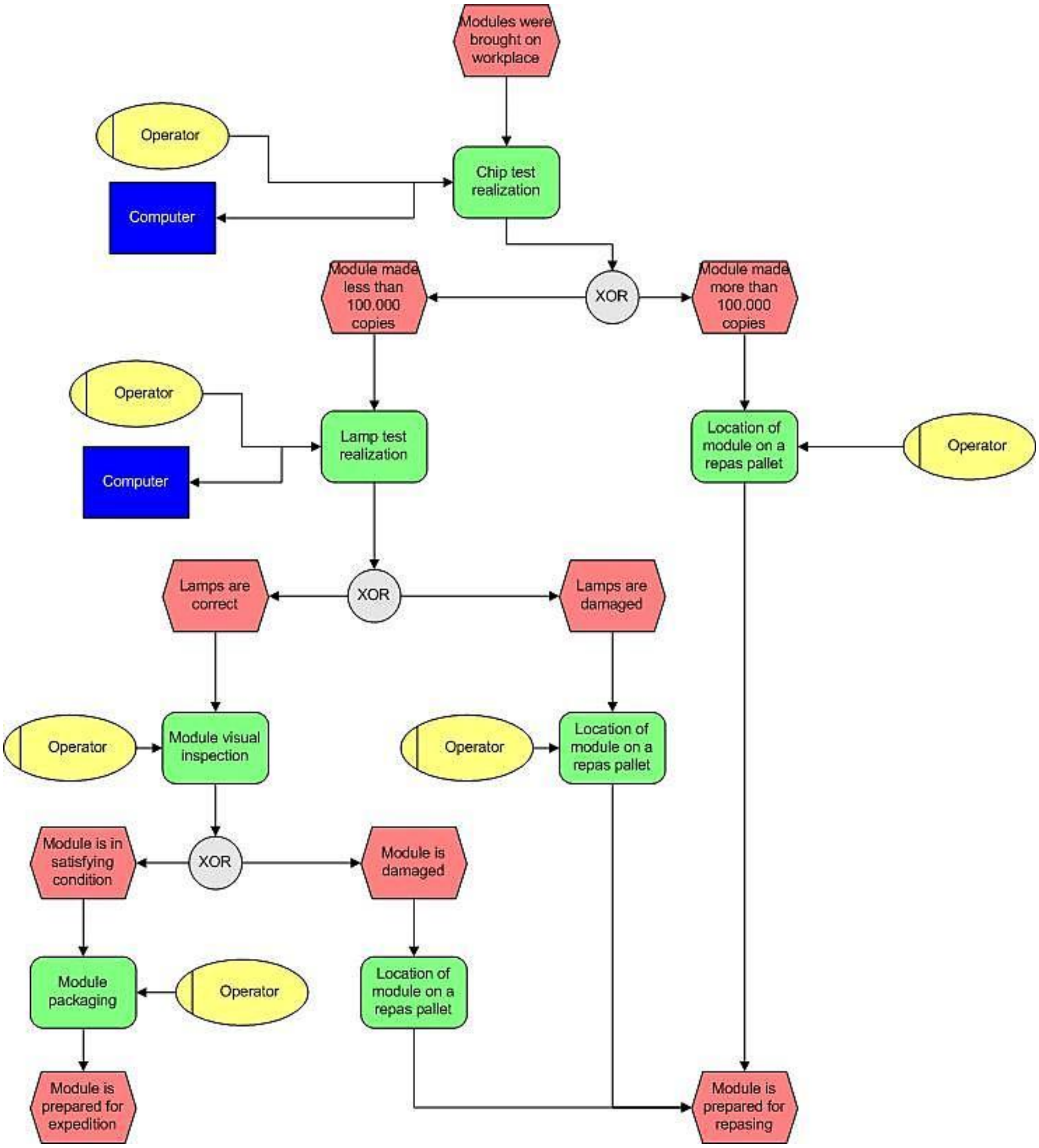


Figure 21: Clean&Screen flowchart

Clean&Screen- is a workplace operated by one operator, the job description includes sorting of modules into two groups, modules which need to be repased and modules in sufficient condition to be immediately packed for expedition. Except sorting process, the operator uses inserting machine to prepare components used at the advanced preparation workplaces and helps at the same workplace in case of free time capacity. The C&S position does not have a strictly set daily norm. This workplace enables to prepare even tripled amount of modules per shift as needed at the following activity. Thanks this predefined reserves it is possible for the worker to replace missing operator at any different position. On the other hand it leads to low utilization of the worker when no absence.

Figure 22: Clean&Screen workplace

6.2.2 Reman activity

Repasing is an activity carried by 4 operators at the same time. Each of them has a daily norm of 26 modules. This position covers cleaning of the module, dismantle, replacement of the necessary parts and assembly.

Figure 23: Reman process workplace

Some parts are immediately substituted by new purchased parts. The other parts are fixed at the advanced preparation workplaces and used again:

- UPPER INPUT GUIDE ASSY;
- UPPER EXIT GUIDE ASSY ;
- WEB ASSY;

6.2.3 Advanced preparation I

Advanced preparation I workplace concentrates on the electricity panel UPPER INPUT GUIDE ASSY and its correction. Since the operator fixes all panels exchanged at the repasing workplaces, its norm depends on the repasing workplace norm (usually 104 panels). At the beginning operator picks up panels from the repasing workplaces. The panels are dismantled, the head of the panel is separately taken apart and subsequently new cables are inserted in. The panel`s body is cleaned, bolted with the new head and assembled together with the new cables again. In this condition, electricity panel can be used in the repased modules.

Figure 24: Advanced preparation I workplace

6.2.4 Visual Inspection

Visual inspection is a position where the operator has to execute all the necessary tests and visual inspections before the module is packed. Except control activity, small repairs, which cannot be assigned to any of repasing operators, belong to him as well. Controlling worker is responsible for modules` correctness and functionality. The whole control process is shown below.

Figure 25: Visual Inspection workplace

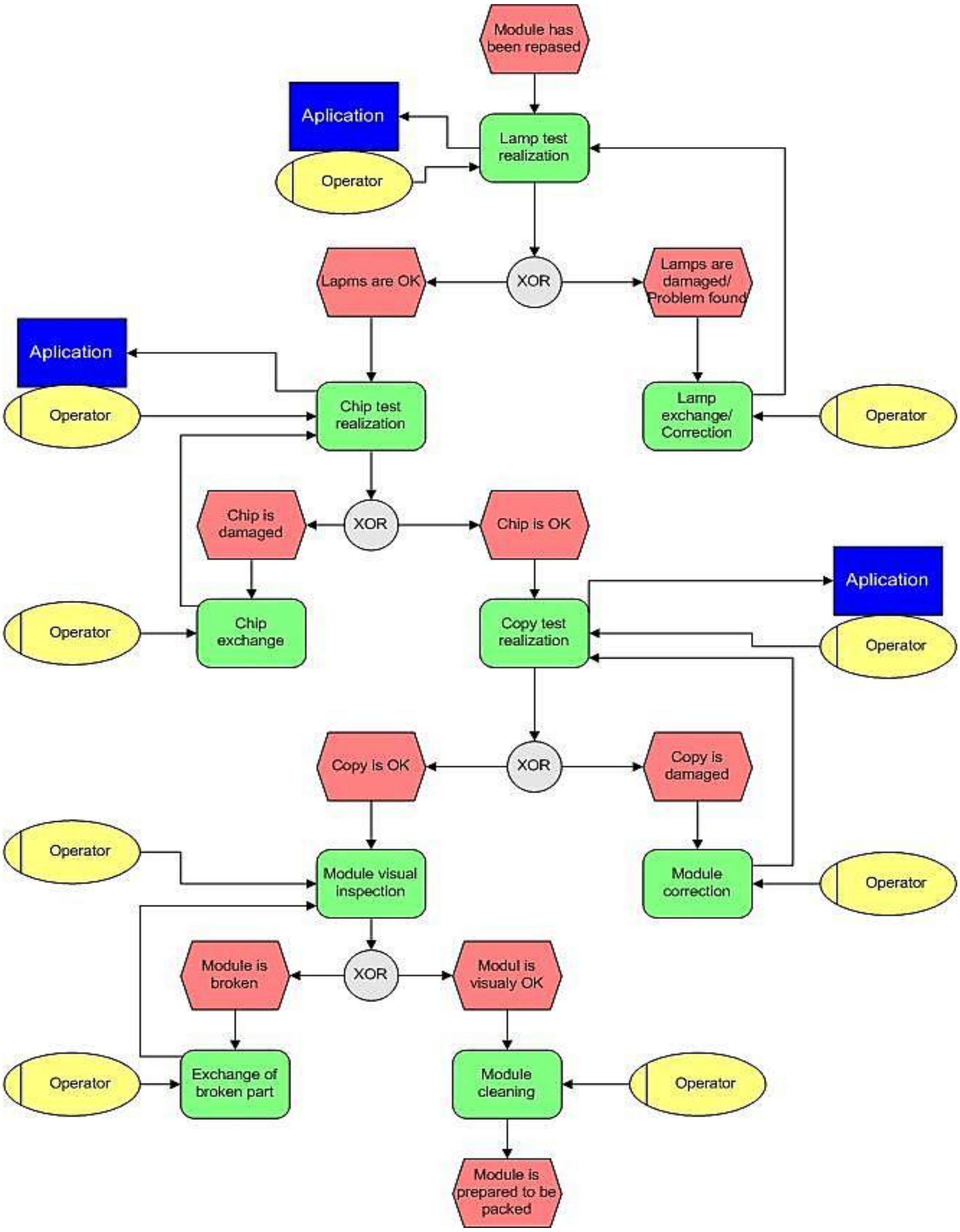


Figure 26: Visual inspection flowchart

6.2.5 Advanced preparation II

Advanced preparation II is performed by one operator as well. Activity at this workplace concerns at two components the UPPER EXIT GUIDE ASSY and the WEB ASSY. The norm is set in the same principle as at the previous workplace and depends on the repasing norm (usually 104 pieces per shift for each component).

- Upper exit guide assy correction lies in exchange of the fingers – stripper parts and its cleaning;
- Web assy is firstly dismantled, the red rolls called Tension roll assy are sorted out into the groups for future usage. The cleaning web is always replaced with a new one and afterward again assembled with eligible tension roll.

Figure 27: Advanced preparation II workplace

6.2.6 Packing

Packing is the last activity of the fuser line. After the module is checked, the operator realizes a special test and make sure the module is prepared to be dispatched. Modules are packed in the carton boxes together with the ozone filter, the green world booklet and instructions. The boxes are sealed at the wrapper and finally placed on a pallet of 40 pieces. Besides packing, the operator helps at the advanced preparation I workplace to dismantle and assembly heads.

Figure 28: Packing workplace

7 CURRENT STATE ANALYSIS

The current state analyse underway in three steps. Foremost a value stream map was created, to uncover waste in the whole process. The following is analysing of each position and its time fund review. The last part is about layout analyse and the possibilities of its redesign. All mentioned elements are discussed in more detail below.

7.1 Data collection methodology

For analysing the current state of the lines I used two different time measuring methods. Firstly I was using the chronometry method to find out the average time of manipulation with module at each position. The first chronometry comprised 50 repetitions of measurements when high frequency of the activity, in the case of the charger and the repasing activity there were 20 repetitions. The other chronometry contained of 20 repetitions at every position.

Secondly, based on the chronometry results, a line optimization was proposed and the positions with modified job description were measured in another way as well. I used the MOST methodology to ensure accomplishment of the proposal. Ultimately the whole process was simulated in the Plant Simulation and submitted to qualified persons.

7.2 Positions analysis

This subchapter is dedicated to deeper time analyse of the single positions. The matrixes compare the chronometry time and the MOST time of single activities and show the usage of the operators. Based on the decision of the assembly hall Head, the workplace cleaning is set to 5 minutes at the end of the shift. The mandatory breaks should take 30 minutes when shift time is 8 hours. Because of long distance between the assembly hall and the canteen, this break was extended to 35 minutes per shift. Short breakfast break lasts from 7:40 am to 7:50 am. Long lunch break lasts from 11:00 to 11:25 because of already mentioned transport.

Fuser operators are working just morning shifts, due to this, their working time is 8,5 hour instead of 8 hours. The working time starts at 6:45 am and finishes at 14:15 pm.

Charger operators are working morning and afternoon shifts and their working time is 8 hours, from 6 am to 2 pm and from 2 pm to 10 pm.

7.2.1 Charger

The charger line is based on two shifts operation, one operator is working the morning shift, the other one the afternoon shift, alternating after one week (when low order, they are working just morning shifts). Their current norm is set on 16 modules per shift and daily shift takes 8 hours. The mandatory breaks are lengthened to 35 minutes due to already mentioned reasons. There is 5 minutes intended for workplace cleaning at the end of the shift. The efficiency of a worker is set on 95 %. After subtraction of non- productive time we get the disposable time exploited for module repasing. Once upon a day an operator wrap the cartoon boxes at the wrapping machine. Usually it takes 30 minutes. Whereas this activity is performed just in one shift a day, I divided the time needed for wrapping into two equal parts. It helps me to create one representative shift which can be further analysed.

The net time determined just for the work with module at the workplace (from unpacking delivered module to its packing into the box and lying on the pallet) is 403 minutes. Based on a chronometry, repasing of a single module takes 23,05 minutes. Time consumed by 16 modules is 368,8 minutes, the operator utilization is just 0,915%. It is possible for the operator handle even 17,48 module to make him 100% used.

Table 7: Charger time analysis I

Position	**Charger**	**Units**
Norm/Shift	16	pcs
Shift	morning, afternoon	
Time fund/ shift	480	minutes
Mandatory breaks including 5 minutes for workplace cleaning	40	minutes
Efficiency	95	%
Disposable time fund	418	minutes
Time without wrapping	403	minutes
Chronometry/module	23,05	minutes
MOST/unit	19,254	minutes
Operator need	0,915	operator
Time consumption	368,8	minutes

Whereas it is appropriate to delegate some activities performed by charger operator, in the table below, I unfolded the whole activity into smaller sections and again compared chronometry and MOST time. Thanks this decomposition it will be easier to assign each activity to another operator.

Table 8: Charger time analysis II

Section	Chronometry time	MOST time	units
Module	23,05	19,254	minutes
Reman process	18,30	14,916	minutes
Packing	1,03	0,69	minutes
Visual inspection	2,58	2,79	minutes
Unpacking	1,14	0,858	minutes

The MOST was conducted by video of the whole charger process. From table it is evident that the activities including just standardized procedure (not requiring inspection) and standardized movements take less MOST time than chronometry time. Activity called the Visual inspection has the MOST time longer than the chronometry time. It is because this activity lies in the searching of detects on the copies from the copy machine. The module on the video required longer searching of defects on the copies than average length. However the visual inspection in general doesn't have any special sequence which would show the standardized/recommended length of inspection according to the for example capacity of the studied area, it is possible just to measure the time of the activity by stopwatches and use it for the MOST time.

7.2.2 Clean&Screen

The Clean&Screen operator is the first one in a touch with a Fuser module. Whereas fuser line is running just morning shifts, the daily shift takes 8,5 hours. The mandatory break is determined on the same basis, there is also 5 minutes allocated for the workplace cleaning. The operator efficiency is set on 95%. This implies that the disposable time fund is 444,5 minutes. Determined norm 104 modules represents daily requirement of repasing workplace, indeed the operator mostly processes at least twice so much. In this case, the next day operators`activities are determined as appropriate from other workplaces.

Roughly 25% of modules is also tested at the lamp test and approximately half of them is inspected visually as well. The inserting activity and height springs adjustment is not a daily activity, but usually takes 2-3 hours. To create a representative shift, in the following table there is daily reserved time for these two operations. The table again compares the chronometry and the MOST time and in conclusion indicates the time consumption of the current norm. In a case of free time, operator is helping at the advanced preparation I workplace with head stripping. This time is not exactly determined and depends on others activities time consumption.

Table 9: Clean&Screen time analysis I

Position	**Clean&Screen**	**Units**
Norm/Shift	104	pcs
Shift	morning	-
Time fund/ shift	510	minutes
Mandatory breaks including 5 minutes for workplace cleaning	40	minutes
Efficiency	95	%
Disposable time fund	444,5	minutes

Table 10: Clean&Screen time analysis II

Section	**Percentage**	**Chronometry time**	**MOST time**	**Units**
Module for repasing	80%	1,35	1,152	minutes
Module with lamp test	15%	1,93	1,632	minutes
Module with visual inspection	5%	5,7	4,95	minutes
Daily module need (104 pcs)	100%	172,07	-	minutes
Inserting /shift, Height springs	cca	60	-	minutes
Residual time	cca	212,43	-	minutes

According to the statistics, 80% of modules go directly to the reman process, 15% of modules are tested in the lamp test, if the test comes out negative the module has to be repased too, remaining 5% go through the lamp test which is positive and afterwards are inspected visually. If daily inserting activity takes 60 minutes, there are 212,43 minutes usually used for modules pre-treatment and frontload. This time fund represents 49,2% of a daily shift.

7.2.3 Reman process

The daily use of modules is 104 pieces. According to the chronometry time, operators utilization is 99,3% and the time needed for working out the modules is 441,22. The only sideline activity made by operators is module repair when given back from the visual inspection. Roughly it is just one module per shift. The other chronometry was done when Alchemy C type of module was repased. The norm is a little bit different due to more complex reman process. Even though the time consumption and operator need was except for the small deviations the same as Alchemy AB results. The reman process is carried by 4 operators, from which everyone has a norm of 26 modules. As they are working just the morning shifts, the disposable time fund is 444,5 minutes as well.

Table 11: Reman process time analysis

Position	Reman process	Units
Norm/Shift	26	pcs
Shift	morning	-
Time fund/ shift	510	minutes
Mandatory breaks including 5 minutes for workplace cleaning	40	minutes
Efficiency	95	%
Disposable time fund	444,5	minutes
Chronometry/unit	16,97	minutes
Operator need	99,3	%
Time consumption	441,22	minutes

7.2.4 Advanced preparation I

The advanced preparation I workplace focuses on UPPER INPUT GUIDE ASSY repair. The disposable time fund is the same for all fuser workplaces, therefor it is 444,5 minutes. The number of required operators is 1,45. Whereas the position is performed just by one operator (100% used), half of a shift is covered by the operator working at the packing workplace or alternatively the one working at the Clean&Screen workplace. The activity mostly left to others is head stripping and reassembling and takes 199,26 minutes or 45% of the disposable time.

Table 12: Advanced preparation I time analysis

Position	Advanced preparation I	Units
Norm/Shift	104	pcs
Shift	morning	-
Time fund/ shift	510	minutes
Mandatory breaks including 5 minutes for workplace cleaning	40	minutes
Efficiency	95	%
Disposable time fund	444,5	minutes
Chronometry/unit	6,19	minutes
Operator need	1,45	%
Time consumption	643,76	minutes
Cooperating operator	199,26	minutes

7.2.5 Advanced preparation II

The operator at this workplace repairs two different components, 104 pieces from both of them per shift. The disposable time fund for the components together is 444,5 minutes. There are two sideline activities too. The operator has to complete the Support components every shift as well as stick the labels on a Lower part. Labels are stuck on the Lowers always immediately in the beginning of a shift. It takes roughly 15 minutes.

Table 13: Advanced preparation II time analysis I

Position	Advanced preparation II	Units
Norm/Shift	104	Pcs
Shift	morning	-
Time fund/ shift	510	Minutes
Mandatory breaks including 5 minutes for workplace cleaning	40	Minutes
Efficiency	95	%
Disposable time fund	444,5	Minutes

The support components are completed continuously every day, the demand is approximately 60 left supports and 40 right supports.

If there are 104 Web Assy, 104 Upper Exit Guide Assy processed, 100 supports completed and half an hour is intended for sticking the labels, the operator need is 91,2% and the time consumed by these activities is 405,12 minutes.

Table 14: Advanced preparation II time analysis II

Section	**Amount (pcs)**	**Chronometry time**	**Units**
Web Assy	104	1,17	Minutes
Upper Exit Guide Assy	104	1,86	Minutes
Sticking labels (total time)		30	Minutes
Completing supports	100	0,6	Minutes
Time consumption		405,12	Minutes
Operator need		91,2	%

7.2.6 Visual Inspection

Table 15: Visual Inspection time analysis

Position	**Visual Inspection**	**Units**
Norm/Shift	104	pcs
Shift	morning	-
Time fund/ shift	510	minutes
Mandatory breaks including 5 minutes for workplace cleaning	40	minutes
Efficiency	95	%
Disposable time fund	444,5	minutes
Chronometry/unit	2,52	minutes
MOST/unit	3,198	minutes
Repairs (10 per shift)	8	minutes
Operator need	77	%
Time consumption	342,08	minutes

The visual inspection of a single module takes 2,52 minutes. The MOST time is a little bit longer, roundly 3,198 minutes. It is caused by video, which was used for the time analysis and its length is 3,32 minutes. Activity itself spent more time because of dirtier module even though recorded visual inspection almost doesn't include waste. Except the inspection, the operator cares about module repairs which are not a mistake of specific operator but mostly damaged lamps. There are roughly 10 repairs per shift. Time consumed by these activities is 342,08 minutes and thus the need of the operator is 77%.

7.2.7 Packing

The starting point is the disposable time fund again. To test a module in the lamp test and pack it takes 1,8 minutes. The operator has two side line activities. The first one is making up the top covers for the reman process. The number of the covers depends on the reman process demand, but usually this activity takes less than half an hour. The other one is related to the advanced preparation I workplace. The rest of the shift operator continuously cooperates with UPPER INPUT GUIDE ASSY repair. It is possible for her to spend even 227,3 minutes out there, this time express 51% of the disposable time.

Table 16: Packing time analysis

Position	Packing	Units
Norm/Shift	104	pcs
Shift	morning	-
Time fund/ shift	510	minutes
Mandatory breaks including 5 minutes for workplace cleaning	40	minutes
Efficiency	95	%
Disposable time fund	444,5	minutes
Chronometry/unit	1,8	minutes
MOST packing	1,36	minutes
Operator need	93,7	%
Time consumption	187,2	minutes
Top cover assembly	30	minutes
Advanced preparation I	227,3	minutes

Due to the cooperation at the advanced preparation workplace is needed 199,26 minutes and the operator working at the packing workplace has available 227,3 minutes, his overall utilization is 0,94%.

These two workplaces are quite distant one from another. It is a big waste to transfer between them every 15 minutes. This time losses are not taken into consideration in a table over.

7.3 Layout analysis

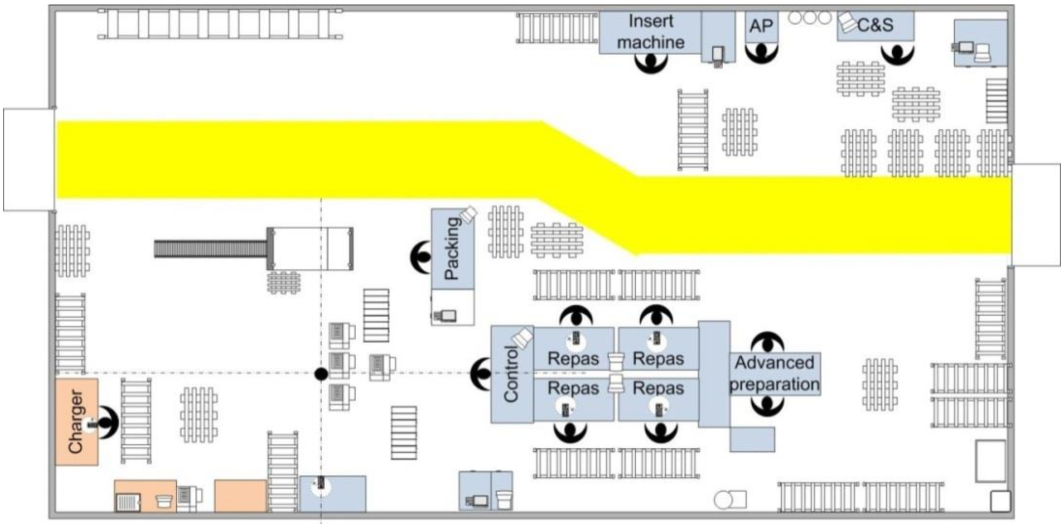


Figure 29: Repasing hall layout

The current layout was designed when the fuser line was moved to the new assembly hall. It is characterized by two separate areas

- Charger area (pink);
- Fuser area (blue);

At present there are no different lines in the Reman hall. Charger layout consists of 3 tables; the table with special equipment for reman process, the table with chip tester, the table for packing. There is a shelf unit with mostly used components behind the operator. Another one is right next to the table for reman process. This shelf unit includes all components needed for work at the workplace. Module is unpacked at the pallet no. 1. Afterwards it is processed at the table with special equipment. When the reman process is finished, module is checked at the table no. 2 and placed into the box at the table no. 3. Then ready module is laid at the pallet no. 2.

Figure 30: Charger line layout

The Fuser Layout is divided as well. There is an independent area for Clean&Screen workplace. The operator here uses three tables:

- The table with crum tester to find out how many times a module has been used until now;
- The table with lamp tester right next to the first one;
- The table with insert machine for side line activities;

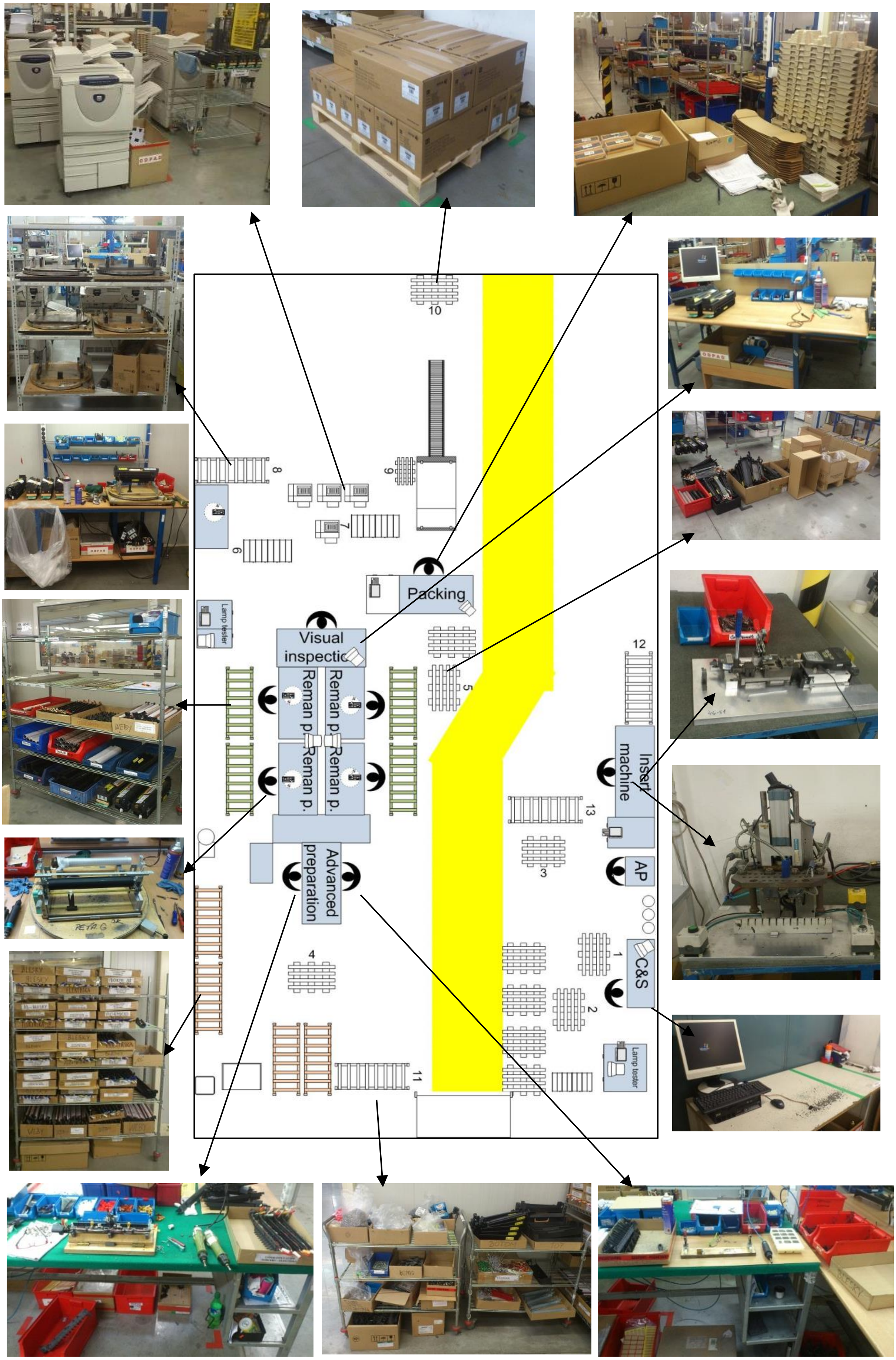
There are three pallets determined for rubbish of modules (cartoon boxes, plastic bags and other trash), one pallet including polystyrene parts to lye prepared modules into. The place reserved for a pallet with new modules from store is marked by no. 1. The one with mark no. 2 is prepared for modules to be repased. The last one pallet (no. 3) is already full and waiting to get colder and be transferred closer to the reman process.

After modules are cooled down, the pallet is transferred on the place no. 4. Every operator of the reman process has his own shelf unit behind himself (green shelf units). This shelf unit contains:

- new components;
- modules to be repased;
- already rebuilt parts from advanced preparation workplace;
- parts which should be rebuilt at advanced preparation workplace for another use;
- documents which must be filled during shift;

Operators from the advanced preparation pick up the parts to be rebuilt from green shelf units. Components prepared to be used again are placed into the shelf units of orange colour. There are four shelf units, while each of them belongs to specific type of modules (Alchemy AB, Alchemy C, Leander, Sorcery). Components are taken from here by reman process operators. This workplace includes a separate table marked AP to set the height springs. Operators lay repased modules on the shelf unit no. 6 and after visual inspection it is placed on unit no. 7 to be packed. Cartoon boxes for packing are situated on a pallet no. 9. After wrapping process, boxes are placed on a pallet no. 10.

Shelf units 11, 12, 13 as well as pallets no. 5 are in general used for components storage. Shelf unit no. 8 covers module holders for reman process (there are different holders for specific type of a module). The table next to the rack is the same as the tables of reman process. It is usually used for module repair.


10
8
9
7
6
Packing
Lamp tester
Visual inspection
Reman p.
Reman p.
Reman p.
Reman p.
5
12
Insert machine
13
3
AP
Advanced preparation
4
1
C&S
2
Lamp tester
11

8 OPTIMIZATION PROPOSAL

8.1 Conditions

Charger

On behalf of increased customer`s request from 400 modules per month to 1000 modules per month, the line has to be optimized, the number of needed operators must be calculated and the new norms must be set.

There are also requirements given by the Head of the assembly hall influencing optimization process. Charger operators should perform just repasing activity. All other related activities should be delegated to the operators from the fuser line. Control should be performed with the same person for both projects due to experience and expertise in assessing quality of print. These conditions became the corn stone of the task.

Table 17: Charger production plan

Month	May	June	July	August	September	October	November	December
Charger pcs	416	384	800	1000	1000	1000	1000	1000

Fuser

It is probable that the production will be increased of 26 modules a day, but not permanently. This situation will derive from orders and should last until the end of May 2013. That`s why it doesn`t have to be taken into consideration.

Table 18: Fuser production plan

Item	June	July	August	September	October	November	December
Leander	280	280	240	240	240	280	200
Alchemy C	120	120	120	120	120	120	120
Alchemy AB	1500	1500	1500	1500	1600	1500	1400
Sorcery	520	560	480	600	680	600	560

8.2 Process analysis

Table 19: Fuser process analysis

	Alchemy AB		Operation	Transportation	Inspection	Storing	Waiting	Transportation distance	Amount of inventory in the store	Inventory at the workplace	Already prduced/ shift	Left to produce/ shift	Norm/shift	Number of operators
No.	Activity	Workplace name, type of equipment												
1	Storing	Receiving store				△			875					
2	Transportation	Forklift/Van		⇨				255						
3	Storing	External store				△			80					
4	Transportation	Pallet truck		⇨				49						
5	Sorting	Clean&Screen	○							0				1
6	Transportation	Pallet truck		⇨				44						
7	Storing	Internal store				△	3		130					
8	Transportation	Pallet truck		⇨				46						
9	Reman process	Repasing	○							43	54	76	130	5
10	Transportation	Operator		⇨				2,5						
11	Inspection	Visual inspection			⌧					6	48	82	130	1
12	Transportation	Operator		⇨				3						
13	Packing	Packing	○							7	41	89	130	1
14	Transportation	Pallet truck		⇨				18						
15	Storing	Expedition store				△			280					
	Total frequency		**3**	**7**	**1**	**4**								**7**
	Total time (hours)						**3**							
	Total inventory (pcs)								**1365**					
	Total distance (metres)							**418**						

The process analysis focuses just on fuser modules. The fuser process includes much more stores, waiting and is divided into smaller subprocesses, all provided by different operators. On the contrary, the charger process includes just storing in a receiving store, very reman process performed by the same operator and storing in the expedition store. That`s why it is not the subject of process analysis.

The process starts in the receiving store. The inventories of AB module are too high. This is caused by deal between Greiner Assistec and XEROX Company. Due to the deal GA must always buy all the modules, which are in the central store of XEROX. The purchase price is 0,01 € for one module. Even though this price is really low, storing cost are raising up. However, these inventories cannot be changed, and there is no point to analyze them more into the deep.

Modules are further transported mostly by forklift (in the case of bigger amount by van) to the external store right next to the assembly hall. From this place, modules are sequentially transferred to C&S workplace to be sorted.

As modules have to cool down around 3 hours after sorting, whole pallets are again transported to the store, in this case the internal one. The store is also used for frontload of modules when the entire shift aims on sorting activity. During one shift it is possible to produce a frontload in amount of three days. Pallets with sorted modules are moved to hall again, when there is a requirement from reman process workplace.

The following activities don´t face this big problem with the storing. The minimum inventories on single workplaces occur just because some operators are during the shift performing activities on two or more workplaces. These inventories are never left for another shift. After packing, the full pallet of 40 modules is transported to the expedition store and afterwards dispatched to the customer.

8.2.1 Improved process analysis

Table 20: Improvement of process analysis

5	Sorting	Clean&Screen	○							0				1
6	Transportation	Pallet truck		⇨				44						
7	Storing	Internal store				△	3		130					
8	Transportation	Pallet truck		⇨				46						
9	Reman process	Repasing	○							43	54	76	130	5

Proposal for improvement targets on points 6-8. According to the calculations it takes 2, 85 hours to handle the entire pallet of sorted modules. It is exactly the time needed for modules to cool down. If operator will be working every day both at the C&S workplace as well as at the advanced preparation workplace, it is possible for him to sort just such amount of modules as is required from the following process. At the same time the sorted pallets don`t have to be transported to the store. The special layout will be created at the C&S workplace for short just 3 hours “storage” of pallet with sorted modules. After 3 hours, when modules at the RP workplace are fully processed, the empty pallet from RP is removed to the store, full one from C&S workplace is transported to RP workplace to be in 3 hours processed and just sorted modules from C&S workplace are placed to newly created layout to cool down in 3 hours again. Detailed explanation is shown in the figure below.

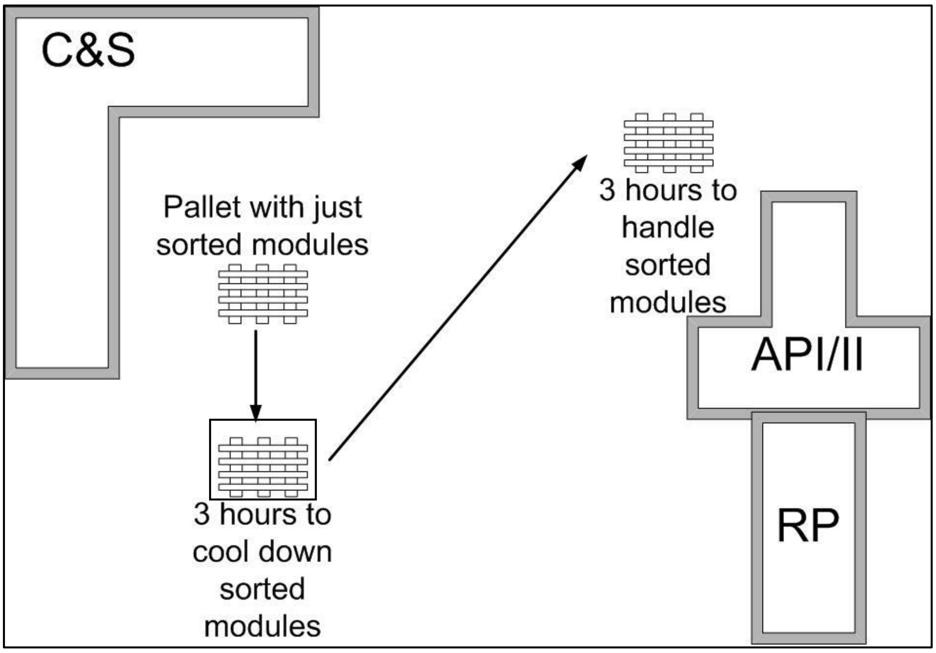


Figure 31: Supplying reman process WP by modules without storing

8.3 Work reorganization

As our optimized line doesn't work in one piece flow, it is not appropriate to use MURA analysis to balance the line. Also not every workplace will be changed or rebalanced by the optimization. The work reorganization relates to Charger workplace, VI workplace, C&S workplace and Packing workplace. All other workplaces won`t be changed at all.

Table 21: Relocation of activities

Activity	Originally performed by	Newly performed by
Unpacking (charger modules)	Charger WP	Packing WP
Reman process (charger modules)	Charger WP	Charger WP
Testing (charger modules)	Charger WP	Visual Inspection WP
Visual control (charger modules)	Charger WP	Visual Inspection WP
Packing (charger modules)	Charger WP	Packing WP
Wrapping charger boxes	Charger WP	Charger WP
Correction of wrong fuser modules	Visual Inspection WP	Packing WP
Cooperation at AP I	Packing WP	C&S

Charger

The customers`requirement will be increased up to 1000 pieces per month. Due to this growth, some activities must be delegated to other workplaces. The charger operator will provide just very reman process to handle as much modules per shift as possible. According to the number of working days per month, which is 21, it is needed to handle 39 modules per day, when producing 800 pcs/month or 48 modules per day, when producing 1000 pcs/ month. The next table shows the number of needed operators to handle 800 and 1000 modules per month.

Table 22: Charger WP new state

<table>
<tr><th>Workplace</th><th colspan="4">Charger</th></tr>
<tr><td>Working days/ month</td><td colspan="4">21</td></tr>
<tr><td>Time fund/shift</td><td colspan="4">403 min</td></tr>
<tr><td>Reman process</td><td colspan="4">18,3 min</td></tr>
<tr><td>Max possible/shift</td><td colspan="4">22 pcs</td></tr>
<tr><th>Pcs/ month</th><th colspan="2">800</th><th colspan="2">1000</th></tr>
<tr><td>Pcs / day</td><td colspan="2">39</td><td colspan="2">48</td></tr>
<tr><td rowspan="2">Required operators/ shifts per month</td><td>Morning shift</td><td>Afternoon shift</td><td>Morning shift</td><td>Afternoon shift</td></tr>
<tr><td>1 / 21 shifts</td><td>1 / 16 shifts</td><td>1/ 21 shifts</td><td>1 / 21 shifts
2 / 4 shifts</td></tr>
</table>

In the case of daily production 39 modules, both morning and afternoon shift must be working with one operator. The morning shift should be running every working day in a month and afternoon shift will be necessary 16 times in month.

Providing daily production of 48 modules, there will be both full shifts (21 working days with morning and afternoon shift too), moreover it well be necessary to use one more operator during 4 afternoon shifts.

Visual inspection

The visual inspection workplace will be enriched of charger testing and charger visual inspection. On the other side corrections of fuser modules will be redeployed to another position. Every shift the operator must inspect 104 fuser modules and 39 or 48 charger modules. As this workplace is working just morning shift, charger modules handled at afternoon shift will be prepared for the next morning shift to be controlled. These activities should take from 360 to 385 minutes.

Table 23: Visual inspection WP new state

Workplace	**Visual Inspection**		
No. of operators	1		
Shift	Morning		
Working days/ month	21		
Time fund/shift (min)	444,5		
Visual inspection	Fuser	Charger	
Time (min)	2,52	2,58	
Pcs/ month	**different types**	**800**	**1000**
Pcs / day	104	39	48
Time consumption (min)	262,08	100,62	123,84
Version	Fuser+ Charger 800	Fuser+ Charger 1000	
Total time consumption (min)	362,7	385,92	
Residual time (min)	81,8	58,58	

Whereas each module is specific and in some cases the copy testing or lamp testing is needed to be performed even twice the residual time won’t be dedicated to any other activities.

Packing

The packing workplace will be modified as well. Currently the operator spends half a shift by cooperating at the AP I workplace. This practise will be transferred to another operator. Instead of it, packing workplace will also include charger unpacking and packing.

Activity concerning about top cover assembly stays untouched and falls within packing workplace too. This combination of activities takes from 300 to 320 minutes. Residual time will be intended for fuser module repairs, originally provided by VI workplace.

Here again the operator works just morning shifts, that`s why charger modules must be at the end of morning shift unpacked for the whole afternoon shift. Simultaneously in the beginning of morning shift there will be repased charger modules waiting for being packed.

Table 24: Packing WP new state

Workplace	**Packing**		
No. of operators	1		
Shift	Morning		
Working days/ month	21		
Time fund/shift (min)	444,5		
Type	Fuser	Charger	
Packing (min)	1,8	1,03	
Unpacking (min)	-	1,14	
Pcs/ month	**different types**	**800**	**1000**
Pcs / day	104	39	48
Time consumption (min)	187,2	84,63	104,16
Top cover assembly (min)	30		
Version	Fuser + Charger 800	Fuser + Charger 1000	
Total time consumption (min)	301,83	321,36	
Residual time (min)	142,67	123,14	

Clean&Screen

The new way of the C&S workplace working is described in the previous chapter. If material flow works just in time and operator is daily processing just the required amount of modules, the time consumed by sorting modules is approximately 170 minutes. Operator still carries out inserting and spring height setting. Residual time of more than 200 minutes will be used for cooperation with AP I workplace, initially carried by packing workplace.

Table 25: C&S WP new state

Workplace	**Clean&Screen**
No. of operators, shift	1, Morning
Working days/ month	21
Time fund/shift (min)	444,5
Daily module need	104 pcs
Time consumption (min)	172, 07
Inserting , Height springs (min)	60
Residual time (min)	212,43

8.4 New layout proposal

Layout changes regard mostly to the charger line area. The tables for charger reman process move on closer to the visual inspection. There are two tables situated opposite each other.

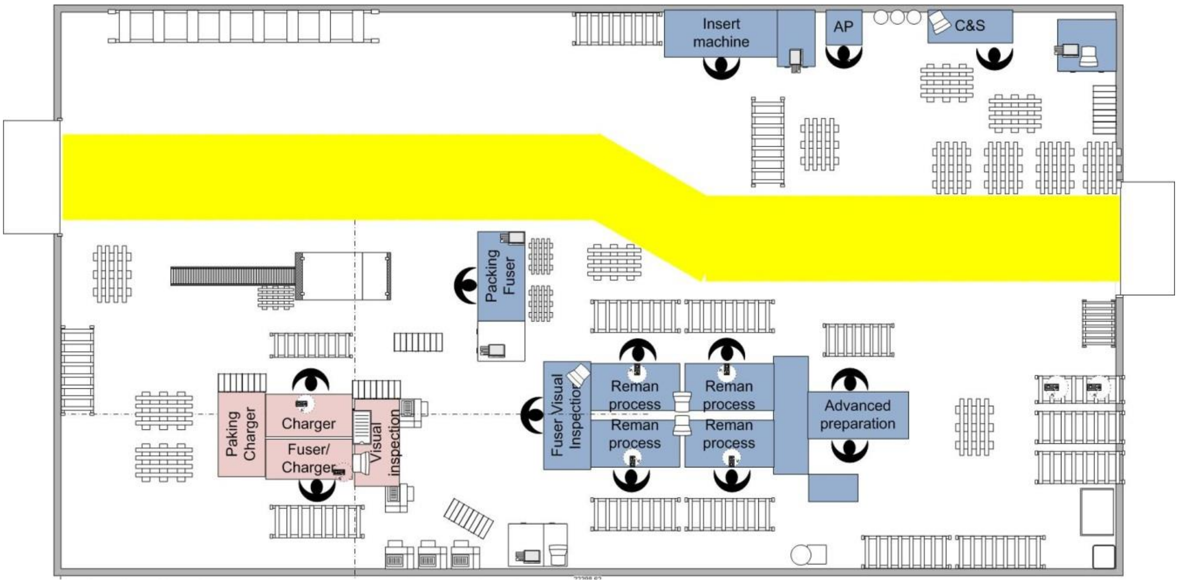


Figure 32: New repasing hall layout proposal

One table appertains just to charger project, the other one is combined. In the case of two charger operators at the afternoon shift, the tables will be used by the charger project. During morning shift the other table will be used for modules` repairs. After processing a charger module operator just place module on a rack which is just next to the VI table devoted for charger modules. Previously this place contained copy machines. The machines will be transferred to the wall of the way. This creates place suitable for VI operator to control both fuser and charger modules.

The empty corner space originally designed for the charger line will serve as area for unpacking and packing of charger modules. After unpacking the operator place a module on a rack next to the charger table. Inspected modules are usually placed on the packing table. Afterwards they are set on a pallet and transported to the store.

9 PROCESS SIMULATION

The following chapter should confirm the line optimization capacities and feasibility of the project. The whole process was simulated in Plan Simulation SW. It is divided into 5 parts:

- The green charger part including source, very reman process of charger modules and buffer (small rack used as intermediate step between charger process and visual inspection); during afternoon shift , charger operators places here the modules, which will be inspected next morning shift;
- The orange fuser part containing source, C&S, four reman process`s workplaces and again buffer, where are laid modules before visual inspection;
- The blue visual inspection part, focusing just on single workplace, which is due to the optimization used by both projects;
- The pink packing area concerning also on one workplace shared by both projects;
- The yellow expedition drains showing the exact number of processed modules, the drain is unique for each project;

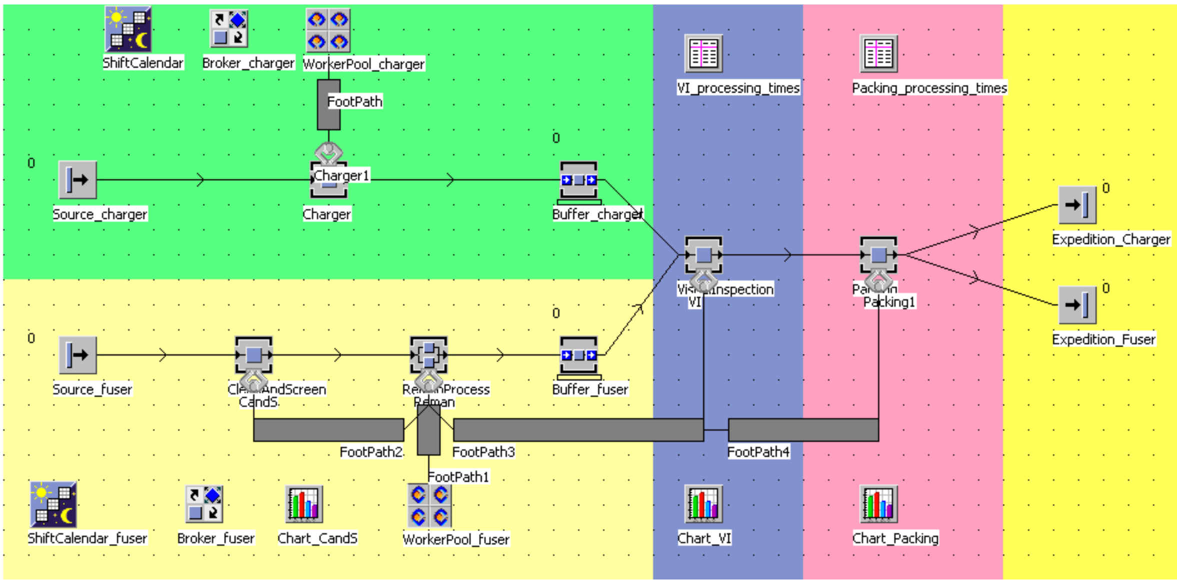


Figure 33: The areas of simulated process

9.1 Basic Settings

Charger area

The charger workplace requires two working shifts. The simulation process is designed for the production of 800 pcs per month.

The processing time was set on 18 minutes 20 seconds according to chronometry. Shift calendar includes two shifts. The working time is not 8 hours, the setting takes into consideration 15 minutes per shift needed for packing on wrapping machine and 5 minutes for workplace cleaning. That`s why morning shifts spend from 6:00 am till 13:40, the breaks take all together 35 minutes due to long distance to the canteen in a different building.

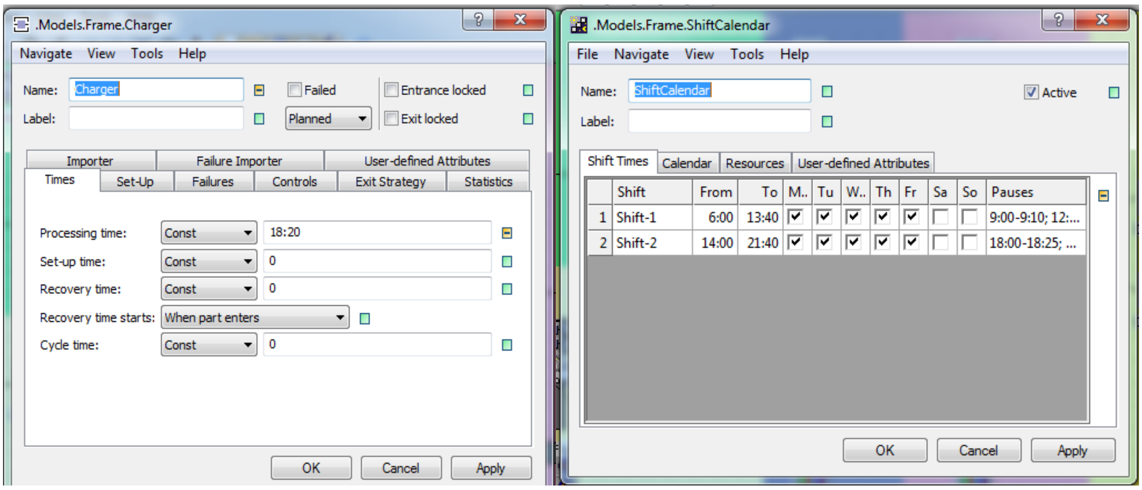
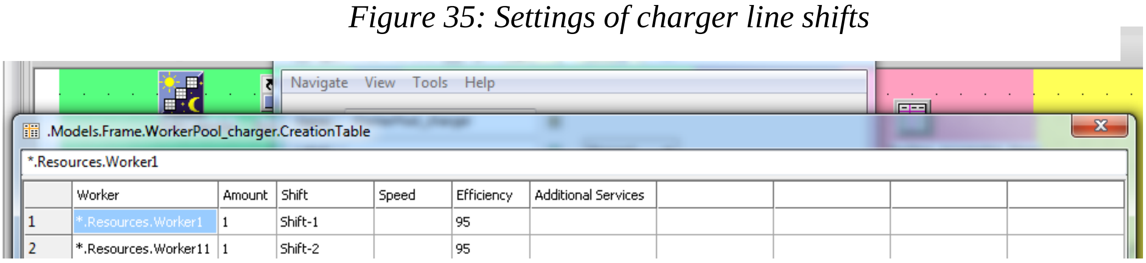


Figure 34: Charger area settings

The workerpool settings concern on the number of workers per shift. As was already mentioned before, due to the volume of production, there is just one operator per shift, the workers` efficiency is 95%.

Figure 35: Settings of charger line shifts



Fuser

The fuser general settings are mostly related to the shifts and number of operators. These setting cover following workplaces: S&C, Reman process, Visual inspection, Packing. As the fuser line if working just morning shifts, this parameter is set in the simulation process as well. With the working time from 5:45 to 14:15, they have obligatory breaks of 35 minutes. The efficiency is again determined on 95%. Number of operators working at the line is 7. This simulation doesn`t take into consideration advanced preparation, as these workplaces weren`t changed at all and don`t influence the continuity of the production.

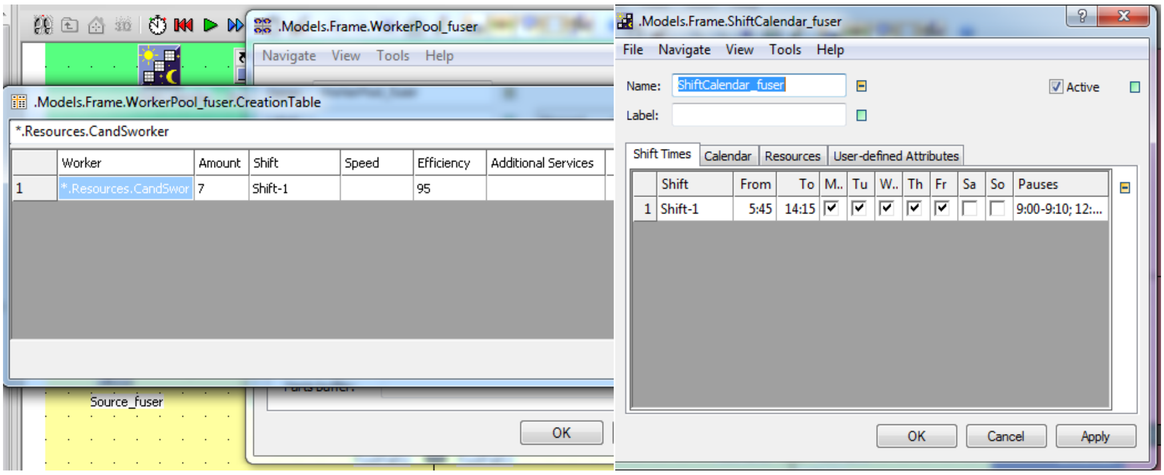


Figure 36: Fuser line settings

Clean&Screen

The Clean&Screen workpalce setting contains just determiantion of the processing time. According to the different processing times depending on the type of module and its handling, the avarage processing time was count.

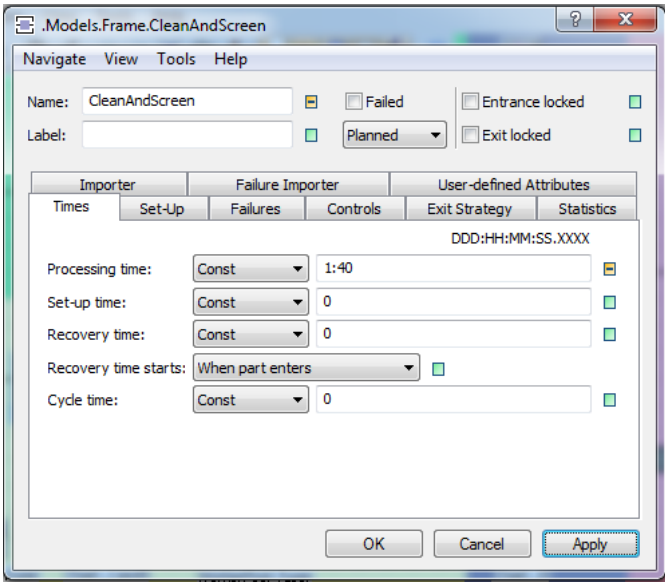


Figure 37: C&S workplace setting

Reman process

The reman process is represented by four operators performing the same activities at each shift. Based on the number of operator, the parallel process function was used for this area. There are four workplaces determined by X dimension: 2 and Y dimension: 2. Processing time complies with the results of the chronometry.

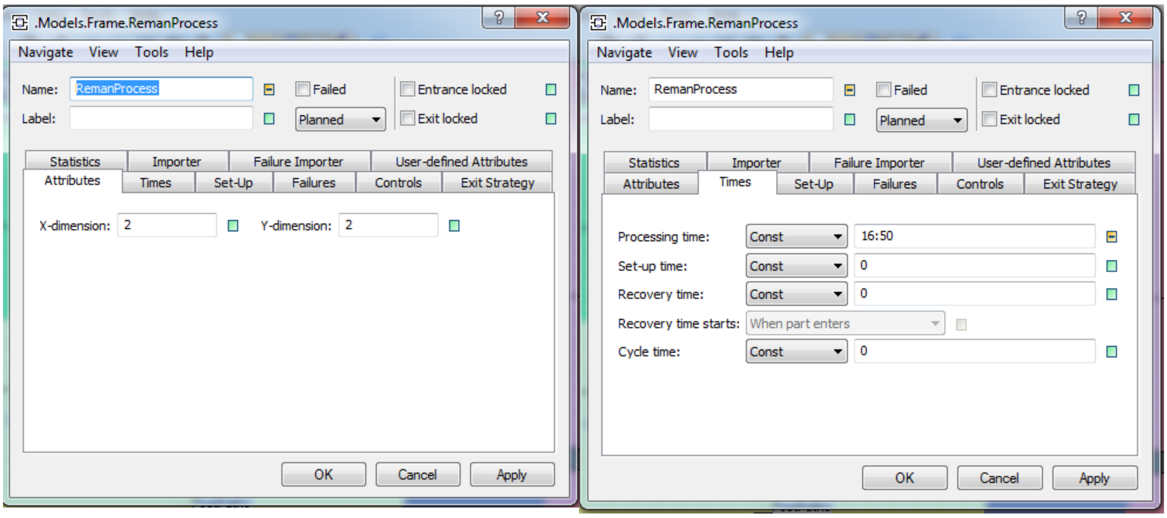


Figure 38: Reman process WP settings

Visual inspection

The visual inspection workplace is performed by one operator. Based on the new optimization, the operator will handle two different types of module, which have also different processing times. Due to this fact, there was a List(Type) used for processing time identification. The times are also consistent with the chronometry results.

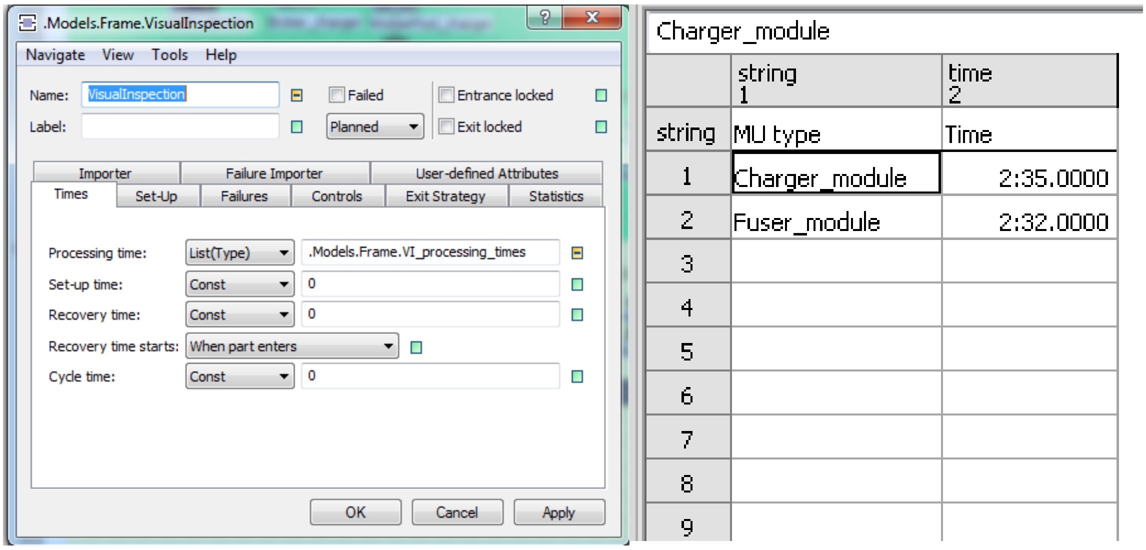


Figure 39: Visual Inspection WP settings

Packing

The packing workplace is fundamentally the same as previous workplace. The only difference lies in the identification of charger module processing time.

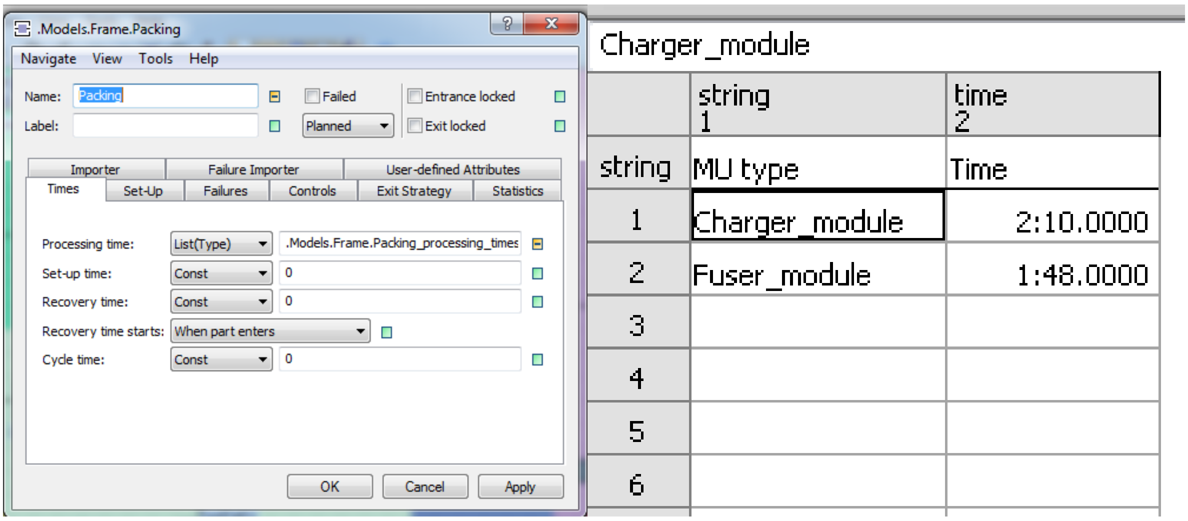


Figure 40: Packing WP settings

As the operator unpacks the modules as well as packs them, the processing time is the sum of these times and again based on the chronometry results.

9.2 Gradual results

State 0 (5:45 am)

State 0 shows the situation before the process is launched at the time 5:45 am, when the fuser line is supposed to start the production. All the counters have zero value.

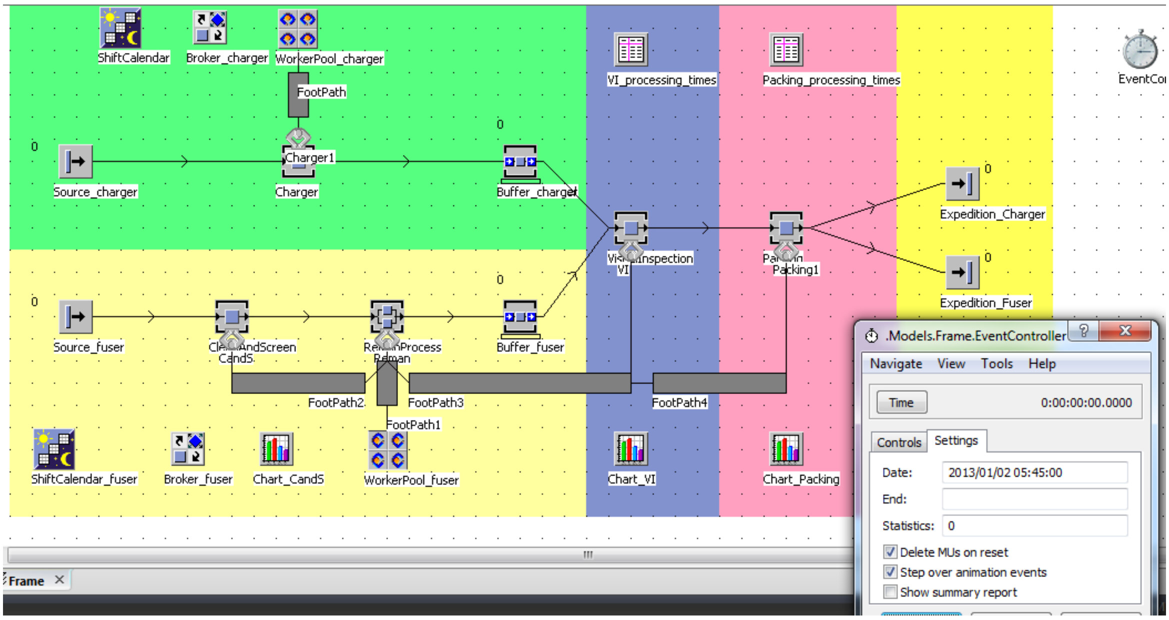


Figure 41: Process simulation- initial state

State 1 (6:00 am)

State one describes the process after 15 minutes. The fuser line is already producing (fuser modules are just at the reman process). Charger line is just launching the production; its counters have still zero value.

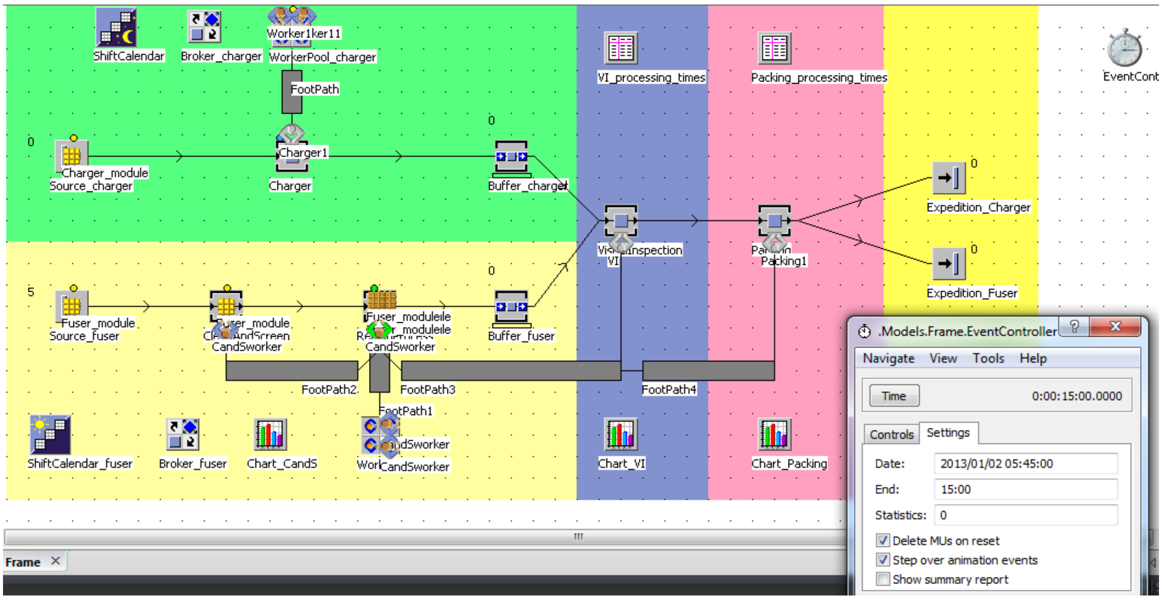


Figure 42: Process simulation- state at 6:00 am

State 2 (2:00 pm)

At 2 pm the charger line is finishing the morning shift, the operator has handled 22 modules. There are no modules in buffer as the last 15 minutes worker was working at the wrapping machine.

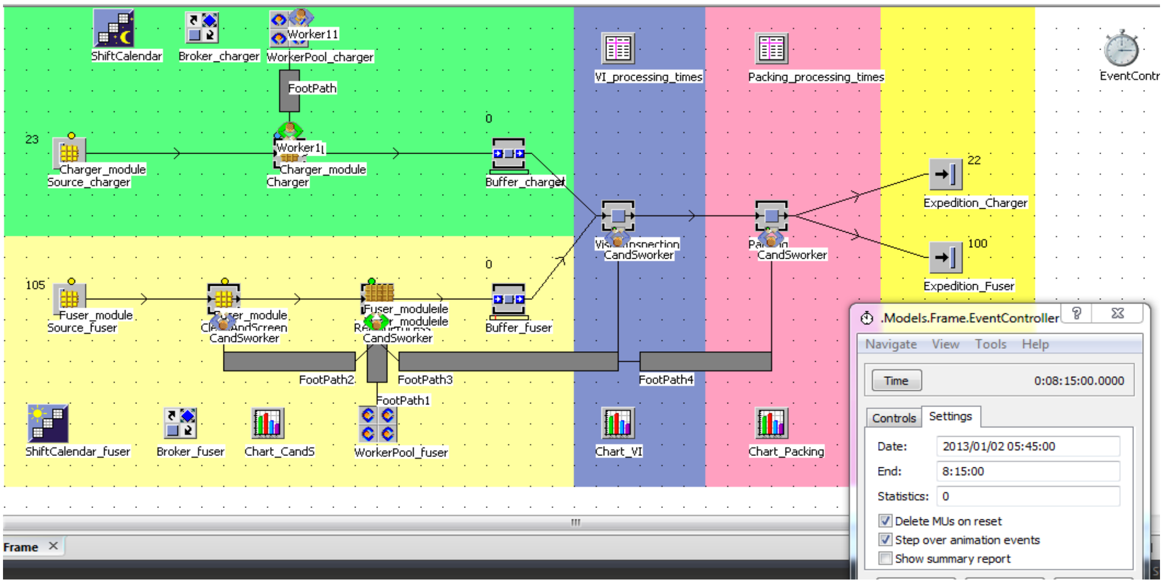


Figure 43: Process simulation- state at 2:00 pm

The fuser line is still producing modules, after 8 hours and 15 minutes they have processed 100 modules.

State 3 (2:15 pm)

State number 3 registers the situation after 8 hours and 30 minutes, in other words at the time, when the fuser production is finishing. The line has produced 104 pcs. At the same time charger line is already working afternoon shift represented by one operator. After 15 minutes the first module is being processed by operator at the reman process.

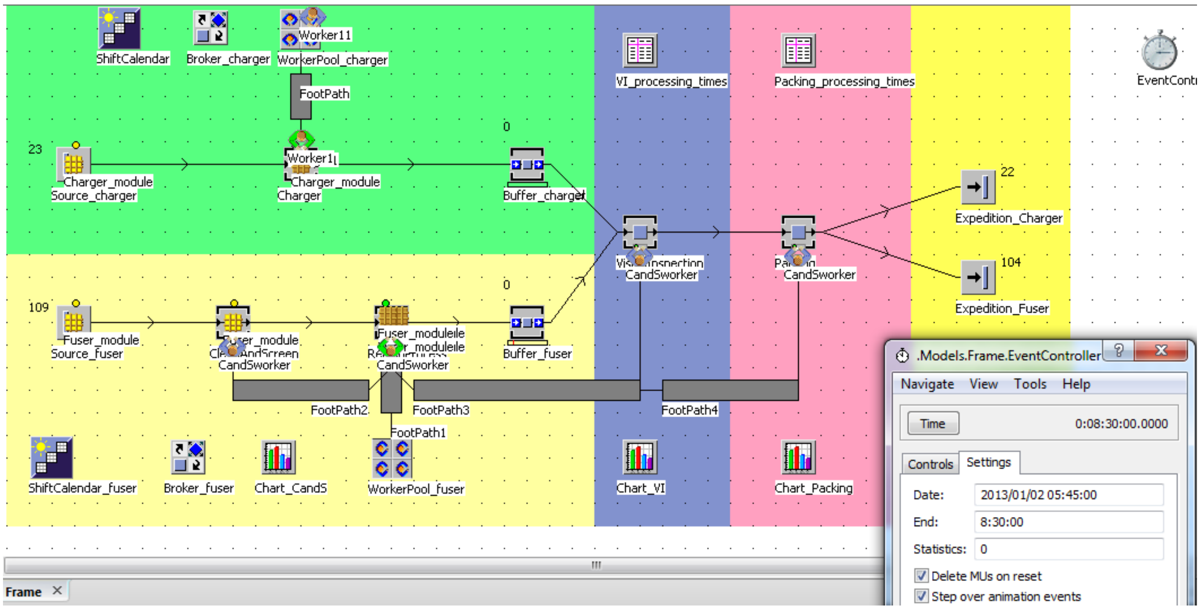


Figure 44: Process simulation- state at 2:15 pm

State 4 (10:00 pm)

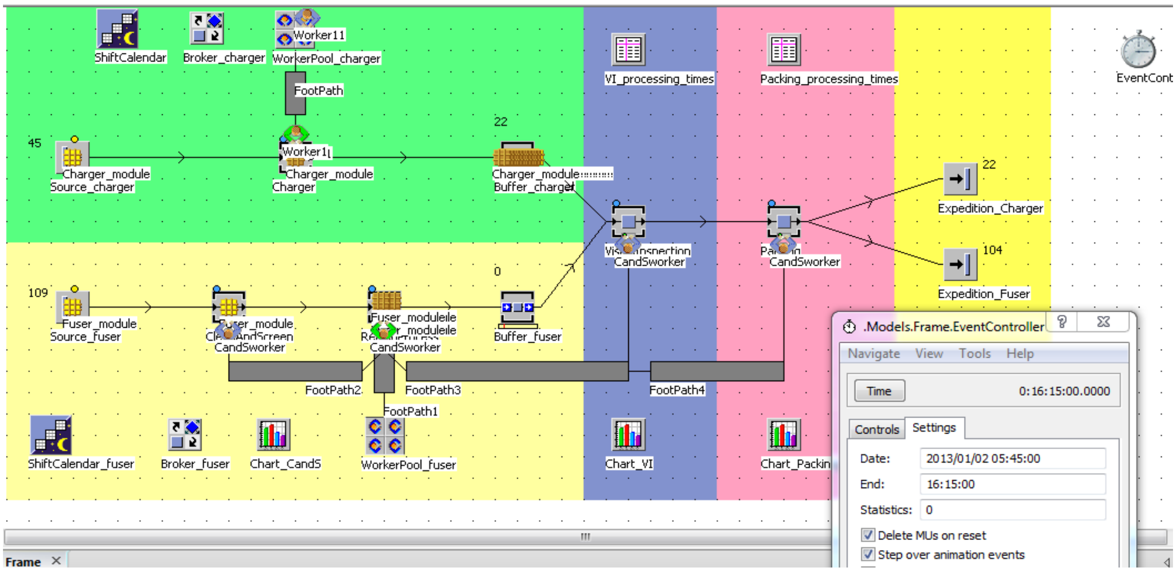


Figure 45: Process simulation- state at 10:00 pm

The last figure shows the situation at 10:00 pm, when the charger afternoon shift is just ending. There are 22 modules in the buffer waiting for morning shift to be visually inspected and packed.

9.3 Efficiency charts

The following charts were specially created for C&S WP and packing WP. Whereas these operators have combined activities:

- The C&S operator: C&S workplace + advanced preparation (1/2 of the shift);
- The packing operator: packing workplace + module repairs;

it was necessary to prove, that they are able to manage both activities in terms of the time. From the charts it can be seen that both operators were working at their primary workplace less than 50% of the shift. The rest of the shift they were blocked or waiting. This time represent the period, they should be working at their secondary workplaces.

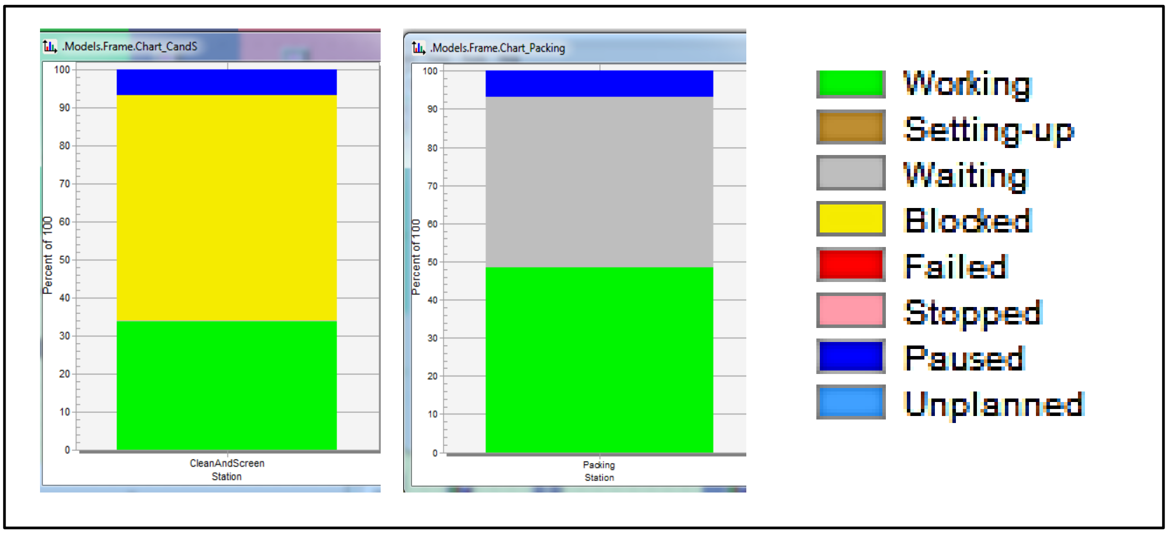


Figure 46: Efficiency charts

10 RACKS STANDARDIZATION

A part of the project was also racks standardization in the hall. This activity covered three racks including production components. The location of the racks is shown in the layout below.

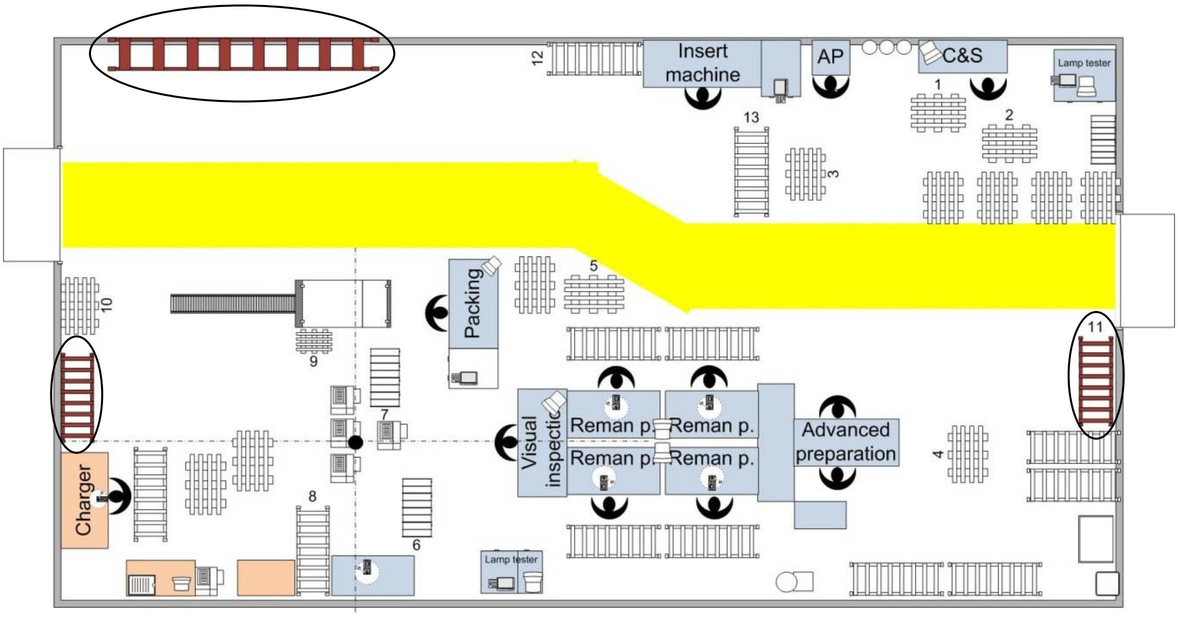


Figure 47: Position of standardized racks

Initially the racks fell within "unguided production". To consider shelf system as guided one, it was needed to name and label each component in the rack and determine its permanent position. In this respect, labels were created and stuck on a shelf to mark a part for production. Labels had to involve four different indications:

- The corporate logo;
- Official name of a component;
- SAP number used for work with SW;
- Picture of a component;

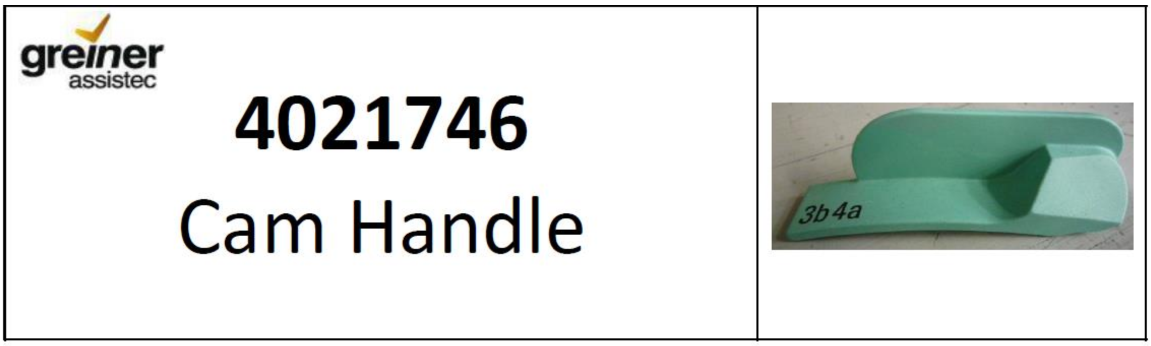


Figure 48: Label for racks´ visualization

Some of components are not being ordered from supplier, because they were obtained from the damaged and lately stripped- down modules and it is possible to use them for reman process again. Because of that, these components don’t have their own SAP number, but merely a store number. Currently modules are not stripped- down anymore and inventories of these components are decreasing. That`s why these parts will be used just until they reach zero inventories. Afterwards it will be necessary to order new components from a supplier. New components will have also their own SAP number.

At the same time standard layout was created and placed at the related rack. The left picture below shows the standar layout of the left FUSER rack, the right one shows its placement on the shelf.

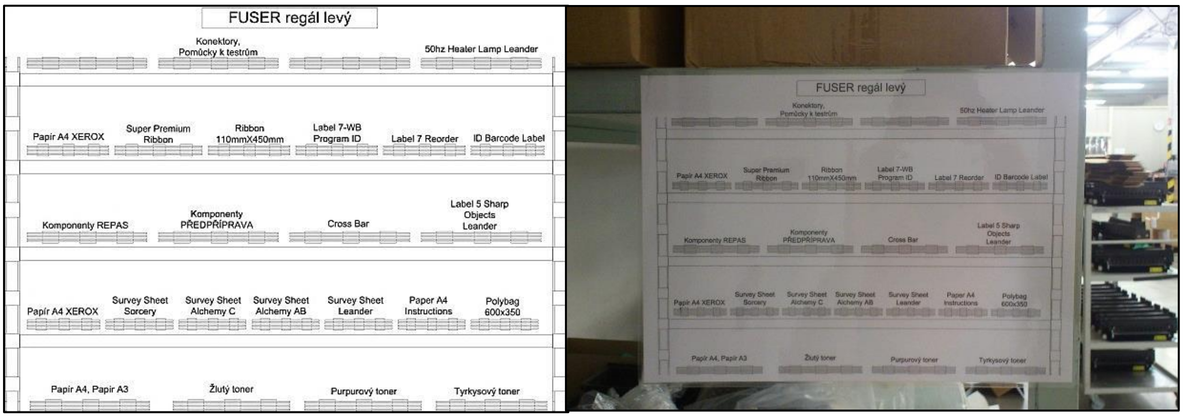


Figure 50: Standardized positions

Another issue with the standardization activity was multitude of open bags with components in bulks placed in cardboard boxes. Open bags don`t preserve the components from dust and other dirt. Except this, bags seem to be disorganized and disordered. This type of components location is desultory and less well manipulatable. The components here are

Figure 49: Boxes for components

not marked as well and the rack is supposed to be unguided.

The problem was solved thanks purchase of plastic box for the components. The plastic boxes are different size and include partitions to isolate different types of components. The boxes also include covers to protect part from dust and dirt. Each component is labeled and promptly marked exactly as the racks before.

This arrangement enables easier manipulation with the components and seems to be organized. Comparison between the initial and the current state represent following pictures.

Figure 51: Standardized rack of Advanced preparation workplaces before (left) and after (right)

11 PROJECT EVALUATION

The assembly optimisation project is not a costly one. The only current expenditure appertains to the plastic boxes purchase as a part of rack standardisation. Boxes were purchased at Auer Packaging company for 153,33€. The detailed costing is shown in the table below.

Table 26: Evaluation of the project

Product	L x W x H (cm)	Amount	Product number	Price EUR/ 1 pcs	Price EUR / Products
Plastic box	60x23,4x14	5	RK 6214	5,49	27,45
Cover		5	SD 6234	4,76	23,8
Front window		5	ES 214	0,6	3
Partition		20	QT 214	0,82	16,4
Plastic box	60x15,6x9	3	RK 61509	3,86	11,58
Cover		3	SD 6156	3,58	10,74
Front window		3	ES 1509	0,48	1,44
Partition		12	QT 1509	0,56	6,72
Plastic box	30x15,6x9	3	RK 31509	2,21	6,63
Cover		3	SD 3156	2,39	7,17
Front window		3	ES 1509	0,48	1,44
Partition		3	QT 1509	0,56	1,68
Plastic box	30x23,4x9	3	RK 3209	2,74	8,22
Cover		3	SD 3234	2,94	8,82
Front window		3	ES 209	0,48	1,44
Partition		3	QT 209	0,6	1,8
Postage				15 €	15 €
Total price EUR				47,55 €	153,33 €
Total price CZK					**3 925,25 CZK**

All other standardisation materials, printed labels and foils, didn’t have to be purchased. The materials like these are always present at the company due to frequent usage and that`s why I do not count them in the project cost.

The changed layout issue similarly doesn`t require any special expenses. This change is not a radical one, necessary activities concern about the change of the charger tables, racks and copy machines. A little bit more complicated is preparation of optimal electronics position. Since both lines are not working night and weekend shifts and the fuser line is neither working afternoon shift, all these activities can be performed during lines non-working time by the company`s maintenance employees in the range of their working time. Project also doesn`t require more employees for increased production, this implies no more extra costs for manufacturing employees.

12 ADDITIONAL IMPROVEMENT SUGGESTIONS

12.1 Potential line layout and 3D design

New layout design is mostly based on a relocation of the Charger workplace and the better approach of the shared workplaces by operators. Thanks the relocation it is easier for the packing operator to share both, the charger packing as well as the fuser packing workplace. Fundamentally the same are also the workplaces of visual inspection.

The potential line is designed in a way to eliminate operators´ motions to minimum. As it is necessary to reach fluent flow of the product, all the workplaces are linked together by gravitational conveyors. It enables better time utilisation and higher work efficiency. The whole line-feeding activity is performed by milkrunner. Workbenches are designed with the front feeders, compared to the storing racks behind the operators in the initial state.

In the initial state the operators were taking unrepased modules and placing already repased modules on their own. In the case of new layout design milkrunner refills the table feeders by modules before process. After the reman process is done, an operator lays a module on a gravitational conveyor, which leads the module to the next workplace.

The connection between the advanced preparation workplaces and the reman process workplaces works at the same principle. Originally the AP operators gathered the parts to be repaired at the AP workplaces. Afterwards the repaired parts were collected by individual operators who were going to use them. The new gravitational conveyor between the workplaces enables the transport of these parts without any additional movements. After the processing, the parts are put into the AP rack, from where they are taken by milkrunner and put into the feeders at the working tables of operators.

Positions of the working tables are designed in a way to reach easily conveyors as well as to fulfill simply the feeders.

12.2 Potential 3D workplaces

The following section describes the specific workplaces and their features. The C&S workplace is almost unchanged as there is no specific tooling which requires adapted workbench.The typical appearance is respected, but the bench is designed in a simple way to leave as much space as possible for the operator´s activities. The blow gun is displaced to the C&S WP, to prepare modules for the immediate RP without any further cleaning.

Reman process workplace (fuser and charger)

The reman process WP is almost identical for fuser and charger. The only difference lies in the width as the charger process requires more tooling to be handled (signed as a special tooling in the picture below).

The workbench contains of a multilevel tray system. The upper feeders declining to the operator serve for screws and components. The feeders declining out of the operator are used for empty boxes from components, which are collected by milkrunner. The bottom feeders also declining to the operator are reserved for scraps and modules which should be processed.

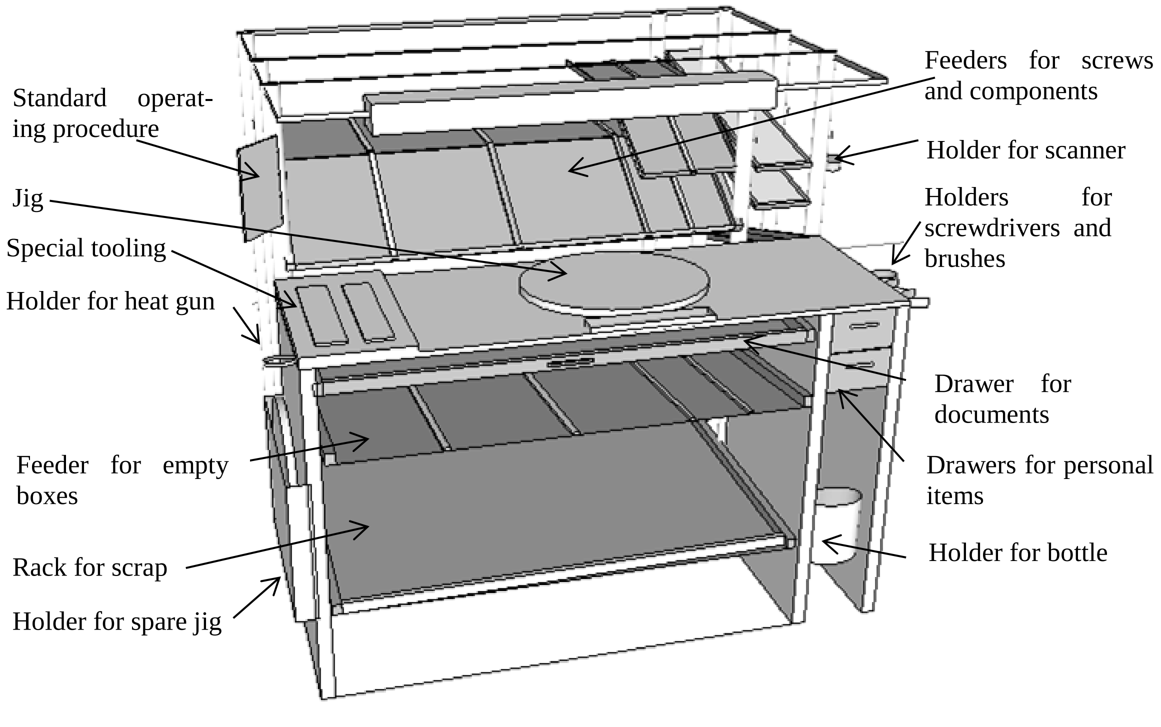


Figure 52: Potential design of reman process WP

Each workbench includes two types of drawers, the low one stretching under the work desk is determined for documents related to the production. The other drawers are used for personal items.

Specific holders are part of the workbench as well. On the table there are located holders for bottle, screwdrivers, brushes, scanner, heat gun and standard operating procedure. Special holder is designed for spare jig, which was previously stored in a rack. In the new proposed state this rack is not used anymore. All reman process workplaces are placed along the conveyor and so connected with the VI workplaces.

Visual Inspection and Packing workplaces

VI and packing workplaces create all together a specific section of the layout. There are 4 positions performed by 2 operators. This location of workbenches makes it easy for operators to operate more projects during the shift.

Fuser VI and packing

After the reman process of fuser modules is finished, these are sent by conveyor to the VI workplace. The whole process is set into the L layout. Finishing the testing, a module is moved to the VI workbench, which contains just two types of feeders (the upper one for screw

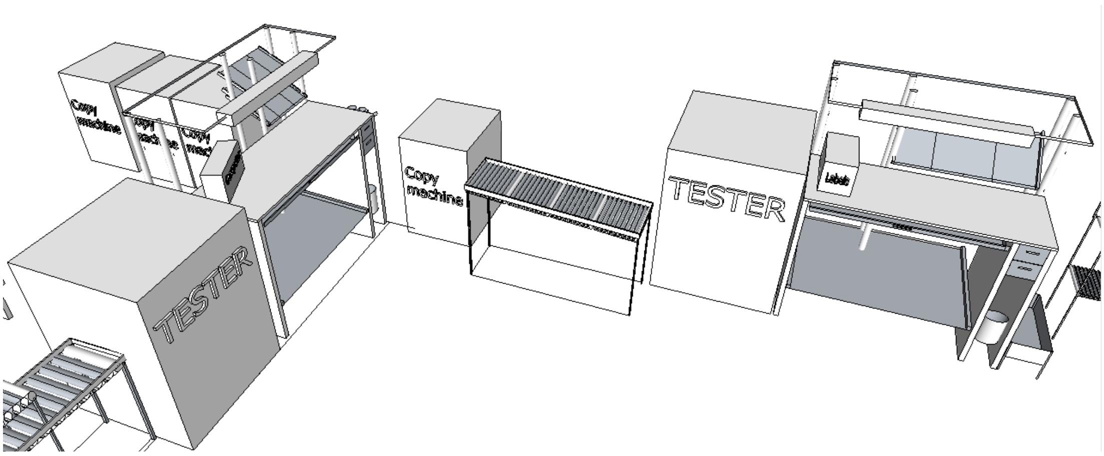


Figure 53: potential design of fuser VI and packing workplaces

drivers, the bottom one for scrap and modules which are necessary to be repaired), drawers and holders (for water, brushes and screwdrivers). Since the modules are not dismantled here, there is no jig on the work desk, just the computer for unloading the modules. After the copy test and cleaning, the module is shifted via gravitational conveyor to the packing workplace. The packing workbench is almost the same as VI. Moreover it includes a machine for labels and a special ramp for pasteboard boxes for modules.

Charger VI and packing

Charger modules are also shifted by the separate conveyor. The visual inspection workbench is quite simple as it includes just bottom tray for scraps and modules which have to be repaired. On the desk there are testers, label machine and computer. The water holder and drawers are standard for each workbench. Performing a copy test, the modules are placed at the rack coupling together VI and packing workplace. The charger packing workplace is utterly identical to fuser one.

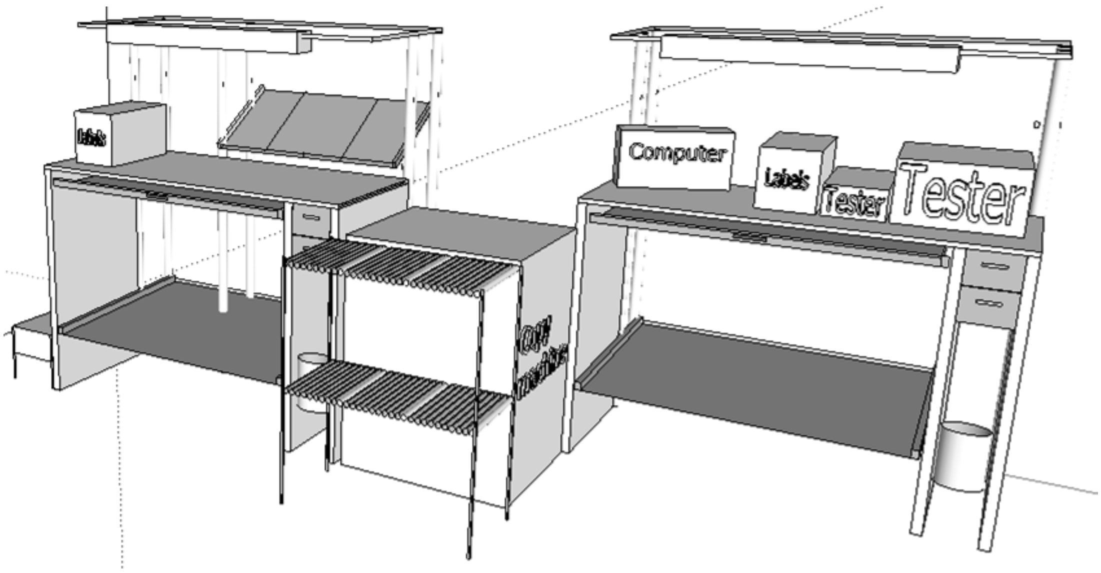


Figure 54: Potential design of charger VI and packing workplaces

Advanced Preparation workplaces

These workbenches are basically the same as reman process one. They differ in the jig which is specific for each process. Except the main working desk there are some additional benches according to the combination of the performed processes.

Advanced Preparation I

The workplace covers also a place where the head of the panel is dismantled and subsequently new cables are inserted in. After processing the head, it is laid on a conveyor,

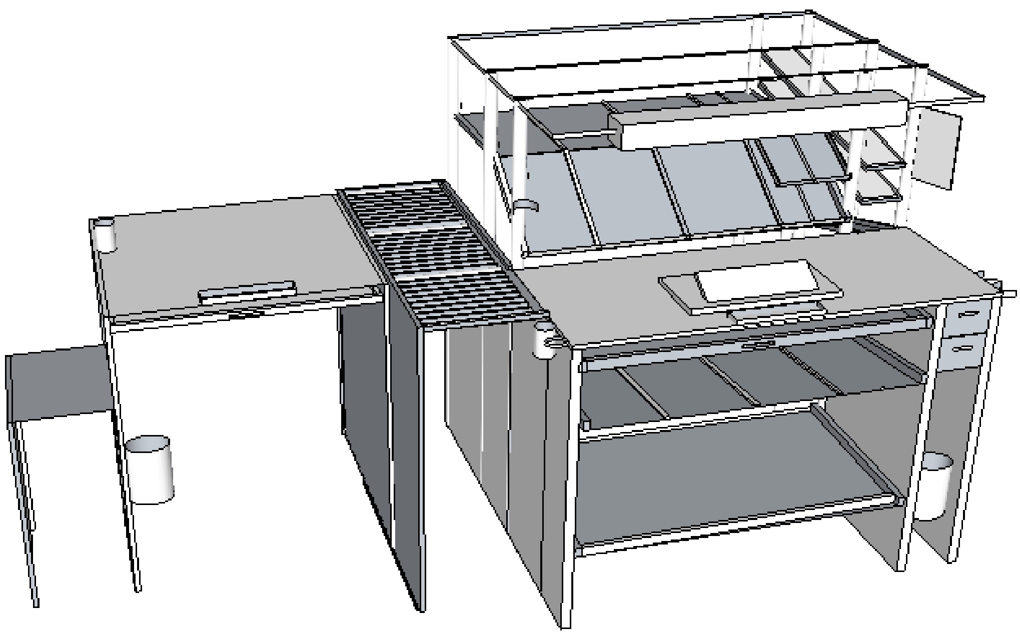


Figure 55: Potential design of API workplace

which is gravitational and shifts the head to the AP operator? The lower ramp is used for the box with completed heads.

Advanced Preparation II workplace

In this case the additional bench serves for setting the hights used for the AP process. The only holder at the workbench is earmarked for heat gun. The lower ramp is again determined for the box with the completed parts.

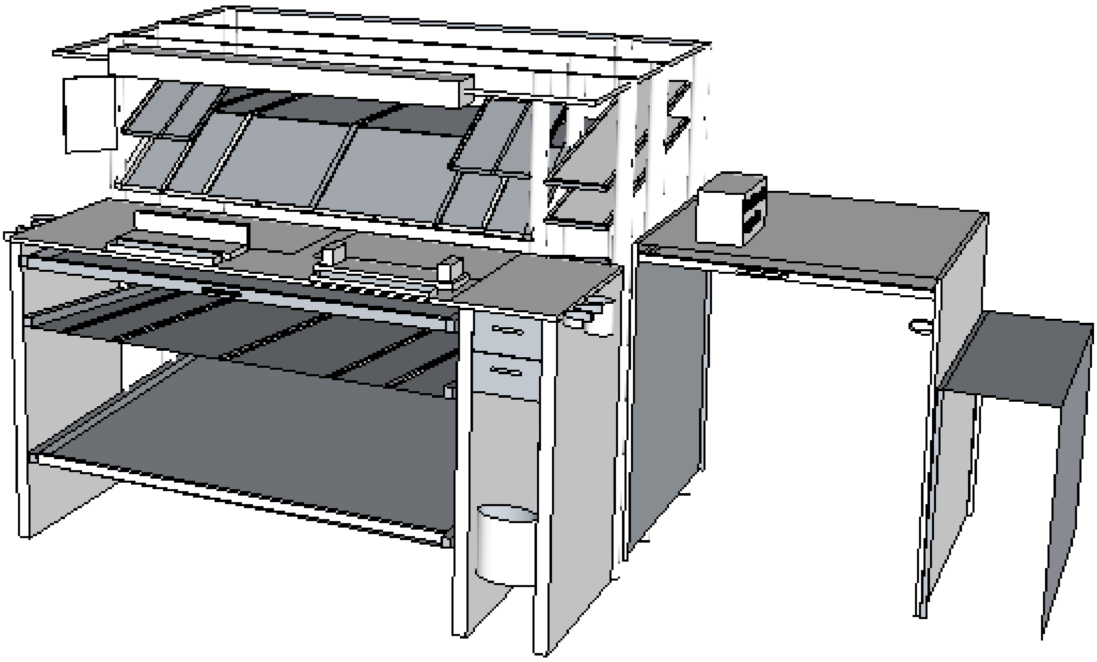


Figure 56: Potential design of APII workplace

Clean&Screen workplace

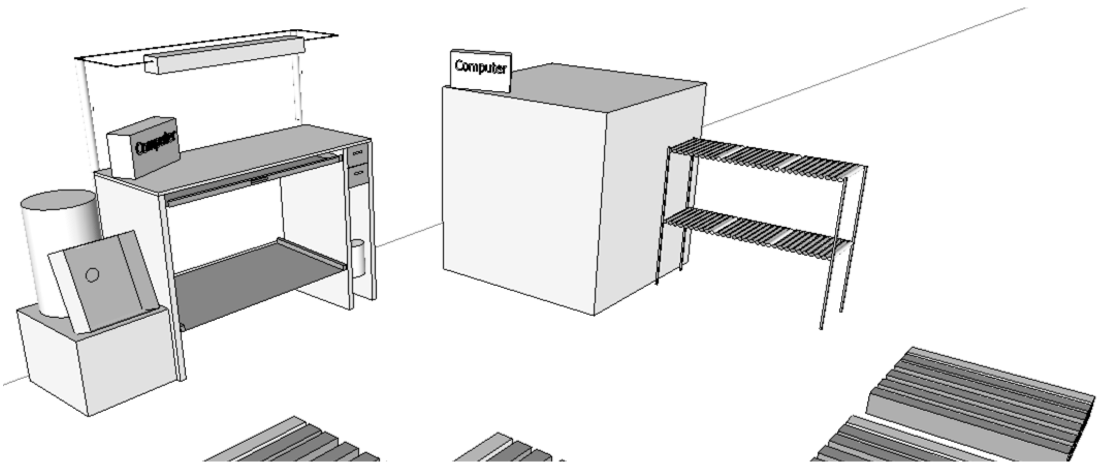


Figure 57: Potential design of C&S workplace

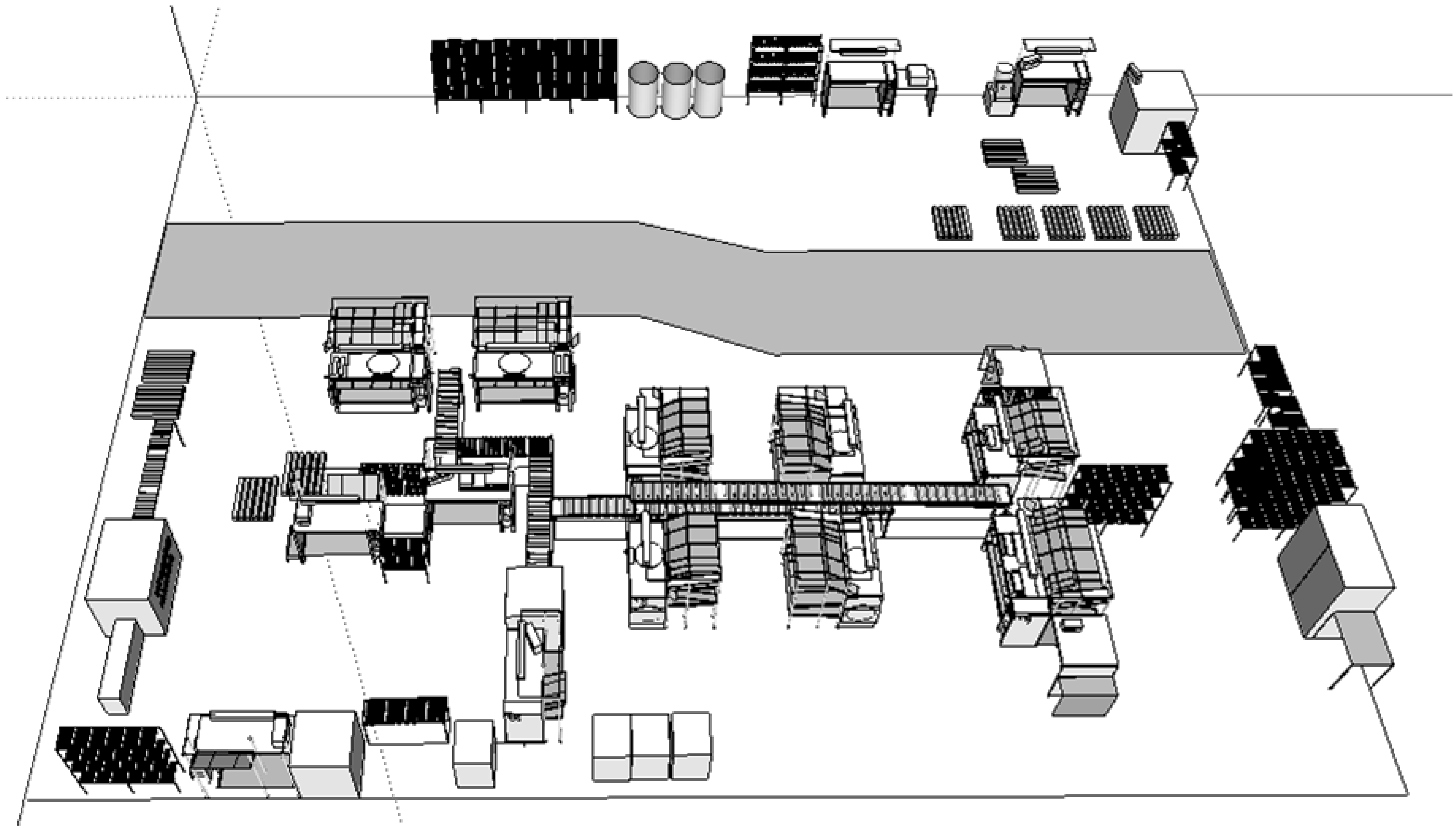


Figure 58: Potential design and layout of the assembly lines

12.3 Supply by Kanban

The line is designed in the way that separates full and empty boxes for components. On the top shelf unit declining toward the operator full boxes with components should be inserted. The rack declining away from the operator is devoted to empty ones. All the manipulation with components should be carried out only by the line feeder.

When production is switched to another type, the line feeder has a feeding plan to cover initial operators´ needs. Subsequently he renews components due to operators' consumption. In practice it works as follows. After the operator empties the box, inserts it into corresponding shelf unit for empty boxes. This is a sign for line feeder to capture the empty box and replace it by full one, but feeding the associated rack unit for full boxes.

In this case electronic kanban works between supermarket and the store of material, but within rack units and supermarket kanban has the character of empty box for components.

Regarding the line feeder, he takes over all activities associated with the feeding line, even those that were originally performed by operators (as refilling modules for reman process, all kinds of screw).

CONCLUSION

The Master thesis deals with optimization of the repasing line at Greiner Assistec, Ltd. Company faced an increased order of remanufactured XEROX modules. Based on the customer requirements and conditions of GA, the activities performed during the whole process were reallocated and subsequently balanced.

In pursuance of the literature sources, theoretical part established the basic terms needed to develop the analytical part. At the beginning, lean production and mostly used methods were characterised. Subsequently I also dealt with concepts of waste, time consumption standards and MOST methodology, inventory management as well as principles of assembly.

Collection of data required for optimization proposal took roughly one month. The primary method for data acquisition was chronometry performed in two repeatings for each position. The success of the project is to include all who are in touch with existing procedures. That is why I chose similar tactics to process the task. Discussing the details of process with operators and line feeders and equally tolerating the conditions laid down by process managers, I prepared a preliminary draft.

Working out the complete optimization proposal of the visualization tools took about the same time slot. The chronometry results and new capacity abilities were confirmed by MOST technique and Plant Simulation, process simulation software.

In the final stage of the thesis I designed a new potential line, whereas it requires higher investment, it is still a matter of future. A part of this proposal is also new line feeding system based on kanban, where one empty box/ one empty position for components is always replaced by full one, all managed by line feeder.

The optimisation proposal has not been applied yet. As it requires stable amount of operators and all of them are working with efficiency over 90%, new operators must be accomplished to replace original ones in case of absence. As this education is time consuming, the implementation is expected in the near future.

BIBLIOGRAPHY

[1] DENNIS, Pascal, c2002. *Lean production simplified: a plain language guide to the world's most powerful production system*. New York: Productivity Press, 170 p. ISBN 1563272628.

[2] DRAHOTSKÝ, Ivo & Bohumil ŘEZNÍČEK, 2003. *Logistika: procesy a jejich řízení*. Ed. 1. Brno: Computer Press, 334 p. ISBN 8072265210.

[3] EMMETT, Stuart, 2008. *Řízení zásob: jak minimalizovat náklady a maximalizovat hodnotu*. Ed. 1. Brno: Computer Press, 298 p. ISBN 978-80-251-1828-3.

[4] CHROMJAKOVÁ, Felicita & Rastislav RAJNOHA, 2011. *Řízení a organizace výrobních procesů: kompendium průmyslového inženýra*. Žilina: GEORG, 138 p. ISBN 978-80-89401-26-0.

[5] JIRÁSEK, Jaroslav, 1998. *Štíhlá výroba*. Ed. 1. Praha: Grada, 199 p. ISBN 8071693944.

[6] KEŘKOVSKÝ, Miloslav & Ondřej VALSA, 2012. *Moderní přístupy k řízení výroby*. Ed. 3.V Praze: C.H. Beck, 153 p. ISBN 978-80-7179-319-9.

[7] KOLARIK, William J., c1999. *Creating quality: process design for results*. Boston: WCB/McGraw-Hill, 641 p. ISBN 0070363099.

[8] KOŠTURIAK, Ján & Zbyněk FROLÍK, 2006. *Štíhlý a inovativní podnik*. Praha: Alfa Publishing, 237 p. ISBN 80-86851-38-9.

[9] LHOTSKÝ, Oldřich, 2005. *Organizace a normování práce v podniku*. Ed. 1. Praha: ASPI, 104 p. ISBN 80-7357-095-5.

[10] LIKER, Jeffrey K., c2004. *The Toyota way: 14 management principles from the world's greatest manufacturer*. New York: McGraw-Hill, 330 p. ISBN 0071392319.

[11] MAŠÍN, Ivan, c2003. *Mapování hodnotového toku ve výrobních procesech*. Edd. 1. Liberec: Institut průmyslového inženýrství, 80 p. ISBN 80-902235-9-1.

[12] MAŠÍN, Ivan, 2004. *Výroba velkého sortimentu v malých sériích: principy výrobních systémů pro 21. století*. Liberec: Institut technologií a managementu, 101 p. ISBN 8090353304.

[13] MAŠÍN, Ivan & Milan VYTLAČIL, 2000. *TPM: management a praktické zavádění*. Ed. 1. Liberec: Institut průmyslového inženýrství, 246 p. ISBN 8090223559.

[14] ROTHER, Mike & John SHOOK, 1999. *Learning to See*. Brookline: Lean Enterprise Institute, ISBN 0-9667843-0-8.

[15] SIXTA, Josef & Miroslav ŽIŽKA, 2009. *Logistika: metody používané pro řešení logistických projektů*. Ed. 1. Brno: Computer Press, 238 p. ISBN 978-80-251-2563-2.

[16] SYNEK, Miloslav & Eva KISLINGEROVÁ, 2010. *Podniková ekonomika*. Ed. 5. V Praze: C.H. Beck, 498 p. ISBN 978-80-7400-336-3.

[17] TUČEK, David & Roman BOBÁK, 2006. *Výrobní systémy*. Ed. 2. arr. Zlín: Univerzita Tomáše Bati ve Zlíně, 298 p. ISBN 8073183811.

[18] 2005. *Výkladový slovník průmyslového inženýrství a štíhlé výroby*. Ed. 1. Liberec: Institut technologií a managementu.

ONLINE BIBLIOGRAPHY

[19] Balancování operací, *API- Akademie productivity a inovací, s.r.o.* [online]. [cit. 2013-03-20]. Also available at: http://e-api.cz/page/68346.balancovani-operaci/

[20] BOLEDOVIČ, Ľudovít,. 2007. Tréning SMED :Realizované vo firme Pro-fil, s.r.o. *IPA Slovakia* [online]. [cit. 2013-03-20]. Also available at: <www.ulozto.sk/1386702/smed-pdf>.

[21] DEBNÁR, Róbert, 2012. Štíhly vývoj. *IPA Slovakia* [online]. [cit. 2013-03-20]. Also available at: http://www.ipaslovakia.sk/sk/ipa-slovnik/stihly-vyvoj

[22] HANDZOVÁ, Soňa, 2009. Štíhly podnik = viac peňazí. *Strojárstvo / Strojírenství- prvý strojársky server* [online]. [cit. 2013-03-20]. Also available at: http://www.strojarstvo.sk/inc/casopis/022009/46-47.pdf

[23] KORMANEC, Peter, 2007. TQM- Totálne riadenie kvality. *IPA Slovakia* [online]. [cit. 2013-03-20]. Also available at: http://www.ipaslovakia.sk/sk/ipa-slovnik/tqm-totalne-riadenie-kvality

[24] KOŠTURIAK, Ján, 2012. Štíhla administratíva. *IPA Slovakia* [online]. [cit. 2013-03-20]. Also available at: http://www.ipaslovakia.sk/sk/ipa-slovnik/stihla-administrativa

[25] KRIŠŤÁK, Jozef, 2012. MOST- Maynard Operation Sequence Technique. *IPA Slovakia* [online]. [cit. 2013-03-20]. Also available at:

http://www.ipaslovakia.sk/sk/ipa-slovnik/most-maynard-operation-sequence-technique

[26] KYSEĽ, Marek, 2012. Štíhla výroba- lean. *IPA Slovakia* [online]. [cit. 2013-03-20]. Also available at: http://www.ipaslovakia.sk/sk/ipa-slovnik/stihla-vyroba-lean

[27] Just in Time. *API- Akademie productivity a inovací, s.r.o.* [online]. [cit. 2013-03-20]. Also available at: http://e-api.cz/page/68347.just-in-time/

[28] Porovnanie japonského a amerického manažmentu. *EuroEkonóm.sk- ekonomika pre ekonómov* [online]. [cit. 2013-03-20]. Also available at: http://www.euroekonom.sk/manazment/vseobecny-manazment/porovnanie-japonskeho-a-americkeho-manazmentu/

[29] STRACHOTA, Svatopluk, 2009. Postup při zavádění štíhlého výrobního systému - Leanu. *API- Akademie produktivity a inovací, s.r.o.* [online]. [cit. 2013-03-20]. Also available at: http://e-api.cz/article/68820.postup-pri-zavadeni-stihleho-vyrobniho-systemu-8211-leanu

[30] Supermarket. *API- Akademie productivity a inovací, s.r.o.* [online]. [cit. 2013-03-20]. Also available at: http://e-api.cz/page/68345.supermarket/

[31] Štíhlá výroba. *API- Akademie productivity a inovací, s.r.o.* [online]. [cit. 2013-03-20]. Also available at: http://e-api.cz/page/67819.stihla-vyroba/

[32] The Backbone of Lean in the Back Shops. *Duggan Associates- Lean training and implementation experts* [online]. [cit. 2013-03-20]. Also available at: http://www.dugganinc.com/cms/index.php?aid=126

[33] UHROVÁ, Monika, 2012.Štíhla logistika. *IPA Slovakia* [online]. [cit. 2013-03-20]. Also available at: http://www.ipaslovakia.sk/sk/ipa-slovnik/stihla-logistika

[34] Základy montáže. [online]. [cit. 2013-03-20]. Also available at: <http://old.fst.zcu.cz/_files_web_FST/_dokumenty_FST/_akreditace-FST-09/DATA/ukazky/2%20ZAKLADY%20MONTAZE%20FOL.pdf>.

[35] ZLOCHOVÁ, Martina, 2012. Optimalizace výrobních buněk. *API- Akademie produktivity a inovací s.r.o.* [online]. [cit. 2013-03-20]. Also available at: http://e-api.cz/article/70911.optimalizace-vyrobnich-bunek/

LIST OF ABBREVIATIONS

AD I	Advanced Preparation I
AD II	Advanced Preparation II
C&S	Clean&Screen
Etc.	et cetera
GA	Greiner Assistec
GAU	Global Assembly Unit
NVA	Non value added
RP	Reman Process
VA	Value added
VI	Visual Inspection
WP	Workplace

LIST OF FIGURES

Figure 1: Lean Company 10
Figure 2: Lean Production elements 13
Figure 3: Kaizen umbrella 15
Figure 4: TPM pillars] 16
Figure 5: Work study partition 24
Figure 6: Chronocyclogram 26
Figure 7: Work measurement division 28
Figure 8: ABC analysis 32
Figure 9: Pull and push system 33
Figure 10: Heijunka box 35
Figure 11: Supermarket pull system 36
Figure 12: Map of worldwide activities of Greiner Group 42
Figure 13: Organizational structure 43
Figure 14: Product portfolio 44
Figure 15: Injection moulding machine 44
Figure 16: Injection moulding A Lounge layout 45
Figure 17: Injection moulding B Lounge layout 46
Figure 18: Assembly hall layout 46
Figure 19: Charger workplace 49
Figure 20: Flowchart of the whole Fuser module process 50
Figure 21: Clean&Screen flowchart 51
Figure 22: Clean&Screen workplace 52
Figure 23: Reman process workplace 52
Figure 24: Advanced preparation I workplace 53
Figure 25: Visual Inspection workplace 54
Figure 26: Visual inspection flowchart 54
Figure 27: Advanced preparation II workplace 55
Figure 28: Packing workplace 56
Figure 29: Repasing hall layout 65
Figure 30: Charger line layout 66
Figure 31: Supplying reman process WP by modules without storing 72
Figure 32: New repasing hall layout proposal 76

Figure 33: The areas of simulated process 77
Figure 34: Charger area settings 78
Figure 35: Settings of charger line shifts 78
Figure 36: Fuser line settings 79
Figure 37: C&S workplace setting 79
Figure 38: Reman process WP settings 80
Figure 39: Visual Inspection WP settings 80
Figure 40: Packing WP settings 81
Figure 41: Process simulation- initial state 81
Figure 42: Process simulation- state at 6:00 am 82
Figure 43: Process simulation- state at 2:00 pm 82
Figure 44: Process simulation- state at 2:15 pm 83
Figure 45: Process simulation- state at 10:00 pm 83
Figure 46: Efficiency charts 84
Figure 47: Position of standardized racks 85
Figure 48: Label for racks´ visualization 85
Figure 49: Boxes for components 86
Figure 50: Standardized positions 86
Figure 51: Standardized rack of Advanced preparation workplaces before (left) and after (right) 87
Figure 52: Potential design of reman process WP 91
Figure 53: potential design of fuser VI and packing workplaces 92
Figure 54: Potential design of charger VI and packing workplaces 93
Figure 55: Potential design of API workplace 93
Figure 56: Potential design of APII workplace 94
Figure 57: Potential design of C&S workplace 94
Figure 58: Potential design and layout of the assembly lines 95

LIST OF TABLES

Table 1: Difference between American and Japanese management 12
Table 2: PQCDSM Check-list... 27
Table 3: 5W1H Check-list... 27
Table 4: MOST division 29
Table 5: Assembly typology due to mechanization and automatization aspects 38
Table 6: SWOT Analysis 48
Table 7: Charger time analysis I 58
Table 8: Charger time analysis II.. 59
Table 9: Clean&Screen time analysis I 60
Table 10: Clean&Screen time analysis II... 60
Table 11: Reman process time analysis... 61
Table 12: Advanced preparation I time analysis.. 62
Table 13: Advanced preparation II time analysis I 62
Table 14: Advanced preparation II time analysis II.. 63
Table 15: Visual Inspection time analysis 63
Table 16: Packing time analysis.. 64
Table 17: Charger production plan.. 69
Table 18: Fuser production plan 69
Table 19: Fuser process analysis 70
Table 20: Improvement of process analysis *71*
Table 21: Relocation of activities 72
Table 22: Charger WP new state.. 73
Table 23: Visual inspection WP new state... 74
Table 24: Packing WP new state 75
Table 25: C&S WP new state 75
Table 26: Evaluation of the project 88

APPENDICES

APPENDIX P I: Maynard operation sequence technique tables

APPENDIX P II: Logical framework

APPENDIX P III: RIPRAN

APPENDIX P IV: Fuser Value stream map

APPENDIX P V: Motion analysis

APPENDIX P I: MAYNARD OPERATION SEQUENCE TECHNIQUE TABLES

Packing	Sequence	
Grasping paperboard, its folding	A 1 B 6 G 1 M 1 X 6 I 0 A 0	1
Turning the box	A 0 B 0 G 0 M 3 X 0 I 0 A 1	1
Grasping filling, placing into the box	A 1 B 6 G 3 A 1 B 0 P 3 A 0	1
7 steps and laying the box on the table	A 0 B 0 G 0 A 10 B 0 P 1 A 0	1
Detaining of the bag, opening and placing on the table	A 1 B 0 G 1 A 1 B 0 P 6 A 0	1
3 steps, getting a module, 3 steps, placing it to the tester	A 6 B 0 G 1 A 6 B 0 P 3 A 0	1
Closing the window, 3 steps	A 1 B 0 G 1 M 1 X 0 I 0 A 6	1
Taking a label, 1 step, sticking it on module	A 1 B 0 G 1 A 3 B 0 P 6 A 0	1
Closing the window, 3 steps	A 1 B 0 G 1 M 1 X 0 I 0 A 6	1
Opening the window	A 1 B 0 G 1 M 1 X 0 I 0 A 0	1
Taking module, 3 steps, placing it on a rack	A 1 B 0 G 1 A 6 B 0 P 1 A 0	1
Taking a tool and cleaning module	A 1 B 0 G 1 A 1 B 0 P 3 C 3 A 3 B 0 P 1 A 0	1
Grasping module, 4 steps, laying it into the plastic bag	A 1 B 0 G 1 A 6 B 0 P 3 A 0	1
Rolling module in a back, placing it into the cartoon-board	A 0 B 0 G 1 A 1 B 0 P 6 A 0	1
Taking a filling, booklet, instructions and filter and placing it to the box	A 1 B 0 G 1 A 1 B 0 P 3 A 0	4
1 step, taking labels, 1 step, sticking it	A 3 B 0 G 1 A 3 B 0 P 3 A 0	2
Closing a box, 2 steps, laying it on a wrapping machine	A 1 B 0 G 1 A 6 B 6 P 6 A 0	1
15 steps, taking box from a roller belt, 6 steps, placing box on a pallet, 10 steps back	A 32 B 6 G 3 A 10 B 0 P 3 A 24	1
Total	**227 TMU**	**1,36 min**

Visual Inspection	Sequence																						
7 steps taking a label, sticking it on a module	A	10	B	0	G	1	A	1	B	0	P	6	A	0									1
Closing the window, 3 steps	A	1	B	0	G	1	M	1	X	0	I	0	A	6									1
Waiting, opening the window	A	1	B	0	G	1	M	1	X	10	I	0	A	0									1
Taking module, 2 steps, lying it on a rack	A	1	B	0	G	3	A	3	B	0	P	1	A	0									1
Taking module, 3 steps, placing it into the tester	A	1	B	0	G	1	A	6	B	0	P	3	A	0									1
Closing the window, 2 steps	A	1	B	0	G	1	M	1	X	0	I	0	A	3									1
Taking module, 5 steps, placing it on a table	A	1	B	0	G	1	A	10	B	0	P	1	A	0									1
Taking tester clamps and 2x enclose to module	A	1	B	0	G	1	A	1	B	6	P	6	F	3	A	1	B	0	P	1	A	0	2
1 step, pressing button on a keyboard	A	3	B	0	G	0	M	1	X	0	I	0	A	0									1
Taking module, 4 steps, opening slightly a copy and inserting module into	A	1	B	0	G	1	A	6	B	6	P	6	A	0									1
Closing a copy door, waiting 8 seconds	A	1	B	0	G	1	M	3	X	20	I	0	A	0									1
Pressing a button, waiting 18 seconds	A	1	B	0	G	1	M	1	X	42	I	0	A	0									1
1 step, taking copies and checking visually 2 seconds, 4x	A	1	B	0	G	1	A	0	B	0	P	0	T	6	A	1	B	0	P	1	A	0	4
taking all copies and throwing them away	A	1	B	0	G	1	A	1	B	0	P	0	A	0									1
Opening copy door	A	1	B	0	G	1	M	3	X	0	I	0	A	0									1
Taking module, 4 steps, lying it on a table	A	1	B	0	G	3	A	6	B	0	P	1	A	0									1
Visual inspection	A	0	B	0	G	0	A	0	B	3	P	0	T	6	A	0	B	0	P	0	A	0	1
Taking spray, using it	A	1	B	0	G	1	A	1	B	0	P	0	S	3	A	1	B	0	P	1	A	0	1
Taking clout, using it	A	1	B	0	G	1	A	1	B	3	P	0	S	10	A	1	B	0	P	1	A	0	1
Taking brush, using it	A	1	B	0	G	1	A	1	B	0	P	0	S	3	A	1	B	0	P	1	A	0	1
Taking spray, using it	A	1	B	0	G	1	A	1	B	0	P	0	S	8	A	1	B	0	P	1	A	0	1
Taking brush, using it	A	1	B	0	G	1	A	1	B	0	P	0	S	42	A	1	B	0	P	1	A	0	1
Visual inspection	A	0	B	0	G	0	A	0	B	0	P	0	T	20	A	0	B	0	P	0	A	0	1
Taking clout, using it	A	1	B	0	G	1	A	1	B	0	P	0	S	3	A	1	B	0	P	1	A	0	1
Visual inspection	A	0	B	0	G	0	A	0	B	0	P	0	T	6	A	0	B	0	P	0	A	0	1

Taking brush, using it	A 1 B 0 G 1 A 1 B 0 P 0 S 10 A 1 B 0 P 1 A 0	1
Taking clout, using it	A 1 B 0 G 1 A 1 B 0 P 0 S 1 A 1 B 0 P 1 A 0	1
Visual inspection	A 0 B 0 G 0 A 0 B 0 P 0 T 20 A 0 B 0 P 0 A 0	1
Taking spray, using it	A 1 B 0 G 1 A 1 B 0 P 0 S 1 A 1 B 0 P 1 A 0	1
Taking clout, using it	A 1 B 0 G 1 A 1 B 0 P 0 S 16 A 1 B 0 P 1 A 0	1
Taking brush, using it	A 1 B 0 G 1 A 1 B 0 P 0 S 10 A 1 B 0 P 1 A 0	1
Taking clout, using it	A 1 B 0 G 1 A 1 B 0 P 0 S 6 A 1 B 0 P 1 A 0	1
Taking screwdriver, using it	A 1 B 0 G 1 A 1 B 0 P 0 F 10 A 1 B 0 P 1 A 0	1
Taking brush, using it	A 1 B 0 G 1 A 1 B 0 P 0 S 6 A 1 B 0 P 1 A 0	1
Taking clout, using it	A 1 B 0 G 1 A 1 B 0 P 0 S 3 A 1 B 0 P 1 A 0	1
Taking screwdriver, using it	A 1 B 0 G 1 A 1 B 0 P 0 F 10 A 1 B 0 P 1 A 0	1
Taking pen, filling document	A 1 B 0 G 1 A 1 B 6 P 0 R 6 A 1 B 0 P 1 A 0	1
Taking module, 8 steps, placing it on a rack	A 1 B 0 G 1 A 10 B 0 P 1 A 0	1
Total	**533 TMU**	**3,198 min**

Clean&Screen (1)	**Sequence**	
Taking a knife, 3 steps, unpacking box	A 1 B 0 G 1 A 6 B 0 P 1 C 20 A 3 B 0 P 1 A 0	1
Taking out of the box paper, filter and upper cover, 2 steps, throwing it away, 3x	A 1 B 0 G 1 A 3 B 0 P 1 A 4	3
Grasping module, 6 steps, lying it on a table	A 1 B 0 G 1 A 10 B 0 P 1 A 0	1
Taking a crum tester, placing	A 1 B 0 G 1 A 1 B 0 P 6 A 0	1
Pressing a button on a keyboard	A 1 B 0 G 0 M 1 X 3 I 0 A 0	1
tester disconnecting	A 1 B 0 G 1 A 1 B 0 P 1 A 0	1
Taking module, 3 steps, lying it on a pallet, 6 steps back	A 1 B 0 G 1 A 6 B 6 P 3 A 10	1
Taking out of the box plastic bag, paper, down cover, 2 steps, throwing it away, 3x	A 1 B 0 G 1 A 3 B 0 P 1 A 4	3
Turning the box	A 1 B 0 G 1 M 3 X 0 I 0 A 0	1
Cutting box, 2 steps, throwing it away	A 3 B 0 G 1 A 3 B 0 P 1 C 24 A 3 B 0 P 1 A 0	1
Total	**192 TMU**	**1,152 min**

Clean&Screen (Lamp tester)	**Sequence**																						
Taking a knife, 3 steps, unpacking box	A	1	B	0	G	1	A	6	B	0	P	1	C	20	A	3	B	0	P	1	A	0	1
Taking out of the box paper, filter and upper cover, 2 steps, throwing it away, 3x	A	1	B	0	G	1	A	3	B	0	P	1	A	4									3
Grasping module, 6 steps, lying it on a table	A	1	B	0	G	1	A	10	B	0	P	1	A	0									1
Taking a crum tester, placing	A	1	B	0	G	1	A	1	B	0	P	6	A	0									1
Pressing a button on a keyboard	A	1	B	0	G	0	M	1	X	3	I	0	A	0									1
tester disconnecting	A	1	B	0	G	1	A	1	B	0	P	1	A	0									1
Taking module, 5 steps, placing it on a table	A	1	B	0	G	1	A	10	B	0	P	1	A	0									1
Opening tester window	A	1	B	0	G	1	M	1	X	0	I	0	A	0									1
Taking module from table, inserting into tester	A	1	B	0	G	1	A	3	B	0	P	3	A	0									1
Closing tester window	A	1	B	0	G	1	M	1	X	0	I	0	A	0									1
3 steps, pressing a button on a keyboard, waiting	A	6	B	0	G	0	M	1	X	10	I	0	A	0									1
Taking a label, sticking it on a module	A	6	B	0	G	1	A	1	B	0	P	6	A	0									1
Closing the window, 3 steps	A	1	B	0	G	1	M	1	X	0	I	0	A	6									1
Waiting, opening the window	A	1	B	0	G	1	M	1	X	10	I	0	A	0									1
Taking module, 3 steps, lying it on a pallet, 6 steps back	A	1	B	0	G	1	A	6	B	6	P	3	A	10									1
Taking out of the box plastic bag, paper, down cover, 2 steps, throwing it away, 3x	A	1	B	0	G	1	A	3	B	0	P	1	A	4									3
Turning the box	A	1	B	0	G	1	M	3	X	0	I	0	A	0									1
Cutting box, 2 steps, throwing it away	A	3	B	0	G	1	A	3	B	0	P	1	C	24	A	3	B	0	P	1	A	0	1
Total	**272 TMU**										**1,632 min**												

Clean&Screen (Visual Inspection)	Sequence	
Taking a knife, 3 steps, unpacking	A 1 B 0 G 1 A 6 B 0 P 1 C 20 A 3 B 0 P 1 A 0	1
Taking out of the box paper, filter and upper cover, 2 steps, throwing it away, 3x	A 1 B 0 G 1 A 3 B 0 P 1 A 4	3
Grasping module, 6 steps, lying it on a table	A 1 B 0 G 1 A 10 B 0 P 1 A 0	1
Taking a crum tester, placing	A 1 B 0 G 1 A 1 B 0 P 6 A 0	1
Pressing a button on a keyboard	A 1 B 0 G 0 M 1 X 3 I 0 A 0	1
Tester disconnecting	A 1 B 0 G 1 A 1 B 0 P 1 A 0	1
Taking module, 5 steps, placing it on a table	A 1 B 0 G 1 A 10 B 0 P 1 A 0	1
Opening tester window	A 1 B 0 G 1 M 1 X 0 I 0 A 0	1
Taking module from table, inserting into tester	A 1 B 0 G 1 A 3 B 0 P 3 A 0	1
Closing tester window	A 1 B 0 G 1 M 1 X 0 I 0 A 0	1
3 steps, pressing a button on a keyboard, waiting	A 6 B 0 G 0 M 1 X 10 I 0 A 0	1
Taking label, sticking it on module	A 6 B 0 G 1 A 1 B 0 P 6 A 0	1
Closing the window, 3 steps	A 1 B 0 G 1 M 1 X 0 I 0 A 6	1
Waiting, opening the window	A 1 B 0 G 1 M 1 X 10 I 0 A 0	1
3 steps, taking module, 2 steps, laying it on a table	A 6 B 0 G 3 A 3 B 0 P 1 A 0	1
Visual inspection	A 0 B 0 G 0 A 0 B 0 P 0 T 131 A 0 B 0 P 0 A 0	1
Taking module, 4 steps, placing it, 3 steps back	A 0 B 0 G 0 A 6 B 0 P 1 A 6	1
Taking out of box plastic bag, paper, down cover, 2 steps, throwing it away	A 1 B 0 G 1 A 3 B 0 P 1 A 4	3
Turning the box	A 1 B 0 G 1 M 3 X 0 I 0 A 0	1
Cutting box, 2 steps, throwing it away	A 3 B 0 G 1 A 3 B 0 P 1 C 196 A 3 B 0 P 1 A 0	1
Total	**491 TMU**	**4,95 min**

Charger Unpacking	**Sequence**	
Taking box from a pallet	A 1 B 6 G 1 A 1 B 0 P 1 A 0	1
Opening box	A 1 B 0 G 0 A 0 B 0 P 6 A 0	1
Grasping module, 6 steps, placing it into holder	A 1 B 0 G 1 A 10 B 0 P 3 A 0	1
6 steps, grasping polystyrene fillers and throwing them away 6x	A 10 B 0 G 1 A 1 B 0 P 0 A 0	6
Taking knife and cutting box	A 1 B 0 G 1 A 1 B 0 P 3 C 20 A 1 B 0 P 1 A 0	1
Folding box, placing it	A 1 B 0 G 1 M 3 X 6 I 0 A 0	1
Total unpacking time	**1430 TMU**	**51,48 sec**

Charger Dismantle, Assembly	**Sequence**	
6 steps, taking brush, using it	A 10 B 0 G 1 A 1 B 0 P 1 S 24 A 1 B 0 P 1 A 0	1
Taking a clout, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 6 A 1 B 0 P 1 A 0	1
Taking brush, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 10 A 1 B 0 P 1 A 0	1
Opening bottle, wetting clout	A 1 B 0 G 1 M 3 X 3 I 0 A 0	1
Taking a clout, using it	A 1 B 0 G 1 A 1 B 0 P 6 S 152 A 1 B 0 P 1 A 0	1
Closing bottle	A 1 B 0 G 1 M 3 X 0 I 0 A 0	1
Taking screwdriver, using it	A 1 B 0 G 1 A 1 B 0 P 1 L 10 A 1 B 0 P 1 A 0	1
Taking brush, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 6 A 1 B 0 P 1 A 0	1
Taking a clout, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 3 A 1 B 0 P 1 A 0	1
Taking cover drawer, placing it into a box	A 1 B 0 G 1 A 1 B 0 P 1 A 0	1
Taking cover fuser, holding it	A 1 B 0 G 3 A 1 B 0 P 0 A 0	1
Grasping brush, cleaning cover fuser	A 1 B 0 G 1 A 1 B 0 P 1 S 12 A 1 B 0 P 1 A 0	1
Taking a clout, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 6 A 1 B 0 P 1 A 0	1
Placing cover base into a box	A 0 B 0 G 0 A 1 B 0 P 1 A 0	1
Taking screwdriver, using it	A 1 B 0 G 1 A 1 B 0 P 1 L 10 A 1 B 0 P 1 A 0	1
Placing screws, held in a hand	A 0 B 0 G 0 A 1 B 0 P 1 A 0	5
Taking belt aasy, placing it	A 1 B 0 G 1 A 1 B 0 P 1 A 0	1
Taking a clout, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 32 A 1 B 0 P 1 A 0	1

Placing belt assy into box	A 1 B 0 G 1 A 1 B 0 P 1 A 0	1
Transferring module into another holder	A 1 B 0 G 1 M 3 X 0 I 3 A 0	1
Taking a clout, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 28 A 1 B 0 P 1 A 0	1
Taking brush, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 10 A 1 B 0 P 1 A 0	1
Taking screwdriver, using it	A 1 B 0 G 1 A 1 B 0 P 1 L 10 A 1 B 0 P 1 A 0	1
Placing screws, held in a hand	A 0 B 0 G 0 A 1 B 0 P 1 A 0	1
Taking cover base, holding it	A 1 B 0 G 1 A 1 B 0 P 0 A 0	1
Taking brush, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 10 A 1 B 0 P 1 A 0	1
Placing kept cover base	A 0 B 0 G 0 A 1 B 0 P 1 A 0	1
Taking tester clamps and 2x enclose to module	A 1 B 3 G 1 A 1 B 0 P 3 F 16 A 1 B 3 P 1 A 0	1
Turning module	A 1 B 0 G 1 M 3 X 0 I 3 A 0	1
Taking screwdriver, using it	A 1 B 0 G 1 A 1 B 0 P 1 L 85 A 1 B 0 P 1 A 0	1
Taking Chute Baffle, keeping it	A 1 B 0 G 1 A 1 B 0 P 0 A 0	1
Taking brush, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 20 A 1 B 0 P 1 A 0	1
Taking a sandpaper, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 10 A 1 B 0 P 1 A 0	1
Taking brush, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 10 A 0 B 0 P 0 A 0	1
Placing Chute Baffle	A 0 B 0 G 0 A 1 B 0 P 1 A 1	1
Using still kept brush	A 0 B 0 G 0 A 1 B 0 P 1 S 32 A 0 B 0 P 0 A 0	1
Taking Chute Assy	A 1 B 0 G 1 A 1 B 0 P 0 A 0	1
Using still kept brush	A 0 B 0 G 0 A 1 B 0 P 1 S 24 A 1 B 0 P 1 A 0	1
Placing Chute Assy	A 0 B 0 G 0 A 1 B 0 P 1 A 1	1
Taking a clout, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 14 A 1 B 0 P 1 A 0	1
Taking Bracket Rear	A 1 B 0 G 3 A 1 B 0 P 0 A 0	1
Taking a clout, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 10 A 1 B 0 P 1 A 0	1
Lying Bracket Rear	A 0 B 0 G 0 A 1 B 0 P 1 A 0	1
Taking a pitchfork, using it	A 1 B 0 G 1 A 1 B 0 P 1 L 14 A 1 B 0 P 1 A 0	1
Untangling cables	A 1 B 0 G 1 M 1 X 24 I 0 A 0	1
Taking Roll Assy Fus-er	A 1 B 0 G 1 M 3 X 0 I 1 A 0	1
Taking a clout, using it	A 1 B 0 G 1 A 1 B 0 P 1 S 22 A 1 B 0 P 1 A 0	1
Putting on gloves	A 1 B 0 G 1 M 3 X 0 I 3 A 0	2
Taking Roll Assy Fus-er	A 1 B 0 G 1 A 1 B 0 P 0 A 0	1
Taking screwdriver, using it	A 1 B 0 G 1 A 1 B 0 P 1 L 14 A 1 B 0 P 1 A 0	1

Lying Roll Assy Fuser into form	A	0	B	0	G	0	A	1	B	0	P	3	A	0									1
Pushing lever	A	1	B	0	G	1	M	3	X	0	I	0	A	0									1
Extracting Bearing	A	1	B	0	G	1	M	6	X	0	I	0	A	0									1
Taking and placing Bearing	A	1	B	0	G	1	A	1	B	0	P	1	A	0									1
Lying Roll Assy Fuser into form	A	0	B	0	G	0	A	1	B	0	P	3	A	0									1
Pushing lever	A	1	B	0	G	1	M	3	X	0	I	0	A	0									1
Placing Roll Assy into box	A	0	B	0	G	0	A	1	B	0	P	1	A	0									1
Taking clout, using it	A	1	B	0	G	1	A	1	B	0	P	1	S	42	A	1	B	0	P	1	A	0	1
Taking a brush, spraying it	A	1	B	0	G	1	M	1	X	3	I	0	A	0									1
Using brush	A	0	B	0	G	0	A	1	B	0	P	1	S	36	A	1	B	0	P	1	A	0	1
Taking a new Roll Assy from box	A	3	B	0	G	1	A	3	B	0	P	0	A	0									1
Taking clout, using it	A	1	B	0	G	1	A	1	B	0	P	1	S	6	A	1	B	0	P	1	A	0	1
Visual inspection of Roll Assy	A	0	B	0	G	0	A	0	B	0	P	0	T	32	A	0	B	0	P	0	A	0	1
Installing Bearing	A	1	B	0	G	1	A	1	B	0	P	6	A	0									1
Placing Roll Assy into holder	A	0	B	0	G	0	A	1	B	0	P	3	A	0									1
Pushing lever	A	1	B	0	G	1	M	3	X	0	I	0	A	0									1
Replacing Roll Assy	A	1	B	0	G	1	A	1	B	0	P	1	A	0									1
Installing Bearing	A	1	B	0	G	1	A	1	B	0	P	6	A	0									1
Placing Roll Assy into holder	A	0	B	0	G	0	A	1	B	0	P	3	A	0									1
Pushing lever	A	1	B	0	G	1	M	3	X	0	I	0	A	0									1
Replacing Roll Assy	A	1	B	0	G	1	A	1	B	0	P	1	A	0									1
Installing Bearing	A	1	B	0	G	1	A	1	B	0	P	6	A	0									2
Turning Roll Assy	A	0	B	0	G	0	M	3	X	0	I	0	A	0									1
Installing Bearing	A	1	B	0	G	1	A	1	B	0	P	6	A	0									1
Loading Roll Assy on lamps	A	0	B	0	G	0	M	3	X	0	I	6	A	0									1
Undressing gloves	A	1	B	0	G	1	M	3	X	0	I	3	A	1									2
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	6	A	1	B	0	P	1	A	0	1
Taking a screw, placing it	A	1	B	0	G	1	A	1	B	0	P	6	A	0									1
Turning a holder	A	1	B	0	G	1	M	6	X	0	I	1	A	0									1
Placing Chute Assy	A	1	B	0	G	1	A	1	B	0	P	6	A	0									1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	24	A	1	B	0	P	1	A	0	1
Turning a holder	A	1	B	0	G	1	M	6	X	0	I	1	A	0									1
Taking a Chute Baffle, placing it	A	3	B	0	G	1	A	3	B	0	P	3	A	0									1
Taking a paper, plac-	A	3	B	0	G	1	A	3	B	0	P	3	A	0									1

ing it																						
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	115	A	1	B	0	P	1	A	0	1
Taking a paper away	A	1	B	0	G	1	A	1	B	0	P	1	A	0									1
Taking tester, using it	A	1	B	0	G	1	A	1	B	0	P	3	F	24	A	1	B	0	P	1	A	0	1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	10	A	1	B	0	P	1	A	0	1
Taking tester, using it	A	1	B	0	G	1	A	1	B	0	P	3	F	10	A	1	B	0	P	1	A	0	1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	12	A	1	B	0	P	1	A	0	1
Taking tester, using it	A	1	B	0	G	1	A	1	B	0	P	3	F	12	A	1	B	0	P	1	A	0	1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	12	A	1	B	0	P	1	A	0	1
Taking tester, using it	A	1	B	0	G	1	A	1	B	0	P	3	F	10	A	1	B	0	P	1	A	0	1
Putting a paper into the box	A	1	B	0	G	1	A	3	B	0	P	1	A	0									1
Taking Bracket Rear, placing it	A	1	B	0	G	1	A	3	B	0	P	6	A	0									1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	24	A	1	B	0	P	1	A	0	1
Taking crum, lying it	A	1	B	0	G	1	A	1	B	0	P	1	A	0									1
Taking tester, using it	A	1	B	0	G	1	A	1	B	0	P	3	F	3	A	1	B	0	P	1	A	0	1
Taking crum, placing it	A	1	B	0	G	1	A	1	B	0	P	6	A	0									1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	6	A	1	B	0	P	1	A	0	1
Involvement of cables	A	1	B	0	G	1	M	1	X	44	I	1	A	0									1
Putting on gloves	A	1	B	0	G	1	M	3	X	0	I	3	A	0									2
Taking belt aasy, placing it	A	3	B	0	G	1	A	1	B	0	P	1	A	0									1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	6	A	1	B	0	P	1	A	0	1
Taking a clout, using it	A	1	B	0	G	1	A	1	B	0	P	1	S	10	A	1	B	0	P	1	A	0	1
Frame Belt extrusion	A	1	B	0	G	1	M	3	X	0	I	0	A	1									1
Throwing a part away	A	0	B	0	G	0	A	1	B	0	P	1	A	0									1
Visual inspection of Frame belt	A	0	B	0	G	0	A	0	B	0	P	0	T	14	A	0	B	0	P	0	A	0	1
Taking a clout, using it	A	1	B	0	G	1	A	1	B	0	P	1	S	90	A	1	B	0	P	1	A		1
Visual inspection of Frame belt	A	0	B	0	G	0	A	0	B	0	P	0	T	16	A	1	B	0	P	1	A	0	1
Taking a special liquid, using it	A	1	B	3	G	1	A	1	B	0	P	3	S	44	A	1	B	3	P	1	A	0	1
Visual inspection of Frame belt	A	1	B	0	G	1	A	1	B	0	P	0	T	8	A	0	B	0	P	0	A	0	1
Taking belt assy, sliding it on a Frame belt	A	3	B	0	G	1	M	3	X	0	I	3	A	3									1
Turning Belt Assy	A	1	B	0	G	0	M	3	X	0	I	0	A	1									1
Placing terminal	A	1	B	0	G	1	A	1	B	0	P	6	A	0									1
Taking screwdriver,	A	1	B	0	G	1	A	1	B	0	P	1	F	5	A	1	B	0	P	1	A	0	1

using it																							
Taking hand screw-driver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	10	A	1	B	0	P	1	A	0	1
Placing Belt Assy	A	0	B	0	G	0	A	1	B	0	P	1	A	0									
Undressing gloves	A	1	B	0	G	1	M	3	X	0	I	3	A	1									2
Taking Lever, placing it	A	1	B	0	G	1	A	1	B	0	P	3	A	0									2
Placing Belt Assy into a form	A	1	B	0	G	1	A	1	B	0	P	1	A	0									1
Grasping a screw, inserting it into mat	A	1	B	0	G	1	M	1	X	0	I	1	A	1									2
Taking a roll, testing it	A	1	B	0	G	1	A	1	B	0	P	1	M	10	A	1	B	0	P	1	A	3	2
Taking a new roll	A	6	B	3	G	3	A	1	B	0	P	0	A	0									1
Roll registration	A	1	B	0	G	1	A	1	B	0	P	1	R	3	A	1	B	0	P	1	A	0	1
Placing roll on a table	A	0	B	0	G	0	A	3	B	0	P	1	A	0									1
Inserting screw into module	A	1	B	0	G	1	A	1	B	0	P	3	A	0									1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	10	A	1	B	0	P	1	A	0	1
Using spring scale to set the spring	A	1	B	0	G	1	A	1	B	0	P	1	M	96	A	1	B	0	P	1	A	0	1
Taking a cover base, placing it	A	3	B	3	G	1	A	3	B	0	P	6	A	0									1
Moving Chute Low	A	1	B	0	G	1	M	1	X	0	I	0	A	0									1
Inserting screw into module	A	1	B	0	G	1	A	1	B	0	P	3	A	0									1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	42	A	1	B	0	P	1	A	0	1
Turning module	A	1	B	0	G	1	M	3	X	0	I	3	A	0									1
Taking Chute Baffle, placing it	A	3	B	0	G	1	A	3	B	0	P	3	A	0									1
Taking screwdriver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	24	A	1	B	0	P	1	A	0	1
Taking hand screw-driver, using it	A	1	B	0	G	1	A	1	B	0	P	1	F	16	A	1	B	0	P	1	A	0	1
Taking a clout, spraying it	A	1	B	0	G	1	M	1	X	1	I	0	A	0									1
Using clout	A	0	B	0	G	0	A	1	B	0	P	1	S	34	A	1	B	0	P	1	A	0	1
Taking a label	A	1	B	3	G	1	A	1	B	0	P	6	A	0									1
Sticking a label	A	0	B	0	G	0	A	1	B	0	P	3	A	0									1
Taking a pen, using it	A	1	B	3	G	1	A	1	B	0	P	1	R	6	A	1	B	3	P	1	A	0	1
Turning module	A	1	B	0	G	1	M	3	X	0	I	3	A	0									1
Taking a clout, spraying it	A	1	B	0	G	1	M	1	X	1	I	0	A	0									1
Using clout	A	0	B	0	G	0	A	1	B	0	P	1	S	34	A	1	B	0	P	1	A	0	1
Total dismantle, assembly	**2486 TMU**													**14,916 min**									

Charger Visual Inspection	Sequence		
Taking module, laying it to tester	A 1 B 0 G 1 A 6 B 0 P 1 A 0		1
Lining up terminals	A 1 B 0 G 1 A 1 B 0 P 6 A 0		2
Closing tester door	A 1 B 0 G 1 M 3 X 0 I 0 A 0		1
Pressing a button	A 1 B 0 G 1 M 1 X 0 I 0 A 0		1
Taking copies from copy machine	A 6 B 6 G 1 A 6 B 0 P 0 A 0		1
Visual inspection	A 0 B 0 G 0 A 1 B 0 P 1 T 173	A 1 B 0 P 1 A 0	1
Paperclip	A 1 B 0 G 1 M 3 X 0 I 1 A 1		1
Taking a pen, signing copy	A 1 B 0 G 1 A 1 B 0 P 1 R 22	A 1 B 0 P 1 A 0	1
Lying copies on a copy machine	A 1 B 0 G 1 A 10 B 0 P 1 A 0		1
Opening copy machine door	A 1 B 3 G 1 M 3 X 0 I 0 A 0		1
Unscrewing module	A 1 B 3 G 1 L 10 X 0 I 0 A 0		2
Taking module out of machine	A 1 B 0 G 3 A 6 B 0 P 1 A 0		1
Pressing a button	A 1 B 0 G 1 M 3 X 0 I 0 A 0		1
Scanning a code	A 1 B 0 G 1 A 1 B 0 P 1 R 3	A 1 B 0 P 1 A 0	1
Checking the information	A 0 B 0 G 0 A 0 B 0 P 0 T 10	A 0 B 0 P 0 A 0	1
Pressing a button	A 1 B 0 G 1 M 3 X 0 I 0 A 0		1
Placing module on a table	A 0 B 0 G 0 A 10 B 0 P 1 A 10		1
Opening tester door	A 1 B 0 G 1 M 3 X 0 I 0 A 0		1
Disconnecting terminals	A 1 B 0 G 3 A 1 B 0 P 1 A 0		2
Turning module	A 1 B 0 G 1 M 3 X 0 I 0 A 1		1
Placing module into copy machine	A 0 B 0 G 0 A 10 B 3 P 6 A 0		1
Screwing module	A 1 B 3 G 1 L 16 X 0 I 0 A 0		2
Closing copy machine door	A 1 B 3 G 1 M 3 X 0 I 0 A 0		1
Pressing a button	A 6 B 0 G 1 M 1 X 0 I 0 A 1		1
Total Visual inspection	**479 TMU**	**2,79 min**	

Charger Packing	**Sequence**	
Grasping kartboard, its folding	A 3 B 6 G 1 M 1 X 6 I 0 A 0	1
Taking a tool, sealing the kartboard with a tape	A 1 B 0 G 1 A 1 B 0 P 1 C 10 A 1 B 0 P 1 A 0	1
Turning the box	A 0 B 0 G 0 M 3 X 0 I 0 A 1	1
Grasping filling, placing into the box 2x	A 1 B 6 G 3 A 1 B 0 P 3 A 0	2
Detaining of the bag, opening and placing on the table	A 1 B 0 G 1 A 1 B 0 P 6 A 0	1
Rolling module in a back, placing it into the cartoonage	A 0 B 0 G 1 A 1 B 0 P 6 A 0	1
Taking a filling 2x, booklet, instructions and filter and placing it into the box	A 1 B 0 G 1 A 1 B 0 P 3 A 0	5
Closing a box, 3 steps, laying it on a pallet	A 1 B 0 G 1 A 6 B 6 P 6 A 0	1
Total charger packing	**119 TMU** / **0,69 min**	

APPENDIX P II: LOGICALFRAMEWORK

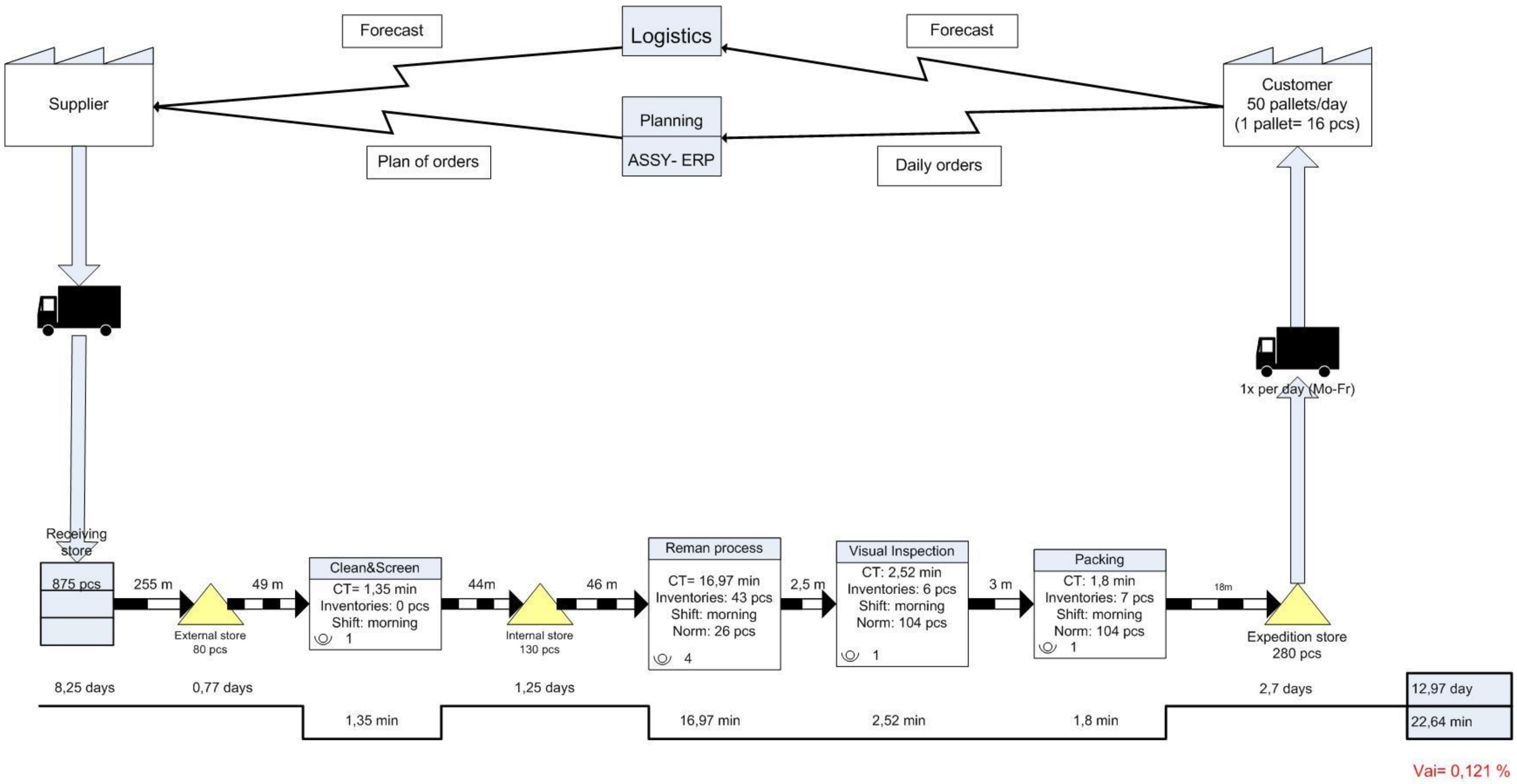
	Tree of goals	Objective indicators	Information resources	Assumptions and risks
Main goal	1.1 Increase company competitiveness	1.1.1 Increased number of customers and orders	1.1.1.1 Statistics	X
Project goal	2.1 Assembly line optimization	2.1.1 Raising work productivity and fluency of material flow	2.1.1.1 Weekly company`s statistics	Acceptation of implemented changes by employees, proper training, explanation of a problematic
Outputs	3.1 Time analyse of each position	3.1.1 Better material and information flow, removal of waste and activities not adding value, new norms, higher production	3.1.1.1 Repeated chronometry	Repeating of chronometry, undistorted behaviour of checked operators, cooperation with employees
	3.2 Optimization proposal	3.2.1 Proposal feasibility	3.2.1.1 Mathematic backgrounds about feasibility	Right way of using methods, sufficient knowledge
	3.3 Implementation and maintaining a new state	3.3.1 Continual inspection	3.3.1.1 Outputs and regular control statistics	Sufficient control after implementation
Activities	4.1 Chronometry	4.1.1 Standardized forms, stopwatches, photos	4.1.1.1 29.1.-15.2. 2013	Undistorted behaviour of checked operators, repeated chronometry
	4.2 Data analyse	4.2.1. Chronometry data, SW	4.2.1.1 15.2.-24.2. 2013	Proper analyse methods, right data
	4.3 Rough draft of optimisation	4.3.1. Analyse results	4.3.1.1 25.2-28.2. 2013	Knowledge in the field
	4.4 Consulting proposals	4.4.1. Meeting with company management, discussion about proposals	4.4.1.1. 1.3. 2013	Inexpensive and advantageous improvements, management support
	4.5 Detailed proposal of improvements	4.5.1. Cooperation with single operators, simulating SW, SW for layout design	4.5.1.1 2.3-10.3. 2013	Operators cooperation

	4.6 Implementa-tion	4.6.1. Visualisation, activities redistribution, new layout, shelf units standardisation	4.6.1.1 11.3-20.3. 2013	Refined proposals, ensur-ing the present of needed tools
	4.7 Inspection	4.7.1. Comparing to initial state	4.7.1.1 21.3-22.3.2013	Maintaining the changes
		Tools	**Time framework**	**Conditions**
				Management support
				Willingness of employees to cooperate
				Required skills and knowledge
				Willingness of project manager to cooperate

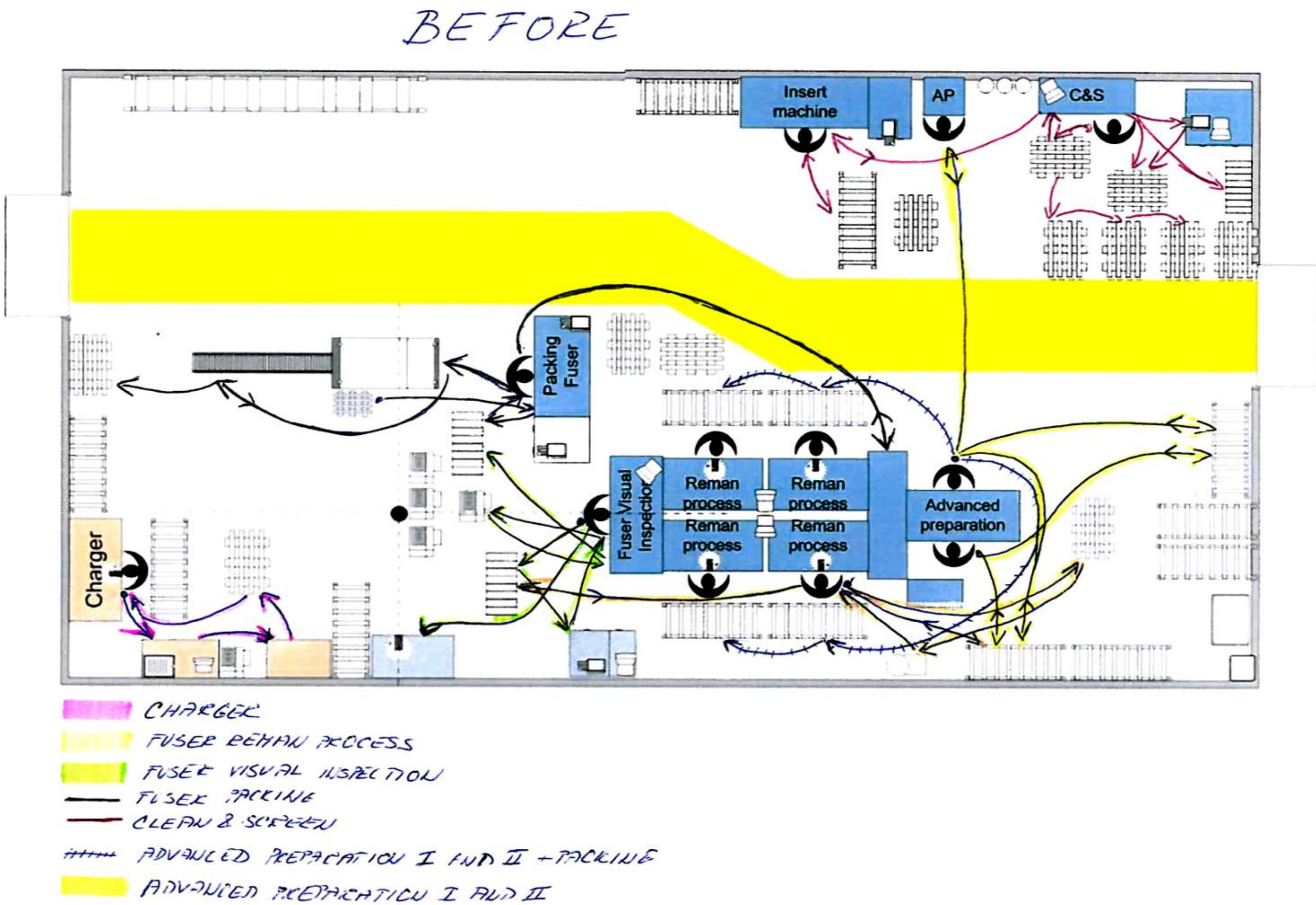
APPENDIX P III: RIPRAN

ID	THREAT	THREAT PROB.	ID	SCENARIO	SCENARIO PROB.	TOTAL PROB.	IMPACT	RISK VALUE	ACTION
1	Distorted behaviour of checked employees	75%	1.1	Irrelevant and not applicable data	20%	Medium	Medium	Medium RV	Explanation of chronometry reason, creation of cooperating working team by management
			1.2	Changes implemented in a wrong way	15%	Medium	Low	Low RV	Frequent discussions about solutions with specialists
2	Small management support	15%	2.1	Proposed changes are impossible to be applied	5%	Low	High	Medium RV	Mathematic back round about advantages of new optimisation proposal, focusing on the most important problems from the management point of view
			2.2	Violate implemented improvement	30%	Low	Low	Low RV	Continual inspection, determination of competences and responsible person
			2.3	Disrespect and non-cooperation with employees	40%	Low	Medium	Low RV	Thorough clarification the reasons and advantages of changes implementation to employees, including employees into the project, accepting their comments and proposals
3	Insufficient knowledge and skills	35%	3.1	Incorrect data analyse	15%	Low	Medium	Low RV	Frequent consultations, self-education, workshops, conferences

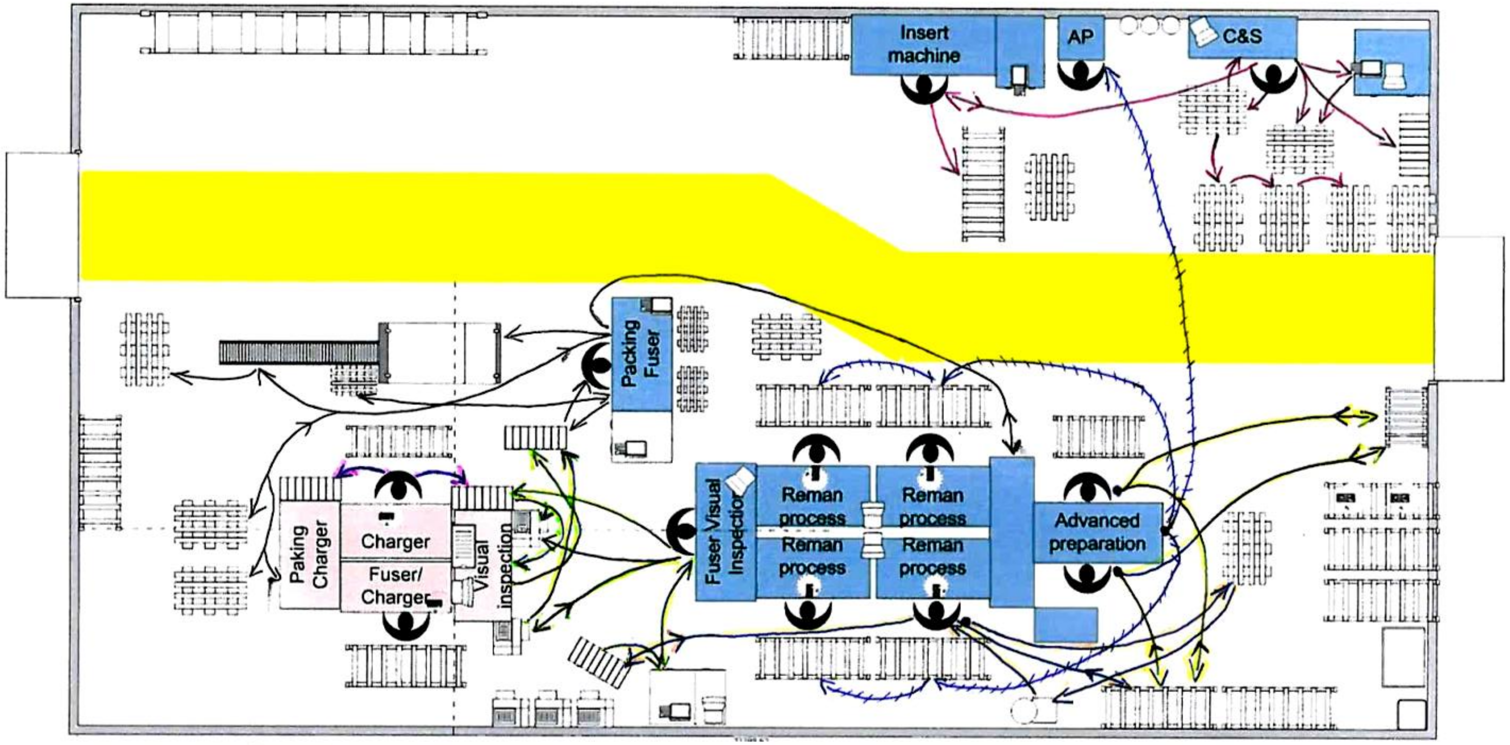
APPENDIX P IV: FUSER VALUE STREAM MAP



APPENDIX P V: MOTION ANALYSIS



AFTER



CHARGER

FUSER REMAN PROCESS

VISUAL INSPECTION FUSER + CHARGER

UNPACKING + PACKING CHARGER ; PACKING FUSER

CLEAN & SCREEN

ADVANCED PREPARATION I AND II + CLEAN & SCREEN

ADVANCED PREPARATION I AND II