INSTITUTO SUPERIOR DE ENGENHARIA DO PORTO
MESTRADO EM ENGENHARIA MECÂNICA




PRODUCTIVITY IMPROVEMENT IN A COMPANY OF THE INDUSTRY OF BOLTING SYSTEMS

JORGE MIGUEL PORFÍRIO OLIVEIRA
dezembro de 2021

POLITÉCNICO
DO PORTO

PRODUCTIVITY IMPROVEMENT IN A COMPANY OF BOLTING SYSTEMS INDUSTRY

Jorge Miguel Porfírio Oliveira

2020/2021

ISEP – School of Engineering, Polytechnic of Porto
Department of Mechanical Engineering

POLITÉCNICO
DO PORTO

POLITÉCNICO
DO PORTO

Instituto Superior de Engenharia do Porto

PRODUCTIVITY IMPROVEMENT IN A COMPANY OF BOLTING SYSTEMS INDUSTRY

Jorge Miguel Porfírio Oliveira
1080839

Dissertation presented to ISEP – School of Engineering to fulfill the requirements necessary to obtain a Master's degree in Mechanical Engineering, carried out under the guidance of Professor Francisco José Gomes da Silva from the Department of Mechanical Engineering, and Co-supervised by Professor Carla Manuela Alves Pinto from the Department of Mathematics.

2020/2021

ISEP – School of Engineering, Polytechnic of Porto
Department of Mechanical Engineering

POLITÉCNICO
DO PORTO

POLITÉCNICO
DO PORTO

JURY

President
Isabel Cristina Silva Barros Rodrigues Mendes Pinto, PhD
Auxiliar Professor, ISEP – School of Engineering, Polytechnic of Porto

Supervisor
Francisco José Gomes da Silva, PhD
Associate Professor w/ Habilitation, ISEP – School of Engineering, Polytechnic of Porto

Second supervisor
Carla Manuela Alves Pinto, PhD
Associate Professor, ISEP – School of Engineering, Polytechnic of Porto

Examiner
Carla Alexandra Soares Geraldes, PhD
Auxiliar Professor, Departamento de Gestão Industrial, Instituto Politécnico de Bragança

ACKNOWLEDGEMENTS

First I would like to acknowledge the company alki Technik GmbH for having given the opportunity of developing there the work for this dissertation, concretely to the General Manager Alexander Kipfelsberger for having selected me to perform the work and also for all the guidance and given ideas that facilitated in the work development and the implementation of the studied solutions, to the Human Resources Director Tatjana Butorac-Kipfelsberger for having enabled the internship and to the Production Director Christian Regensburger for all the guidance provided during the internship and also for having helped in the implementation of studied solutions. I would like also to have a special acknowledge to the production`s employees , Alex Abel , Azime Bilgili, Christian Finkenzeller, Jurij Maier and Drazen Lovric, once they also gave huge contributes for this dissertation work.

I acknowledge Professor Francisco José Gomes da Silva for having supported me in the idea of perform my dissertation work through an internship in a company abroad, even when it seemed almost undoable due the huge difficulties in finding opportunities in a company to perform the master thesis in the context of the pandemic situation, and also for the guidance and key inputs provided during the dissertation development. I acknowledge also Professor Carla Manuela Alves Pinto for the provided support.

I acknowledge my family, my parents, my brother, my sister, my grandmother, with whom I kept always in contact during the internship.

KEYWORDS

Productivity Improvement, Planning, Production Optimization, Kaizen, Visual Management, Facility Layout Optimization, Systematic Layout Planning

ABSTRACT

Nowadays, the companies face an extreme need of having high levels of productivity (P) in order to survive in the market`s competition. In this context, this work was performed in the production department of alki Technik GmbH, a company that operates in the field of bolting systems, making production of tools in a make-to-order (MTO) basis, and services as well. The work had the main aims of measurement of the production performance in terms of its P level and establishment of strategies to reach its improvement.

The first phase of the work was focused in obtaining the necessary elements to measure the real levels of P in a weekly basis, which are the inputs (IN) in terms of time capacity and the outputs (OUT) in terms of time with production of tools and execution of services. After found ways to properly quantify IN and OUT, the P started to be observed and after the first three weeks, the observed Ps were considered too low for what the company needs, and it was also confirmed when compared with P levels presented in another studies. Some improvement methods were implemented, such as, a Visual Management (VM) method, which consisted in establishing each Friday a map with a work plan for the following week and placing it in the workshop, and Kaizen philosophy in terms of asking the employees about activities of their daily work that they considered that could be optimized to proceed with its analysis as Kaizen Optimizations (KOs), in order to find optimization solutions. A total of six KOs were proposed, being the time saving estimate of 101 hours per year. One of the KOs was immediate implemented, as well as the VM method, and the following three weeks showed P improvement, with the observed indexes of 59,2%, 52,1% and 58,3% respectively, when on previous weeks the highest observed value had been 43,7%.

Finally it was made the analysis of the workshop`s layout, as facility layouts play also a huge role in the productive performance, through the Systematic Layout Planning (SLP) method in order optimize the flows. From this analysis, two optimization alternatives (OAs) were designed. OA1, where a few changes are proposed without extra costs have been estimated a cost reduction with flows of 5,94% OA2, where some further changes are proposed, being in this case the estimated costs reduction with flows of 20,3%. However, this last OA would carry costs of its implementation.

The conclusions highlight the P improvement achieved through this work. Further improvement was left through the KOs for the process and OAs for the workshop layout.

PALAVRAS CHAVE

Melhoria da Produtividade, Planeamento, Optimização da Produção, Kaizen, Gestão Visual, Optimização do layout da instalação, Systematic Layout Planning

RESUMO

As empresas, hoje em dia, enfrentam uma necessidade extrema de ter altos níveis de produtividade (P) para sobreviverem na competição do mercado. Nexte contexto, foi realizado este trabalho no departamento de produção da alki TECHNIK GmbH, empresa que opera na área dos sistemas de aparafusamento, fazendo produção de ferramentas numa base de produção para encomenda (MTO), e também serviços. O trabalho teve como principais objetivos medir o desempenho da produção em termos de P, e estabelecimento de estratégias para alcançar a sua melhoria.

Inicialmente o trabalho centrou-se na obtenção dos elementos necessários para medir os níveis reais de P numa base semanal, que são as entradas (IN) em termos de capacidade de tempo, e as saídas (OUT) em termos de tempo produtivo com produção de ferramentas e execução de serviços. Após encontradas formas para quantificar adequadamente IN e OUT, P começou a ser observado e, após as primeiras três semanas, os Ps observados foram considerados muito baixos para as necessidades da empresa, o que também se confirmou por comparação com níveis de P mencionados em outros estudos. Alguns métodos para melhoria foram implementados, como o método de Gestão Visual (VM), que consistiu em estabelecer a cada sexta-feira um mapa com um plano de trabalho para a semana seguinte, e coloca-lo na oficina, e a filosofia Kaizen em termos que questionar os funciários sobre atividades do seu dia-dia que eles considerassem que pudessem ser otimizadas, a fim de proceder com a sua análise como optimizações Kaizen (KOs) e encontrar soluções de optimização. Um total de seis KOs foram propostas, sendo a estimativa de poupança de tempo de 101 horas por ano. Uma das KOs foi implementada de imediato, assim como o método de VM , e as três semanas seguintes revelaram uma melhoria de P, com os índices observados de 59,2%, 52,1% e 58,3%, respetivamente, quando nas semanas anteriores o valor mais alto observado havia sido 43,7%.

Finalmente, foi feita uma análise ao layput da oficina, visto que os layouts também têm um papel fundamental no desempenho produtivo, através da metodologia Systematic Layout Planning *(SLP), para optimizar os fluxos. Desta análise resultaram duas alternaticas de optimização (OAs): OA1, onde algumas alterações são propostas, sem envolver custos extra, tendo sido estimada uma redução de fluxos de 5,94%, e OA2, onde* *algumas alterações adicionais são propostas, sendo neste caso a redução de custos com fluxos estimada de 20,3%. Contudo, esta última OA envolve custos da sua implemtação.*

As conclusões destacam a melhoria de P conseguida através deste trabalho, para além das oportunidades de melhoria adicional que foram deixadas através das KOs para o processo e das OAs para o layout da oficina.

LIST OF SYMBOLS AND ABBREVIATIONS

List of abbreviations

APS	Advanced Planning Systems
C	Cost
c.u	Cost Unit
CAL	Calibration room
CRV	Closeness rating value
D	Distance
DB	Daily Breaks
DM	Daily Meetings
E	Electrical
ERP	Enterprise Resources Planning
EXP	Expedition utensils
GM	General Manager
H	Hydraulic
IN	Inputs
KO	Kaizen Optimization
KPI	Key Performance Indicator
L	Location
LIFT	Storage lift
LP	Labels printing
M	Manual
min.	Minute
MR	Multiplication Ratio
MTS	Make-to-stock
MULTI	Multipurpose workshop
MUP	Multiple Units Production
OA	Optimization Alternative
OEE	Overall Equipment Efficiency
OUT	Outputs
OUTG	Outgoing goods
P	Productivity
P	Pneumatic
PM	Production Manager
PPC	Production Planning and Control
PT	Production Time
REC	Reception shelfs
SERV	Equipment’s for services

SLP	Systematic Layout Planning
SME	Small and Medium Enterprises
STOR	Storage shelfs
TLT	Total Labour Time
TM	Torque multipliers
TW	Torque Wrenches
un.	Unit
VBA	Visual Basic
WPTC	Weekly Production Time Capacity
WS	Workstation

List of units

A	Ampere
h	hour
Hz	hertz
m	meter
mm	milimeter
N	Newton
V	Volt

List of symbols

€	Euro
%	Percentage
~	Approximately

GLOSSARY OF TERMS

Make-to-Order	Production approach where the products are produced just after the orders' confirmation.
Make-to-Stock	Production approach where the products are produced without existence of order`s confirmation.
Crictical Path Method	Resource-utilization algorithm for scheduling project activities mainly through a model of listing all the tasks required to complete the project.
5S	Workplace organization method that uses a list of five terms: Sort, Shine, Sustain, Set in Order and Standardize.
Layout	Physical disposition of the elements in a facility/shopfloor.
SWOT Analysis	Strategic management technique to help an organization to identify Strengths, Weaknesses, Opportunities and Threats of a project.
Industry 4.0	Automation of traditional industrial processes by using smart technology.

FIGURES INDEX

TABLES INDEX

INDEX

INTRODUCTION

1 INTRODUCTION

In this first chapter, some elementary information providing some insights about the overall developed work is presented.

1.1 Host Company

The work for the dissertation was performed at alki TECHNIK GmbH located in Ingolstadt-Germany, in the Production and Development department, from 01/04/2021 to 30/08/2021, under the guidance of Christian Regensburger as Production Manager (PM) and Alexander Kipfelsberger as General Manager (GM).

1.2 Contextualization

Due the existing competition in today`s global market, companies have an extreme need of improve the performance of their production units , in order to reach high levels of productivity (P), and thus survive in the market`s competition (Araújo *et al.*, 2017; Weber *et al.*, 2017).

alki TECHNIK GmbH has been improving its structure over the last years in order to better respond to the market`s demanding and, with that, the company managed to keep accomplishing and even exceeding the customers' expectations in terms of products' quality and provided services, being that, the overall customer satisfaction has been increasing. Nevertheless, the results show that the global revenue resulting from products' and services' sales did not reach yet the levels which the company`s administration thinks to be possible, fact that suggested to the company´s administration that its P level of the production was not optimized, and hence they needed a study to assess the P and its possible scope for improvement.

This work focused in the activity carried out in the production`s workshop, of which, the core outputs (OUT) are the production of torque tools and execution of services, being the inputs (IN) the time capacity with the existent employees.

1.3 Goals

As described in previous section the company needed to know how the production was performing in terms of P, and to find strategies for its improvement. Thus, the following goals were established to carry out the work, step by step, towards the main intended aim:

- General analysis of the production department in order to characterize its workstations, activities performed and also the workshop`s layout.
- Quantification of IN in terms of time capacity.

- Establishment of measurement methods for the produced tools and provided services, in order to get the OUT.
- Establishment of P index as a key performance indicator and proceed with its monitoring.
- Assessment and implementation of strategies for P improvement, observing its effectiveness.

1.4 Methodology

To achieve the settled goals, the following stages were followed:

- ✓ Analysis of the production activities in the production`s workshop.
- ✓ Establishment of the weekly production time capacity (WPTC) as IN.
- ✓ Analysis and consolidation of the existent information about the production times (PTs) of the tools.
- ✓ Institution of methods to measure the production performance in terms of produced tools and executed services, as OUT.
- ✓ Establishment of P index as key performance indicator (KPI) and its monitoring.
- ✓ Bibliographic research over bolting systems, production, planning and control optimization techniques and facility layouts analysis, performed mainly by papers searching in the platform Google Scholar through key words inputs. A few webpages were also accessed.
- ✓ Proposal of production P improvement methods and analysis of its effectiveness.
- ✓ Analysis of the workshop`s layout and proposal of optimization alternatives (OAs) , based Systematic Layout Planning Method (SLP) method , and study of benefits.

1.5 Framework

The dissertation is organized as follows:

Chapter 2 presents the bibliographic research made over the subjects considered relevant in the context of the performed work, specifically section 2.1 contains a brief overview about the industry of bolting systems, section 2.2 presents literature about some addressed topics in what regards with production management, while section 2.3 is about logistics of facility`s layouts. Chapter 3 contains an initial analysis made to the company and its products in sections 3.1, the description of the main problem associated with this work in section 3.2, and the characterization of the workshop presented in section 3.3. Chapter 4 goes deeply into the development (sections 4.1, 4.2, 4.3 and 4.4) , ending with a critical analysis over the found solutions in section 4.5. Chapter 5 contains the conclusions in section 5.1 and a few proposals of future works in section 5.2. Finally all the accessed sources are in chapter six and the attached Annexes in chapter seven.

BIBLIOGRAPHIC WORK

2.1 Bolting systems

2.2 Production Management

2.3 Logistics / Facility layout

2 BIBLIOGRAPHIC WORK

This chapter contains the performed bibliographic research, starting with a brief approach over the industries and products of which the company stands for, following by research about necessary topics during the practical development.

2.1 Bolting systems

The company operates in the development, production, and distribution of products in the field of bolting systems, being them mainly torque multipliers (TM) and torque wrenches (TW). Its application goes over a wide range of sectors, such as, wind energy, steel construction, construction machinery, agriculture and forestry machinery, water/oil/gas/chemicals, as well as food and beverage (alki TECHNIK GmbH, 2021).

2.1.1 Torque multipliers (TM)

A TM is a tool that works following the typical Epicyclic Gearing principle applicable to the transmission systems, in which the main components are the sun gear, the ring gear, the planet gears and planet carrier (Mechanical E-Notes, 2017). An input torque is given and it gets multiplied as per the multiplication ratio and transmitted at the output (Khaled and Abdulhakim, 2020). A simple illustration of the described concept, obtained through the platform gfycaft (2018) and adapted, can be seen in Figure 1.

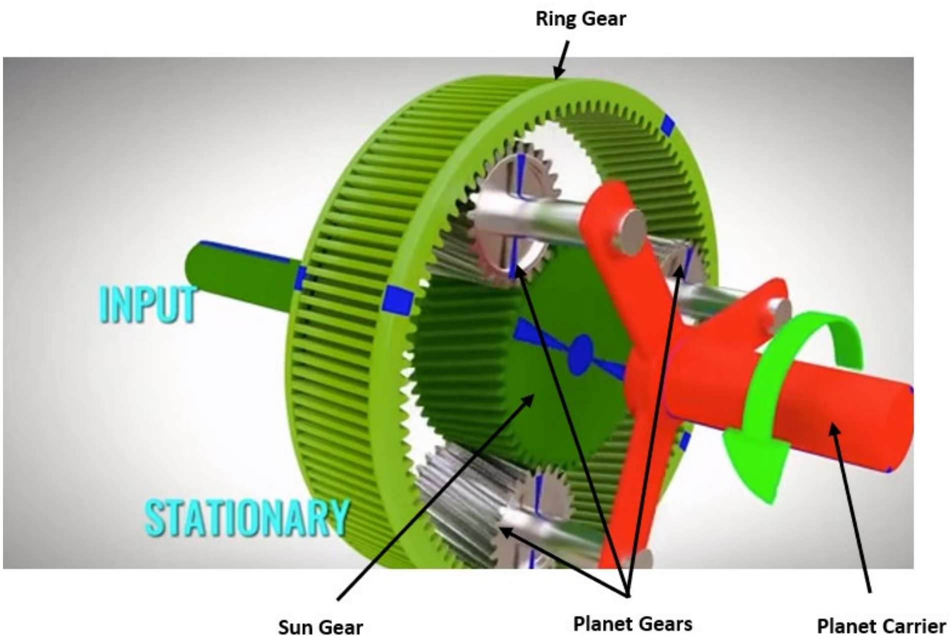


Figure 1 - Epicyclic Gearing principle applicable to TM (gfycat, 2018).

Not a lot of studies can be found in the literature about TM. However, the calibration of TM, that is something that should be regularly performed in torque tools (mountz, 2019), is a topic addressed by the scientific community in a few papers. Khaled and Osman (2017), establish a changing proposal to the procedure of the calibration standard ISO 6789:2017 that allows to decrease the time consuming with calibration in about 50%. Khaled and Abdulhakim (2020) present a proposal for a new torque multiplier calibration standard with the innovation of allowing the uncertainty calculation. Both studies complement its proposals with experimental tests and analysis.

2.1.2 Torque wrenches (TW)

A TW, of which an example is shown in Figure 2, is generally a tool to be used in the tightening of fasten elements such as bolts, nuts or screws (Ogushi, 2020), being that, its usage should ensure the joint to be properly tightened to avoid the loosening, hence the risk of accidents, and also not overly tightened at a point that it might cause the plastic deformation of the fasten element, which will leads to fatigue and fracture which can, obviously, drive to tragic consequences (Xu *et al.*, 2020). Thus it is not surprising that some projects to verify whether the fasten elements are properly tightened, such as the one presented by Kamdi *et al.* (2020).

Figure 2 – Example of a Hydraulic torque wrench (alki TECHNIK GmbH, 2019).

About TW, there are some project oriented studies in the literature, such as a paper from Sniehotta (2017), which presents a development of a modular gearbox for a pneumatic wrench. Vukelic *et al.* (2019) also performed a failure analysis on hydraulic torque wrench in order to understand possible causes of problems, and thus, optimize the design of the tool.

2.2 Production Management

Small and medium sized enterprises (SME) play an important role on countries' economy (Erol and Sihn, 2017; Li *et al.*, 2016), representing about 90% of businesses across the world (Saad *et al.*, 2021). Moreover, they need to respond to their customers' expectations and be competitive on their market, thus, it is not surprising that they are constantly looking for improve their processes through planning, production control and also by monitoring its operational performance (Moeuf *et al.*, 2017).

2.2.1 Productivity (P)

By definition, *P* can be defined as the relation between *OUT* in terms of goods' production and services, and *IN* as resources used (Moktadir *et al.*, 2017), that corresponds to the time capacity (Nakamura *et al.*, 2019).

Thus, *P* index can be calculated trough Eq.1 as follows (Moktadir *et al.*, 2017).

$$P = \frac{OUT}{IN} \quad (1)$$

As already mentioned, *P* is a massive concern that the companies have for enhancing more profit (Moktadir *et al.*, 2017), becoming thus a relevant topic for the scientific community. A set of studies about performed *P* improvements are briefly presented in Table 1.

Table 1 – Papers about productivity improvement.

Reference	**Aims**	**Methodology**	**Findings**
(Moktadir *et al.*, 2017)	To increase the productivity in a production line of company operating in the leather products' industry.	Work study/time work measurement.	The authors present a rearrangement of production line and they estimate that the proposed solution can increase the productivity (which initially is 41,23%) by 12,71%.
(ur Rehman *et al.*, 2019)	To improve productivity of a garment production line in a work wear manufacturing factory.	Time study Technic/work measurement.	The authors proposed a set of improvements based on sequence of activities, tasks reassignment and line balancing, and they observed that machine productivity improved by 36%.
(Yemane et al., 2020)	To find an optimal solution to improve the productivity in a production line of a garment manufacturer.	Computer simulation for modelling of line balancing.	By the application of the simulation model, the authors estimate an output increase from 364 trousers to 379 per day on the production line.

The three described papers reinforce the importance of *P* enhancement in the companies, especially in terms of finding out ways for better use of its time capacity.

2.2.2 Production planning and control (PPC)

PPC is something that an organization should consider on its management system in order to have an efficient, economical and effective manufacturing unit (Kiran, 2019; Usuga Cadavid *et al.*, 2019) Generically, PPC concerns about loading, scheduling, sequencing, monitoring and controlling the use of the available resources *(Oluyisola et al.*, 2021), being that its implementation can lead the companies to a global improvement of a production system (Pablo *et al.*, 2020). Some of existing studies in the literature about PPC systems are briefly presented in Table 2.

Table 2 –Studies and developed works with regards to PPC.

Reference	**Aims**	**Methodology**	**Findings**
(de Man and Strandhagen, 2018)	To show that spreadsheets still plays an important role in PPC, despite the existence of Enterprise Resource Planning (ERP) and Advanced Planning Systems (APS).	Case study by the analysis of three companies in different industries that use spreadsheets on the support to their PPC systems.	The authors concluded that the use of spreadsheets in PPC still dominates over ERP and APS, mainly due the fact that these last ones either require huge investments or are not yet covering all the issues that the managers need to deal with on daily activity.
(Pişec and Pop, 2018)	To create a tracking and planning production program to track the use of resources and execution results.	The production planning was performed through the Critical Path Method.	The authors presented a program for tracking the production planning. The program allows on real time track of the work on each machine, and thus estimate delivery times and costs. The program allows to generate reports to check the efficiency.
(Ellwein et al., 2019)	To introduce a new software architecture for production planning and control systems.	Theoretical conceptualization of a network of production planning systems.	New software architecture that allows the communication between multiples PPC systems of different manufacturers. The authors state as limitation that solution was not implemented.
(Erol and Sihn, 2017)	To present a scalable cloud-based architectural for a PPC.	Rethinking of an existing software for PPC to build a new software architecture with base on process – orientation.	The authors present a software architecture for an intelligent production planning and control service in the cloud, which is intended to be scalable, thus applicable to SME.

As summary it can be stated that some intentions of apply advanced and technological solutions for PPC systems are on the road, however, due to their high initial costs, as well as long period for its implementation, they have not yet a solid application, especially in SME, as it is demonstrated by de Man and Strandhagen (2018), and the same idea is also concluded by Vieira *et al.* (2021) in a recent review paper.

2.2.3 Key Performance Indicators (KPIs)

KPIs are generally quantifiable measures that enable organizations to monitor their success in accomplishing pre-defined goals (Bishop, 2018; Lake, 2015). Operation measurement is vital to avoid the organizations of being in a place of unknown performance (Azizi, 2015; Ferreira *et al.*, 2019) , and also to achieve improvement (Soltanali *et al.*, 2021). A set of works performed around the concept of KPIs are presented in Table 3.

Table 3- Performed studies with KPIs.

Reference	**Aims**	**Methodology**	**Findings**
(Kang *et al.*, 2016)	Framework for the categorization of the KPIs (basic and comprehensive) and also the establishment of relationships between them.	The authors used a case study, in an automotive plant to demonstrate the continuous improvement due the use of KPIs.	The authors projected a hierarchical structure to categorise different KPIs and analyse existing relationships /dependencies between them and they proved also effectiveness by achieving an improvement of 2,6%.
(Joppen *et al.*, 2019)	Creating KPIs on production for industry 4.0 era, considering the common existing ones and newly developed KPI's with regards to Information Technology (IT) performance.	Literature research and project work.	The authors present a proposal to combine the current KPI`s with IT related KPI`s in terms of management (data quality, IT availability), transparency & connectivity (degree of visualization) and Product Management (n.o of products, new product rate), and conclude that it brings benefits.
(Brundage *et al.*, 2017)	To apply graph-based visualizations to study relations between manufacturing-related KPIs.	Application of two graph-based visualization techniques (node-link diagrams and matrix-based layouts) to analyse relationships between KPIs, studying different scenarios.	The authors concluded that the used of graph-visualizations (node-link diagrams and matrix-based layouts) bring benefits as they offer a summary of all KPIs, metrics, and their relationships, however the authors also forecasted some further developments needed to have even more benefits and overcome some limitations.

It can be concluded that it is usual that companies monitor their performance, thus the recent studies around this thematic are more focused on analysing the relationships between KPIs and, also its framework in the industry 4.0 (Pinto *et al.*, 2019).

2.2.4 Production processes' optimization / Lean tools

When the industrial companies are looking for improve/optimize their production`s processes, it is highly common the usage of Lean tools (Rosa *et al.*, 2017; Sousa *et al.*, 2017; Neves *et al.*, 2018; Rosa et al., 2018; Martins *et al.*, 2018; Priyaadarshini *et al.*, 2018; Silva *et al.*, 2021; Martins *et al.*, 2021), as they have precisely the purpose of the referred aims (Mulugeta, 2021) and generally they are proved to help the industry performance (Antoniolli *et al.*, 2017; Correia *et al.*, 2018; Silva & Ferreira, 2019; Carvalho *et al.*, 2020; Tayal and Singh Kalsi, 2021). Some developed works demonstrate how effective might be the application of Lean tools. For example, Dias *et al.* (2019) achieved, in an assembly line of automotive industry, an increasing in production line capacity of 37% and overall equipment efficiency (OEE) of 22% after implementation of lean techniques. Otherwise, Sivaraman *et al.* (2020) applied lean tools and techniques as well, having improved the efficiency by 7% in an engine assembly line at Renault Nissan Automotive India. Otherwise, Moreira *et al.* (2018) obtained 2% to 4% increase in OEE, achieving a cost reduction as well. Following, a more specific overview about the technics effectively applied on the developed work is carried out.

2.2.5 Kaizen

Lean manufacturing seeks for maximize the value of the product by minimizing the waste (Sundar *et al.*, 2014; Costa, *et al.*, 2017). This can be achieved through the practice of *kaizen*, which is a method that focuses in continuous improvement of functions, systems and processes within the company by applying ideas that are not only conceived by the managers but also based on the knowledge, skills, and inputs given by the workers' side (Rosa *et al.*, 2019). Janjić *et al.* (2019) concluded that the improvement of the company`s performance is one of the most important benefits of *kaizen* implementation, in a research study, performed through a questionnaire addressed to a sample of manufacturing companies in Serbia. Usually, *kaizen* implementation does not require a huge financial investment (Shojaei *et al.*, 2019), which makes it attractive for SME. Table 4 contains some papers illustrating Kaizen implementation and its results.

Table 4 -Studies about Kaizen implementation.

Reference	**Aims**	**Methodology**	**Findings**
(Darmawan *et al.*, 2018)	To reduce the rate defect in the pasting process.	Implementation of *Kaizen* Case Study in Automotive Battery.	Initially, the defect rate was 2,47%. After *Kaizen* implementation, the authors observed a reduction of the defect rate in the automotive batteries production to 1,52%.

(Shojaei et al., 2019),	Implementation of productivity management cycle to improve the performance of the production in Pars Khodro Car Corporation, by using *kaizen* approach.	Data collection and analysis through a questionnaire over performance dimensions (work quality, work quantity, collaboration, job knowledge, reliability, timeliness and initiative, personal and personality development, and attitude and leadership) made to the supervisors before *kaizen* implementation and to the employees and supervisors as well after *kaizen* implementation.	The authors analysed the questionaries'' results and checked that the average of all performance dimensions increased after the *kaizen* implementation and concluded that kaizen philosophy leads companies to improve their efficiency, reduce the waste, and improve the productivity.
(Shukla, 2018)	To reduce the lead time of sales order processing, and thus improve the productivity of the organization.	Implementation of *kaizen* and 5S.	After *kaizen* implementation, the overall lead time was reduced by 4.04%.

All the presented studies contemplate *kaizen* philosophy implementation, and all of them found improvements afterwards, which confirms the fact that Kaizen is something that definitely can lead the companies to improvement.

2.2.6 Visual Management (VM)

VM refers to a technic that works as support for decision-making processes and organizational improvement. Its application can improve the transparency and help the crews to identify more closely their tasks, as well as increase their motivation to have a better performance (Jaca *et al.*, 2014; Antoniolli *et al.*, 2017; Glegg *et al.*, 2019). Table 5 shows some works performed with VM.

Table 5 – Some papers about the topic VM.

Reference	Aims	Methodology	Findings
(Steenkamp *et al.*, 2017)	To develop a VM system for Resource Management.	Case study in Stellenbosch University.	The authors implemented VM in the dashboard displaying important manufacturing KPIs.
(Kurdve et al., 2019)	To redesign the visual management boards and include the KPIs considered	Case study performed in two medium small sized companies.	The operators implemented and analysed the daily visual management, and they listed the needed information to perform their daily activities. The method

	relevant by the operators.		was considered useful for improvement.
(Jansson et al., 2016)	Implementation of Knowledge information- visual planning into a process	Case study in a company in Sweden	After implementation, the production flow was improved. The cross-functional understanding of relationships between activities was also increased.
(Zarbo *et al.*, 2015)	To implement the culture of continuous improvements.	Application of a daily visual management board with indicators (quality, time, inventory, productivity …etc)	After one year, daily VM resulted in 42 process improvements. The authors concluded that daily management was, definitely, a key tool that enabled the culture of continuous improvement.

The presented papers showed that, in fact, the implementation of VM is and effective method that can leads the organizations to improvement.

2.3 Logistics / Facility layout

The facility layout problem aims to reach the most efficient physical arrangement of the elements to help the work in shopfloor to perform in a productive way (Naik and Kallurkar, 2016; Elahi, 2021). Improvements in the facility layout can be helpful to reach production efficiency improvement by reducing unnecessary actions and movements, being that, a good layout leads to costs reduction and increased productivity (Prajapat *et al.*, 2016; Freitas *et al.*, 2019; Elahi, 2021).

One of most common methods to optimize facilities' layouts in terms of minimizing the costs is the systematic layout planning (SLP) (Khariwal *et al.*, 2021), which reduce the costs with flows and material handling (Buchari *et al.*, 2018; Haryanto *et al.*, 2021).

By applying the SLP method, the following steps should be considered, according to Khariwal *et al.* (2021), who present a study with the application of SPL which resulted in a new layout proposal that improves the flows and allows to decrease movement in the workshop`s layout:

- Input data and activities;
- Development Activity relationship diagram;
- Development Space relationship diagram;
- Establishment of alternative layouts;
- Evaluation of the proposed alternatives and choice of best one.

Figure 3 shows an illustration of the closeness ratings to be used during the layout's analysis, while Figure 4 presents an example of a relationship diagram. Both figures are also presented in the study performed by Khariwal *et al.* (2021).

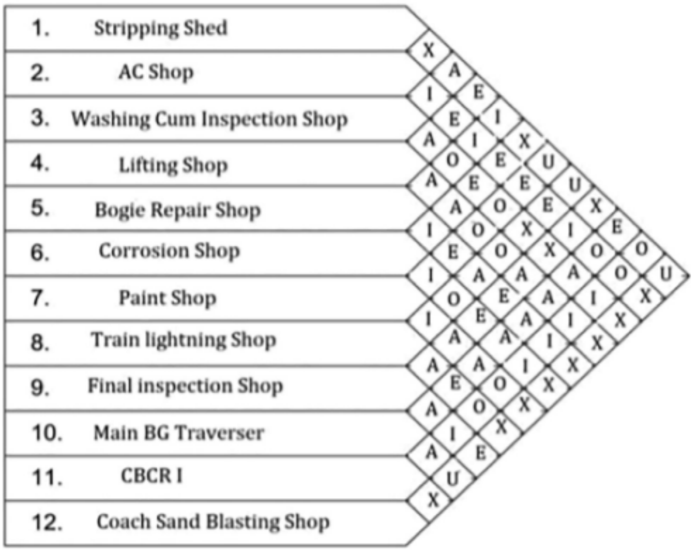


Figure 3 – Closeness ratings to consider in applying SPL (Khariwal *et al.*, 2021)

Rating	Definition	Value	Rating	Definition	Value
A	Absolutely Necessary	4	O	Ordinary Closeness	1
E	Especially Important	3	U	Unimportant	0
I	Important	2			

Figure 4 – Example of relationship diagram obtained through SPL method (Khariwal *et al.*, 2021).

Some studies showing results from practical application of SLP are presented in Table 6.

Table 6 -Studies about application of SLP method.

Reference	Aims	Results /Conclusions
(Buchari et al., 2018)	Improvement of the production layout of a wood processing company, by using the SLP method and line balancing.	With the layout rearrangement through SLP, the authors achieved a reduction of 37,2% in path lengths.
(Suhardi et al., 2019)	To improve the facility layout of a sewing department of a garment company (PT.PMJ) located in Indonesia. It was applied the SLP method, as well as the ergonomics approach.	The authors achieved an improvement 23,88% in distance, 22,92% in material handling costs and 34,01% in transfer time.
(Islam *et al.*, 2017)	To study and implement the most effective and optimal layout in a manufacturing organization.	The authors analysed the current layout and, through the application of SLP, developed three alternatives. The best one was implemented, and it was verified an improvement of 20,9% in the labour productivity, 8,17% in

		machine productivity and 20,91 in the line efficiency.
(Campos, 2020)	To design a layout for a manufacturing unit of an automotive industry company, optimizing the material flows.	The author established a set of alternatives for the layout, using SLP and chose the best one based on decision technique analytic hierarchic process, having achieved improvements of 23% in flows, and an overall reduction of 50% in the overall costs.

PRELIMINARY ANALYSIS

3 PRELIMINARY ANALYSIS

This chapter contains a brief presentation of the company, its products and a first analysis to the production department according the first established objective.

3.1 alki TECHNIK`s overall picture

3.1.1 Company`s presentation

alki TECHNIK GmbH exists since 1984 and operates in the production of high-quality and innovative products in the field of bolting systems for torque applications. The headquarters are located in Ingolstadt, Germany, with the administration, distribution, development , and production departments (alki TECHNIK GmbH, 2021). Figure 5 shows a picture of the main facade of the company facilities.

Figure 5 - View of the company facilities.

Figure 6 shoes some organizational information, such as the head departments, number of employees and average turnover, followed by Figure 7 that contains a simple diagram showing what the company provides.

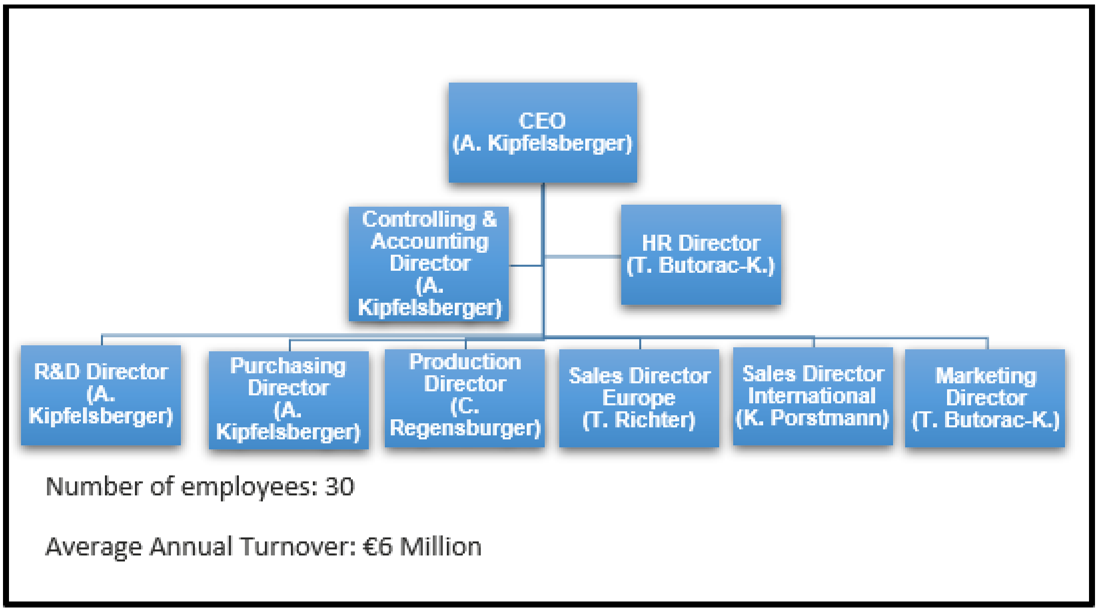


Figure 6 -Company`s organigram.

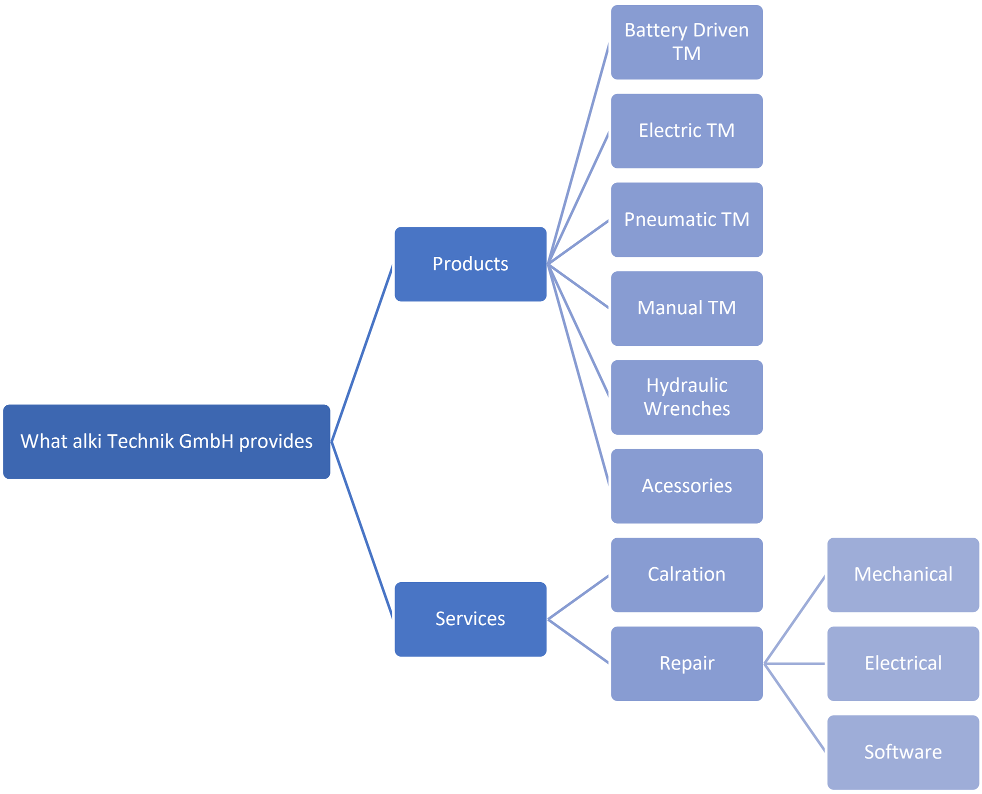


Figure 7 -Products and services provided by the company.

An important point to highlight is the fact that alki TECHNIK GmbH provides its products worldwide under alkitronic`s brand. Figure 8 shows the product's' brand logo as well as some products, just to illustrate the mentioned point.

Figure 8- alkitronic`s brand (alki TECHNIK GmbH, 2021).

3.1.2 Products’ characterization

As mentioned in previous section, regarding the products provided to the market by alki TECHNIK GmbH, they contemplate different types of TM, as well as accessories. In Table 7, a short description of each type of TM with an illustration is presented.

Table 7-Products’ description (alki TECHNIK GmbH, 2019).

Product	Description	Illustration
Battery driven TM	Mobile Equipment work with a Lithium-Ion battery (18 V 5,2 A.h). The torque ranges from 90 N.m to 6000 N.m	
Electric TM	Equipment works using power supply (100-253 V/45-66 Hz). It was designed to be applied where high torques are required. Its torque ranges from 60 N.m to 42.500 N.m	

Pneumatic TMr	Tool to be applied in places/ hazardous areas with ATEX requirements. Its torque ranges from 60 N.m to 48000 N.m.	
Manual TM	Ideal to use in hazardous / explosion risk areas. Its torque ranges from 60 N.m to 42500 N.m.	
Hydraulic Wrenches	Ideal to applications with heavy bolting connections with large threads that need to be tightened with elevated force. Torque ranges from 60 N.m to 42500 N.m.	
Accessories	Standard parts to be fited in the torque tool such as sockets , connectors , reaction arms.	

To make clearer how each of the mentioned TM works, an illustration is displayed in Figure 9.

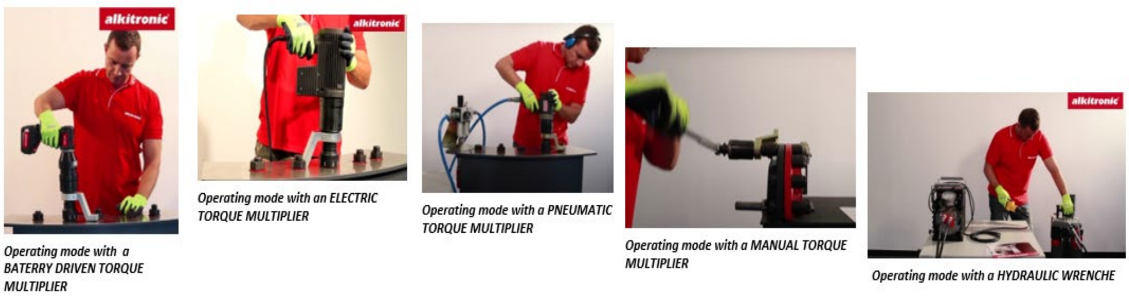


Figure 9-Operating modes of the torque multipliers.

3.1.3 Circuits of products and services

As previous mentioned the company provides products and, also services. For better understanding how the process between the company and customer flows in the two situations, simple diagrams are following exhibited. Figure 10 shows a flow for new products from sending the quotation until the customer receives the product.

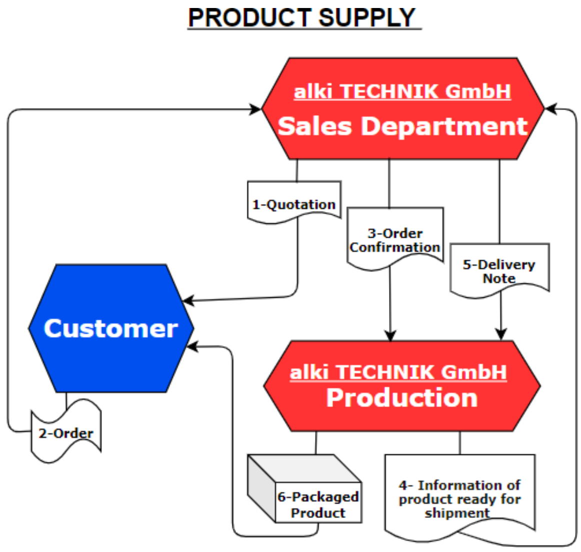


Figure 10 – alki TECHNIK- product supply circuit.

Figure 11 shows a flow for the services, being that, in this situation, normally all starts with the reception of the equipment sent by the customer for repair or calibration service.

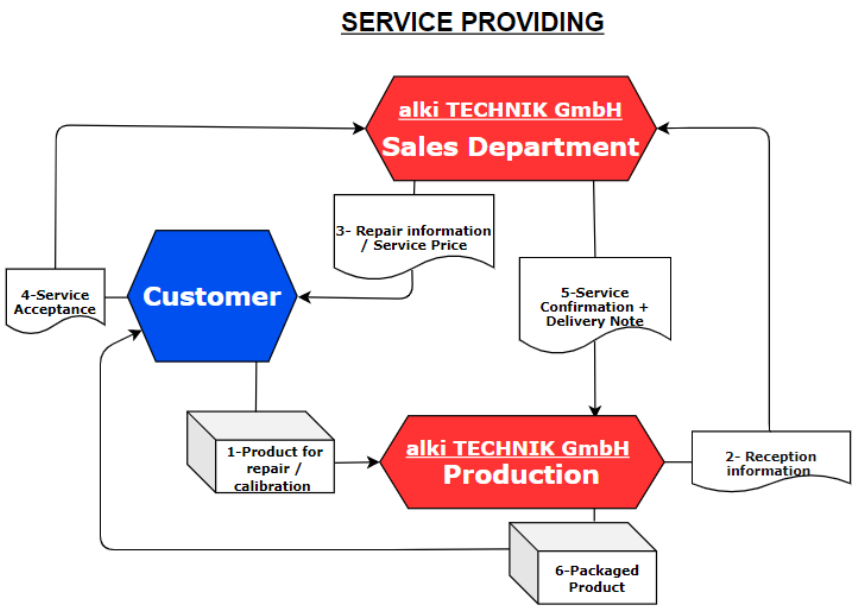


Figure 11 – Services' providing circuit.

3.2 Problem's description

As described in section 1.2, the company needs to assess the scope for P improvement, thus reaching more OUT in produced products and executed services from the existent human resources.

The challenge of this project consisted in firstly establish P level resulting from the current production time capacity as a known parameter, proceed with its monitoring and study ways for its improvement through the production optimization tools or layout optimization.

3.3 Workshop's characterization

In this section an overall picture of the workshop is presented.

3.3.1 Activities performed

As first step, it was made the identification of the main activities performed in the production, as well as its frequency of execution, as it is shown in Table 8.

Table 8 – Workshop`s activities.

Number	Activity	Description	Frequency
1	New tools production	Production of new equipment's / orders	Permanently
2	Services execution	Repairs and calibration	Permanently
3	Expedition	Logistics tasks to get the products ready for shipment	Permanently
4	Goods Reception	Products reception from suppliers or equipment for services	Permanently
5	Travels	Deliveries and pickups in suppliers	Regularly
6	Parts' Project/Development	Design and modelling of parts for the development of equipment	Regularly

For better understanding, Table 9 shows the frequency scales, as well as the criteria used.

Table 9 – Activities' frequency.

Frequency scale	Criteria
Permanently	every day
Regularly	few times/week

3.3.2 Workstations (WSs)

There are currently six WSs in the workshop. Table 10 shows, generically, each one of them, the person allocated, and the activities usually performed according to its assigned numbers in Table 8.

Table 10 – Workshop`s WSs.

WS	Main Human Resource	Activities performed
WS - Battery tools (WSB)	Alex Abel	1,2,6
WS - Electrical tools 1 (WSE1)	Azime Bilgili	1,3,4
WS - Electrical services 2(WSE2)	Christian Finkenzeller	2,6
WS - Manual tools (WSM)	Jurij Maier	1,2,4,5
WS - Pneumatic tools (WSP)	Drazen Lovric	1,2,3,4,5
WS - Hydraulic tools (WSH)	Christian Regensburger (PM)	1,2,6

3.3.3 Layout

Figure 12 shows a simple scheme illustrating the current layout of the workshop with all the locations highlighted and its total length and width in [mm], while Table 11 presents a small description and the activities analysis.

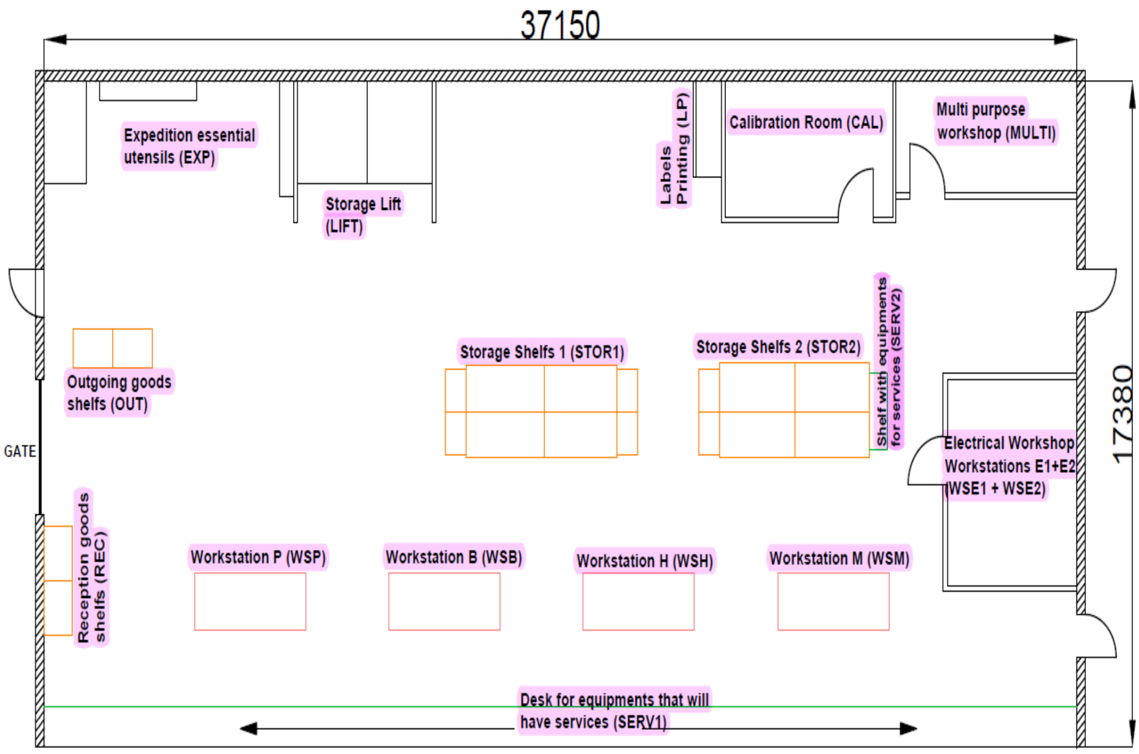


Figure 12 – Workshop`s current layout.

Table 11 – Layout description/ activities analysis.

Location	Description/ Activities analysis
REC	In these shelfs are placed the incoming goods, such as, equipment for services or parts from suppliers.
OUTG	In these shelfs are placed the volumes to be shipped to the customers.
EXP	In this place are weighing scales, dimensions measuring tapes, suitcases/carboards for packing the equipment's.
LIFT	This is a fix automatic storage elevator where some parts and accessories necessary for the tools assembly are stored.
LP	This is a small table with printers for the labels to paste on the equipment.
CAL	This is the place where the equipment are calibrated, as well as the workshop`s printer where the documents from the office are printed, such as orders confirmations.
MULTI	It is where a small workshop a press machine, small oven and some used oils are placed.
WB	Here are the battery driven torque multipliers. This workstation needs a massive use of the calibration room.
WE1/WE2	The employee of WE1 makes the production of Electrical TM, while in WE2 mostly services are performed.
WSM	WS is where the manual torque multiples are produced.
WSP	Pneumatic torque - The employee in this WS makes a massive use of EXP and REC.
WSH	This WS is also the location of the PM, and where hydraulic wrenches are produced.
STOR1	Storage of parts to use in products assembly.
STOR2	Storage of parts to use in products assembly.
SERV1	Place for machines waiting by services (Repair / Calibration) - WSP, WSH, WSB.
SERV2	Place for machines waiting by services (Repair / Calibration) in WSM, WSE2.

Following it can be seen a set of pictures showing some of the described locations:

- Figure 13 – shows a central view of the workshop.
- Figure 14 – shows the CAL, where the calibrations of the TM are executed.
- Figure 15 – shows both sides the WSM.
- Figure 16 – shows STOR1 and STOR2, where the parts for TM assembly are stored.

Figure 13- Central view of the workshop.

From the central view of the workshop it can be seen the WSs on the right side, being the CAL on the left. STOR1 and STOR2 are on the middle behind the green closet, where the employees must go to obtain serial number of each produced tool.

Figure 14 - Picture of the calibration room (CAL).

The CAL contains two calibration stations, being considered as a balanced solution taking into account the needs of calibration and the cost of having a calibration station.

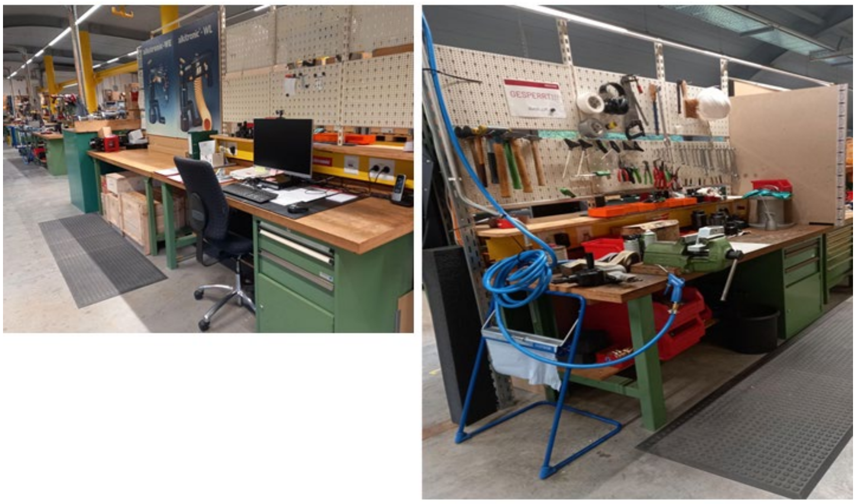


Figure 15 -Picture of a workstation (WSM).

The WS is organized having the necessary tools to the equipment's production and services execution in one of the sides, being the computer and the telephone placed at the opposite side.

Figure 16 – Picture of the central storage shelves (STOR1+STOR2).

As it is visible, the parts' containers are identified and placed on top of in order to enable its easy handling.

Next, for better understand of the workshop process flow, the flowcharts of the processes that will lead to the OUT will be presented.

3.3.4 OUT processes' flowcharts

Figure 17 shows the flowchart with the steps of the process for new tools' production, followed by Figure 18 that contains the flowchart of services' execution. It should be noted that, in both situations, all the process is usually carried out in the same WS.

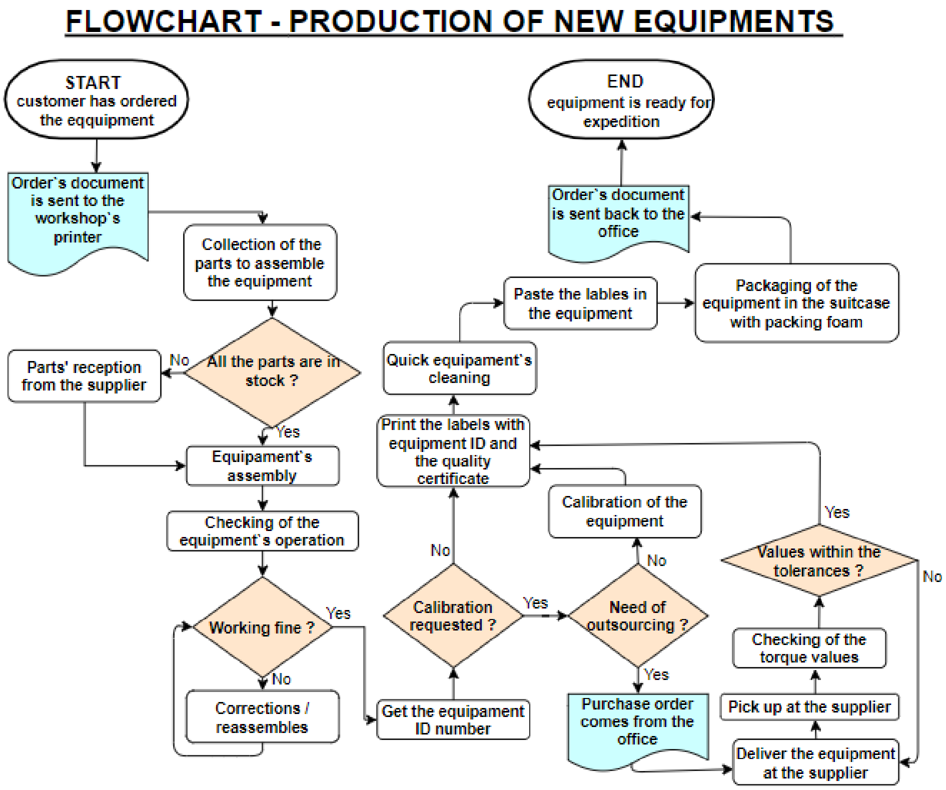


Figure 17 – New tools' production flowchart.

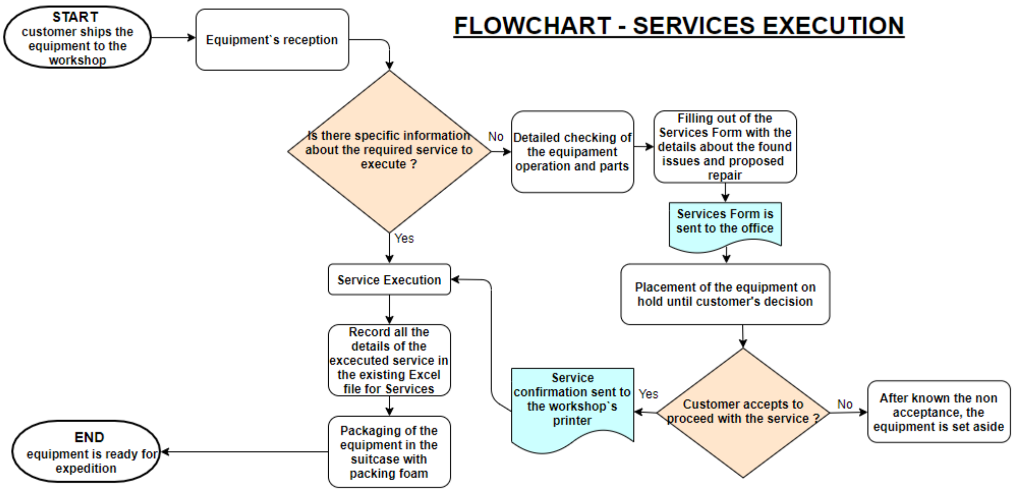


Figure 18 – Services' execution flowchart.

DEVELOPED SOLUTIONS

4 DEVELOPED SOLUTIONS

In this chapter, all the developed practical work is described, as well as the implemented operational solutions. The chapter ends with a critical analysis about the proposed solutions.

4.1 Tools planning and control

After the preliminary analysis, the first main steps carried out were to understand the time capacity presented by the production sector, and also to measure the time necessary for the production of the tools.

4.1.1 Weekly production time capacity (WPTC)

Initially, an analysis to understand the existent time capacity was performed, and it was decided to establish this analysis in a weekly basis, as it is according to the orders´ delivery times. Thus, to establish the existent time capacity in the production, the following steps were considered:

- The total labour time (TLT) of each one of the production employees, including the production manager (PM);
- Subtract to TLT the daily breaks (DB), which are 25 min per day, as well as the time spent on regular daily meetings (DM) as they are non-productive times, being about 20 min per day for the employees, spending the PM about 50 min per day in meetings. Thus, Equation (2) was applied:

$$WPTC = TLT - (DB + DM) \quad (2)$$

Table 12 contains the established WPTC, after the calculations made through Eq. (2).

Table 12 – Standard WPTC.

WS	TLT/week (h)	Coffee Breaks /week (h)	Regular Meetings/ week (h)	WPTC (h)
WSB	40	2,085	1,665	36,25
WSE1	35	2,085	1,665	31,25
WSE2	40	2,085	1,665	36,25
WSM	36	2,085	1,665	32,25
WSP	40	2,085	1,665	36,25
WSH	40	2,085	4,165	33,75
				∑=206

A total of 206h were estimated as standard value of WPTC, however it is known that WPTC will not be constant during the year, due official holydays and people absence, which means loss of capacity resulting from both mentioned situations, thus it was necessary to find a solution for manage dynamically the WPTC over the year. For that purpose, it was conceived a spreadsheet solution through Excel-Visual Basic (VBA) that allows to get accurate values of time capacity over the weeks. Next, a sample of the table with the WPTC is presented in Figure 19, being the complete table with the 52 weeks in the Annexes, followed by a brief illustration of the designed functionality.

2021 (Weeks)	**Standard Capacity (h)**	N° of Hollydays	Capacity loss with Hollydays (h)	Capacity loss with people`s absence (h)	**Real Capacity (h)**
1	**206**	1	41,2	127,75	**37,05**
2	**206**		0	0	**206**
3	**206**		0	0	**206**
4	**206**		0	0	**206**
5	**206**		0	0	**206**
6	**206**	1	41,2	7,25	**157,55**
7	**206**	1	41,2	14,5	**150,3**
8	**206**		0	0	**206**
9	**206**		0	0	**206**
10	**206**		0	7,25	**198,75**

Figure 19 – Sample of WPTC table.

Below, a set of images can be observed, which intend to briefly illustrate the conceived functionality:

- Figure 20 shows an overview of the spreadsheet;
- Figure 21 and Figure 22 show the functionality.

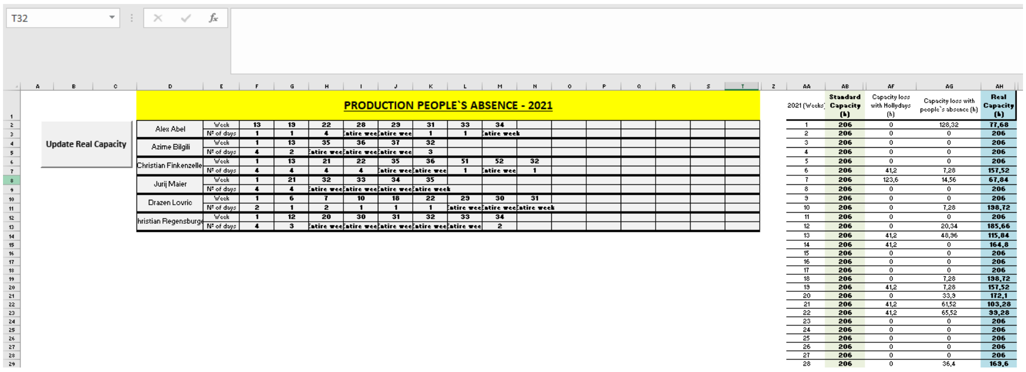


Figure 20 – General view of the spreadsheet.

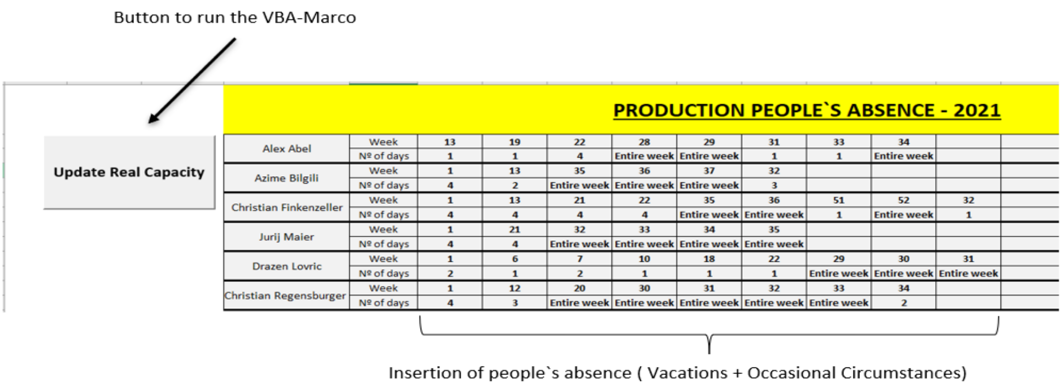


Figure 21 – How WPTC works (1).

2021 (Weeks)	Standard Capacity (h)	N° of Hollydays	Capacity loss with Hollydays (h)	Capacity loss with people`s absence (h)	Real Capacity (h)
1	206	1	41,2	128,32	36,48
2	206		0	0	206
3	206		0	0	206
4	206		0	0	206
5	206		0	0	206
6	206	1	41,2	7,28	157,52
7	206	1	41,2	14,56	150,24
8	206		0	0	206
9	206		0	0	206
10	206		0	7,28	198,72

Real Capacity in all the 52 weeks is updated

Figure 22 – How WPTC works (2).

It should be also mentioned that the number of holidays on each week was also inserted according to the official calendar. As they are well-known, this insertion is made only once a year.

4.1.2 Production time (PT) for the equipment's

The company provides a wide range of products within the various types of torque multipliers previous presented, on section 3.1.2. In that way, the information about the total standard PTs for each equipment already existed from a previous work. A sample of the existing PTs for each tool is showed in Figure 23, as the complete list can be found in the Annexes.

Equipments	PT for 1 un. (min)
HG 10	50
HG 15	58
HG 20	58
HG 30	63
EAF 2/60	159
EAF 2/80	174
EF 600	139
EAF 2/600	204
EAF 2/150	164
EAF 2/200	164

Figure 23-Sample of the list of total PTs tools producing.

The list of PTs for one unit (un.) was already known. However, one issue still remained at this stage, which was about the multiple-unit production (MUP). Moreover, because that task had not been completed on previous work about PT, it needed to be done in this context. The issue was about how to quantify the PT as accurately as possible in case of MUP. This is important because three tasks do not need to be performed as many times as the number of items to produce along the process. Furthermore, the groupage assembly that might result in the time spent per each produced unit, will be different than for single production. Thus, it was clear that, considering in MUP the multiplication ratio (MR), this does not generate the most accurate value.

A simple methodology was established, trying to find a suitable *MR* to estimate the PT in case of MUP as the following description:

- Following up of MUP and observing its total PTs;
- Having the PT for one unit, and the observed times for multiple units produced, calculating the multiplication ratio through the following equation Equation (3):

$$PT_{(Xun.)} = PT_{(1un.)} + PT_{(1un.)} \times (X - 1) \times MR \qquad (3)$$

X - n.o of produced units
$PT_{(xun.)}$ - Recorded time (h)
$PT_{(1un.)}$ - PT for one unit (h)
MR – Multiplication Ratio

- Discussion with the PM and GM about the results, and evaluation of whether it should or not be considered as a multiplication ratio.

It was observed through the execution of the order 2021/ 40721 (which contemplated the production of 40 units of the torque multiplier – HG 20) , and the order 2021/40733 containing 4 units of the torque multiplier – HG 30, plus 5 units of the torque tool – HG 51. Both orders confirmations can be found in the Annexes.

The observed times on each of the followed orders are in Table 13, as well as the existing standard unitary times.

Table 13 - Observed times in MUP.

Order	Standard PT for 1 un. (min)	Total observed time
Production of 40 un. HG-20	58	22h:20min
Production of 4 un. HG-30	63	3h:7min
Production of 5 un. HG51	75	4h:18min

Applying Eq. (3) in the three situations, the following results were obtained:

Order 2021/ 40721:

$$22{,}75 = 0{,}967 + 0{,}967 \times 39 \times F \leftrightarrow F \approx 0{,}567$$

Order 2021/ 40733_Position 1:

$$3{,}12 = 1{,}05 + 1{,}05 \times 3 \times F \leftrightarrow F \approx 0{,}657$$

Order 2021/ 40733_Position 2:

$$4{,}3 = 1{,}25 + 1{,}25 \times 4 \times F \leftrightarrow F \approx 0{,}61$$

After discussion with GM and PM about the obtained results, it was decided to establish the MR for MUO as 0,6 (F= 0,6), although it might not be a fully accurate approach, as there was a short number of observations and the obtained results showed differences. However, it was considered that this first approach would lead to a much more realistic analysis and planning of necessary PTs.

Having the PT as well, the factor to apply in MUO, it was possible to start recording the orders coming into the production and associate its respective PT. The task was made through MS Excel® spreadsheet, as illustrated in Figure 24.

	A	B	C	D	E	G	J
1	New Orders						
2	Entry Week	Entry Date	Order N°	Item	un.	Delivery (Week)	PT (h)
180	29	20/07/2021	41069	EAF 2/200	1	32	2,733333333
181	29	20/07/2021	41073	EAF 2/300	1	31	2,816666667
182	29	20/07/2021	41072	EAF 2/200	1	31	2,733333333
183	29	21/07/2021	41089_1	EFCip R 80p	4	31	8,446666667
184	29	21/07/2021	41089_2	EFCip SG 80	1	31	3,933333333
185	29	22/07/2021	41096	EFCip 65	1	31	3,6
186	29	22/07/2021	41097	EFCip 80	1	31	3,6
188	29	23/07/2021	41102	CLS 2/100	1	31	1,733333333
189	29	23/07/2021	41107	EFCip 30	1	31	3,6
191	30	28/07/2021	41116_1	EFCip R 80p	1	32	3,016666667
193	30	28/07/2021	41118	EFCip 65	1	32	3,6
194	30	28/07/2021	41117	EFCip 70	1	31	3,6
195	30	30/07/2021	41137	EFCip 70	1	31	3,6

Figure 24—Sample of new orders recording performed through spreadsheet.

4.2 Process measurement

At this stage, it had been established how much WPTC as well as PT was necessary for the orders coming into the workshop, nevertheless the production performance was still unknown, as it was necessary to find a way to measure the OUT resulting from the WPTC, which are not only produced orders but also execution of services.

4.2.1 New tools produced - measurement

The found solution to have a measurement of produced tools was a simple form to be manually filled by the employees with order number and date every time a tool production is finished. Once the PTs were already known, having the information about the produced tools would make it possible to convert it in time spent. This form was positioned in the exact place where the employees must drop the finished orders to be collected by the back office, thus it was a simple solution without disturbing the existing process flow. A picture of the used form to record the concluded orders is shown in Figure 25, while the complete form template can be found on the Annexes.

Services - Zeit

SN	Datum	Gerät	Bearbeiter	Zeitaufwand für Mechanisch	Zeitaufwand für Elektrisch	Zeitaufwand für Kalibrierung
1646-02304	29.06.2021	EFC 280	JM	16 min	76 min	21 min
1371-812271	01.07.2021	EFCip 80GE	JM/CHT	18 min	56 min	1h 41 min
1635-812214	05.07.2021	EFCip 60	JM/CHT	12 min	35 min	1h 19 min
1635-812106	05.07.2021	EFCip 60	JM/CHT	12 min	43 min	1h 51 min
1846-812271	05.07.2021	EFCip 70	JM/CHT	20 min	47 min	47 min
471-92345	06.07.2021	EFCip 40	JM	17 min	8 min	25 min
1635-812162	07.07.2021	EFCip 60	JM/CHT	15 min	37 min	1h 47 min
1646-022147	12.07.2021	EFCip 65	JM/	20 min	—	13 min
54022	12.07.2021	HG20	JM	25 min		
446-912045	12.07.2021	EFCip 30	JM/	13 min		
446-82617	12.07.2021	EFCIL6	JM	15 min	20 min	

Figure 25 – Form filled after finished orders.

4.2.2 Services executed - measurement

Regarding the services, they are realistically unpredictable in terms of amount of work to be done and complexity, which disables the establishment of standard PTs, constituting thus an obstacle in planning matter. To proceed with the measurement, it was created a form fill based solution, as it had already been used for new orders produced measurement, however in this context the employees were asked to write directly on the form the time spent after each service executed, as well as the date. Figure 26 shows a picture of the used form already filled out, as an example. The template of this services' form are on the Annexes.

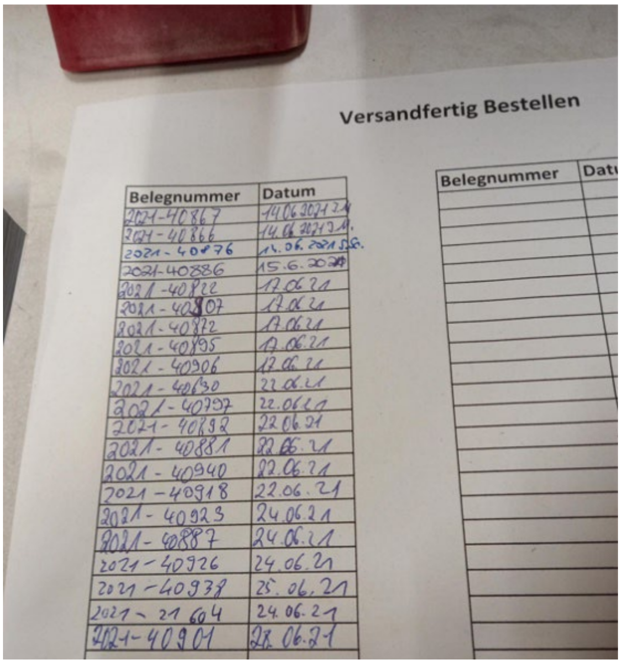


Figure 26— Example of services form.

Afterwards, every week the filled forms were checked, the times started to be noted and inserted in a spreadsheet for analysis. Figure 27 shows the observed values in the first three weeks.

Measurement		
Weeks	New tools finished (h)	Performed Services (h)
26	29,37	26,46
27	18,13333333	38,43
28	31,59	25,47

Figure 27 –Record of times obtained in the first three weeks of observation.

4.2.3 Establishment of P index as KPI

After have obtained the first measurements of production performance, as described in previous section, conditions were met to know the production P level, hence it was immediately established P index as KPI, which was obtained through Eq. (1), considering:

- OUT = Measured new tools + Measured Services
- IN = WPTC

Table 14 contains the first obtained P indexes.

Table 14 – P monitoring

Week	P Index
26	27,10%
27	27,46%
28	33,61%

It was noted that the simple fact of having started with the measurements meant a contribute to improve the performance (P improvement). However, after the analysis with GM and PM, it was considered that P index was clearly too low regarding the P values measured by Moktadir *et al.* (2017) and Yemane *et al.* (2020) in production lines, as can be seen in section 2.2.1. Both authors had initial P levels above 40%. At this stage, it was concluded that, in fact, there was need for P improvement as previously suspected by the company.

4.3 Strategies for P improvement

After it has been found ways of assessing the production performance in terms of P level and have been concluded that it was still at low levels regarding the company needs, it was necessary to study some solutions that might lead to the improvement of P, whose are following presented.

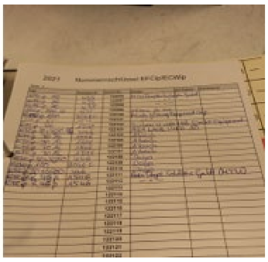
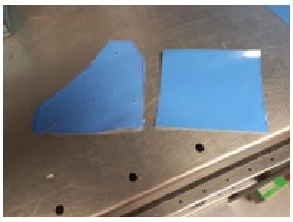
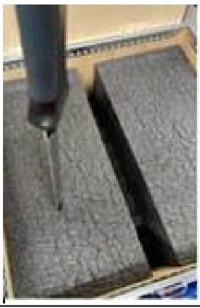
4.3.1 *Kaizen* philosophy

As described in section 2.2.5, *Kaizen* is a method that focus on continuous improvement of the processes, in which, the employees must be also actively involved, not only the managers. The application of this method was approved by the GM and PM, because it was considered that realistically the employees know better than anyone else in the organization what issues they need to face on their daily activities, and thus they could provide important contributions towards improvement. Hence the method was used through the following steps:

- To ask the employees about what activities on the process they consider that could be optimized in order to save time;
- Consider the issue reported as potential *Kaizen* optimization (KO) and proceed with its analysis in terms of time consumption;
- Discuss in meeting with GM and PM about solutions to reach the optimization;
- Analysis of costs and benefits resulting from the obtained Kos.

A total of six main issues shared by the employees were targeted for analysis and respective KO. They are shortly described with some pictures in Table 15.

Table 15 – Problems reported as KOs.

KO proposal		**Pictures**
KO1	Time consumption related to the constant need of manually writing the serial number of each produced tool.	 
KO2	Time consumption related to the cut and drill of small silicone pads to be used in ETMs.	 
KO3	Time consumption related to the need of press the gear boxes.	
KO4	Time consumption related to the need of cut the packing foam to pack the tools in the suitcase.	 
KO5	Time consumption related to the need of cut labels to be pasted in the tools.	

KO6	Time consumption related to the need of assemble the spacer hexagonal bolts.	 

Following the described methodology, it was made the analysis of time consumption of each of the reported problems, as it is presented in Table 16.

Table 16 – Analysis of time consumption related to KOs.

KO	Time consumption (min.)	Estimated executions per year
1	2	1100
2	2,5	275
3	0,6	1300
4	15	150
5	1,5	180
6	1,5	275

It was concluded that the reported KOs would be targeted for improvements. Then, optimization solutions were studied and proposed, as they are shortly described in Table 17.

Table 17 – KOs- found solutions.

KO	Found optimization	Development
1	Spreadsheet solution (Excel-VBA) was designed, which allows the employees to get the serial number on their WS, without need of moving and writing manually.	Immediately implemented.
2	It was found a manufacturer that can supply the silicone pad parts with the desired shape.	It was obtained an offer, purchasing department proceeded with the order.
3	It was confirmed that the supplier of the gearboxes can also perform the pressing.	It was obtained an offer, purchasing department proceeded with the order.
4	It was found a manufacturer that can provide the foam already cut.	It was obtained an offer, purchasing department proceeded with the order.
5	It was found a manufacturer that can supply the labels with the desired shape.	It was obtained an offer, purchasing department proceeded with the order.

6	It was found a manufacturer that can provide the spacer bolts with the desired dimensions.	It was obtained an offer, purchasing department proceeded with the order.

It was found that the improvement of the reported problems according will allows an estimated time saving of almost 101 hours per year, as Table 18 shows.

Table 18 - Time saving estimated with the KOs.

KO	Cost (€)	Estimated time saving / year (h)
1	0	27,5
2	1790 € (300 un.)	11,5
3	1 €/un.(~1300 €/year)	13
4	1783 € (162 un.)	37,5
5	340 € (2000 un.)	4,5
6	256 € (500 un.)	6,88
		100,9

Significative time saving was estimated from KOs. Just KO1 was immediately implemented with the agreement of GM, PM and also the employees. Remaining KOs are in analysis as they carry costs for implementation, however they are intended to be implemented.

4.3.2 Implementation of Visual Management (VM)

After discussion with PM and GM, it was decided to proceed with the implementation of VM strategy. The employees should be sensitized for the need of improve the P, and it was established that each Friday, it should be defined a work plan for the following week that should be also clearly placed in the workshop for the employees, being the workplan discussed with the employees, as VM strategy should bring transparency and have the employees identified with desired results by the top management of the company - the P improvement.

The decided map contains:

- Orders to be produced (including the pending orders of previous weeks plus the orders with delivery planned for the following week) and respective PTs;
- List of goods predicted to arrive from suppliers obtained from the purchasing department;
- Available time for further activities, such as services, production of extra orders or support to the development.

A simple work plan map started to be developed and placed in a central place next to one of the workshop entries, having this implementation started in the end of the week 30. Figure 28 shows an example of a work plan placed in the workshop.

After implementation of the described VM method, and with the P index remaining being monitored, the results exhibited in Table 19 were observed:

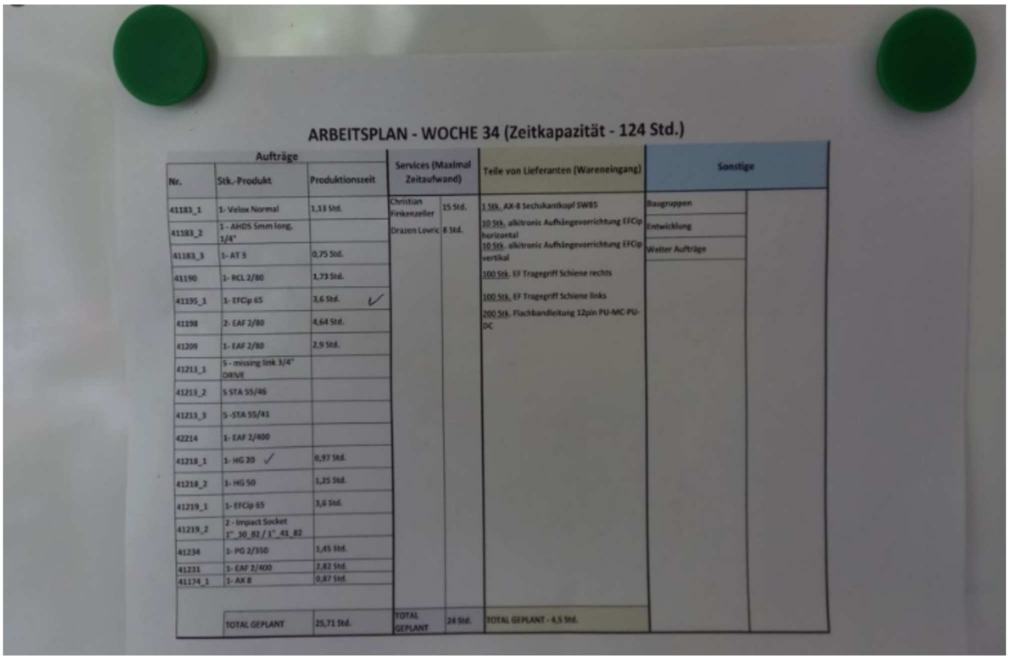


Figure 28 – Example of weekly work plan established in the context of VM method.

Table 19 – P monitoring after VM implementation.

Week	P index
26	27,1%
27	27,46%
28	33,61%
29	43,65%
30	35,22%
31	**59,17%**
32	**52,12%**
33	**58,31%**

It was confirmed that VM strategy with KO1 already implemented produced some immediate effects, once after its first implementation (end of week 30) immediately the P index escalated to 59,17%, remaining above 50% in the following weeks. It was concluded to be and effective strategy to follow.

4.4 Analysis for workshop`s layout optimization

To perform the analysis to find the focus to optimize the existing flows between the WSs and the remaining places presented and described in section 3.3.3, SLP method was followed: However, before that, the distances matrix was built as displayed in Table 20.

Table 20 – Distances matrix between WS and locations (in meters).

	REC	OUT	EXP	LIFT	LP	CAL	MULTI	STOR1	STOR2	SERV1	SERV2
WSB	13,5	14	14,3	10,2	18	24	27	5,8	14,2	3	21
WSE1	32,2	31,5	33,5	27,5	16	7	7,5	16,5	7,5	7	2,2
WSE2	32,2	31,5	33,5	27,5	16	7	7,5	16,5	7,5	7	2,2
WSM	27	28	29	26,5	14,5	10,7	9	12	4,5	3	4,2
WSP	6,4	10,3	12	11	26,5	31,3	34,3	12,1	20,9	3	28
WSH	20	19	20,6	16,3	11,2	16	19	5,7	7,2	3	9,5

4.4.1 Closeness relationships and cost with flows

Based on the analysis of the activities and discussion with the employees, PM and GM, the closeness relationships ratios between the WSs and the remaining locations were established, considering the closeness ratings and its values, according with Khariwal *et al.* (2021), as shown in Table 21, following by the established ratings present in Table 22.

Table 21 – Closeness ratings and values (Khariwal *et al.,* 2021).

Closeness	**Rating**	**Value**
Absolutely Necessary	A	4
Especially Important	E	3
Important	I	2
Ordinary Importance	O	1
Unimportant	U	0

Table 22 - Closeness ratings atributted.

	REC	OUT	EXP	LIFT	LP	CAL	MULTI	STOR1	STOR2	SERV1	SERV2
WSB	I	I	I	A	I	A	O	A	A	A	O
WSE1	I	I	I	O	I	A	O	I	I	O	O
WSE2	O	O	O	O	I	A	I	I	I	A	A
WSM	I	I	I	A	A	E	A	A	A	A	A
WSP	A	A	A	A	A	I	O	A	A	A	U
WSH	I	I	I	A	A	I	O	A	A	A	U

Through the closeness rating values (CRV) presented in Table 21, and the distances showed in Table 20, it was made, for each WS, the cost estimation with flows through following Eq. (4).

$$C = \sum (d_{WS-L} \times CRV_{WS-L}) \quad (4)$$

C – cost with the flows in cost units (c.u.)
D_{WS-L} – distance from the WS to the location L (m)
CRV_{WS-L} – Closeness rating value of the WS to location L

Applying the Eq. (4), C was calculated for each WS, as presented in Table 23.

Table 23 – Costs with flows (current workshop layout).

WS	C (c.u.)
WSB	396,4
WSE1	346,6
WSE2	284,5
WSM	494,9
WSP	505,7
WSH	343,8
	∑=2371,9

After C calculation for the current layout and, following the SLP method, a couple of optimization alternatives (OAs) were outlined, as follows.

4.4.2 OA1

As first approach, it was designed an optimization solution without extra costs. The purposed changes are in Table 24.

Table 24 – Proposed layout changes- alternative 1.

Proposed change	Explanation
To move EXP to a central place and establish it as a packing station (PACK)	Currently, the place EXP which has the packing purpose, is located too far from the WSs, so that it was thought as beneficial having a PACK with the necessary tools, such as the scale and measure tapes, in a central position closer to the WS.
To proceed with a swap between WSH and WSB	As it was described, the employee of the WSB makes a massive use of the CAL, which is not the case of the employee of WSH. Hence, a simple swap between these WS will place the WSB closest to CAL, thus, some flow distance for this employee can be saved.

Figure 29 shows the workshop layout with the referred changes highlighted.

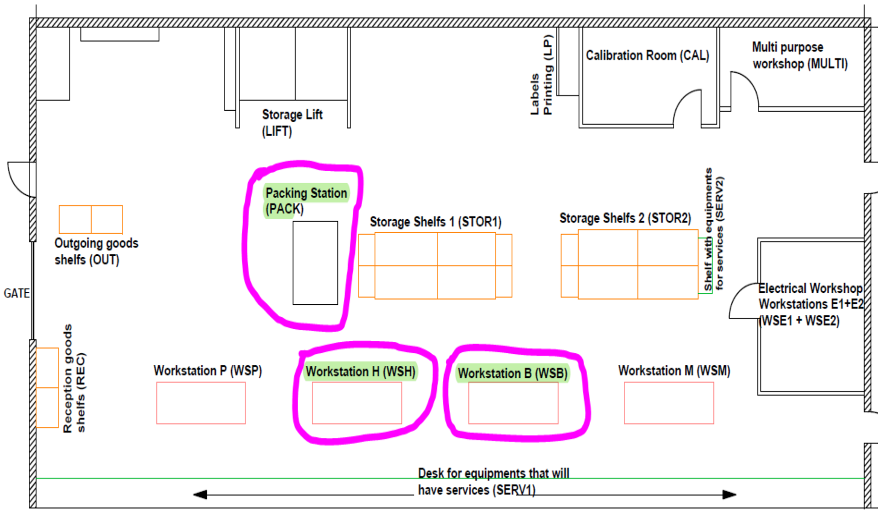


Figure 29 – Workshop layout with optimization OA1.

After this first conceptualization, the distances matrix had to be rebuilt. Table 25 contains the distances matrix, with the distances in [m], considering the changes proposed.

Table 25- Distances matrix with OA1 (in meters).

	REC	OUT	PACK	LIFT	LP	CAL	MULTI	STOR1	STOR2	SERV1	SERV2
WSH	13,5	14	5,1	10,2	18	24	27	5,8	14,2	3	21
WSE1	32,2	31,5	20	27,5	16	7	7,5	16,5	7,5	7	2,2
WSE2	32,2	31,5	20	27,5	16	7	7,5	16,5	7,5	7	2,2
WSM	27	28	16	26,5	14,5	10,7	9	12	4,5	3	4,2
WSP	6,4	10,3	6,8	11	26,5	31,3	34,3	12,1	20,9	3	28
WSB	20	19	10	16,3	11,2	16	19	5,7	7,2	3	9,5

It was possible to estimate C for the proposed scenario, and thus, compare it with the values previously calculated. The results are in Table 26.

Table 26- Costs with flows – OA1.

WS	C(c.u.)	C variation
WSB	341,7	-13,8%
WSE1	319,6	-7,79%
WSE2	271	-4,75%
WSM	468,9	-5,25%
WSP	484,9	-4,11%
WSH	345	+0,349%
	∑= 2231,1	-5,94%

It was checked that the overall cost can be reduced in about 6%, and by swapping WSB and WSH, WSB can have a solid cost`s reduction of 13,8%, as the cost`s variation in WSH will be almost insignificant.

4.4.3 OA2

Another alternative was proposed including the changes of previous section, plus further adjustments considered beneficial. However, these will have costs of implementation. Table 27 displays the further proposed changes in the current layout.

Table 27 - Proposed layout changes - OA2.

Proposed change	Explanation
Increase the storage capacity in WSP; WSH and WSM	Through the closeness relationships' analysis, it can be concluded that the employees of these WS need to move with repeatedly to STOR1 and STOR2, hence having some storage capacity on their WS. This frequency could be reduced
Add LP next to WSH, WSM and WSP	The LP is located next to CAL, because normally the LP is made after the calibration. However, in these referred WSs, most of the tools do not require calibration. Thus, the possibility of performing the labels printing on their WSs would represent a huge benefit in terms of flows reduction.

Figure 30 shows a graphic representation of the described changes.

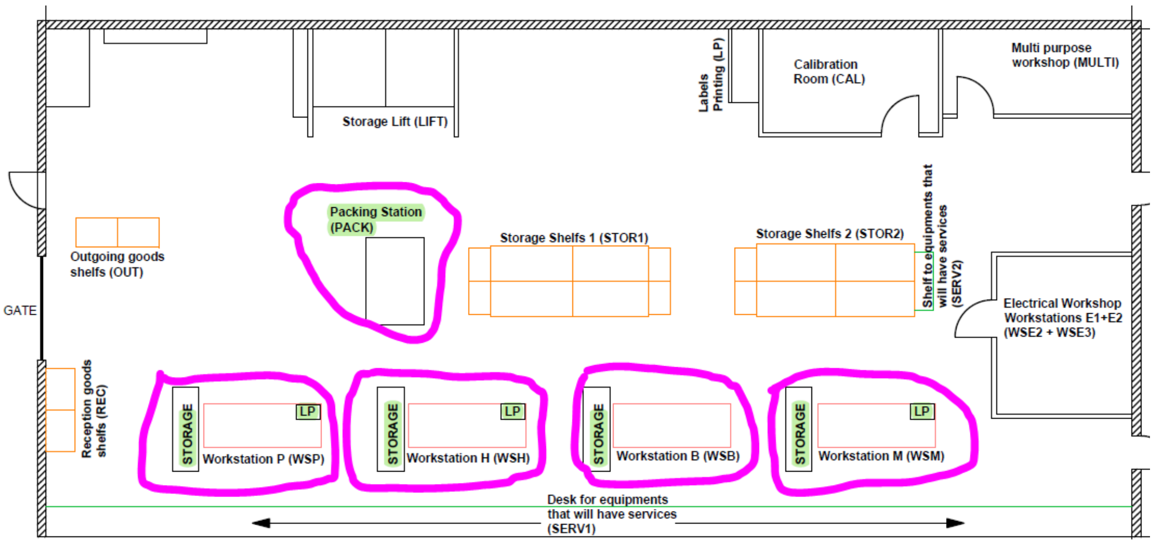


Figure 30 – Illustration of OA2.

In this scenario, the distances matrix remains as shown in Table 25. Nevertheless, due the proposed changes, the closeness ratings with LP, STOR1 and STOR2 will change. Table 28 contains the redefined closeness ratings, highlighting the changed ones.

Table 28 – Closeness ratings considering OA2.

	REC	OUT	PACK	LIFT	LP	CAL	MULTI	STOR1	STOR2	SERV1	SERV2
WSB	I	I	I	A	I	A	O	**I**	**I**	A	O
WE1	I	I	I	O	I	A	O	I	I	O	O
WE2	O	O	O	O	I	A	I	I	I	A	A
WSM	I	I	I	A	**O**	E	A	**I**	**I**	A	A
WSP	A	A	A	A	**O**	I	O	**I**	**I**	A	U
WSH	I	I	I	A	**O**	I	O	**I**	**I**	A	U

Finally, it was calculated C with OA2 and compared the values with the current layout, as shown in Table 29.

Table 29 – Costs with flows – OA2.

WS	C(c.u.)	C variation
WSB	251	-26,9%
WSE1	319,6	-7,79%
WSE2	271	-4,75%
WSM	392,4	-20,7%
WSP	339,4	-32,9%
WSH	315,9	-20,3%
	∑= 1889,3	-20,3%

In this situation, a significative reduction of 20,3% with flows can be achieved. However, its implementation can imply some costs with the label printers, about 415 € each one, considering the Labelident quotation (2021). This cost corresponds to the label printers, but software licences will also be needed, and the storage structure that is about 815 € each one, according to KAISER+KRAFT quotation (2021), considering a mobile structure as possibility. Figure 31 shows the described solutions.

Figure 31 – Checked components in the context of OA2 (Labelident, (2021, KAISER+KRAFT,2021).

4.5 Discussion

This work was performed with the main goal of assessing the real P production level and find out strategies that could lead to its improvement.

A set of stages were carried out to obtain the IN and OUT, in order to start with the P monitoring. The observed P values in the first weeks showed that the highest value was 33,61%, which was considered clearly a low P level. *Kaizen* philosophy was applied by asking the employees about how to lower the time-consuming activities, to be targeted as KOs, having this resulted in 6 KOs with an estimated time saving of 100,9h per year, being that KO1 was immediately implemented, as well as a VM method by establishing and placing in the workshop on each Friday a map with work plan for the following week, after discussed with the employees. After these applied strategies, the P index improved as the values of following weeks were 59,2%, 52,1 and 58,3% respectively, representing a clear improvement comparing with 43,7% as the highest value observed before, or even a greater improvement when compared with the first observed P value, 27,1%. A study over the workshop`s layout was performed through SLP methodology, as facility layouts are considered to have huge influence on productive performances. Two alternatives were proposed, one which involves small changes with no extra costs that might leads to 5,94% reduction of the flows, the second proposed alternative carries some extra costs, however it was estimated a potential of flows reduction of 20,3%.

The findings show good results achieved in terms of P improvement, from the implementation of process optimization methods, such as VM and Kaizen, which evidence the effectiveness of these methods already verified by other authors, as described in section 2.2 and, also scope for further improvement with KOs and proposed OAs for the workshop layout. However, some limitations can be pointed to this approach, such as the lack of more consolidated results due the short observation period. The developed solutions to monitor the production performance demand also a lot of manual inserts, such as the employees having to write in the defined forms every time the tools are produced and services executed, but also by the manager who needs to insert the observed values on the MS Excel® spreadsheet to have P, which might also be considered as a limitation. The workshop layout analysis performed through SLP method can go deeply, by taking in account ergonomic matters.

To summarize this critical assessment to the overall developed work, a SWOT analysis was prepared, which is displayed in Figure 32.

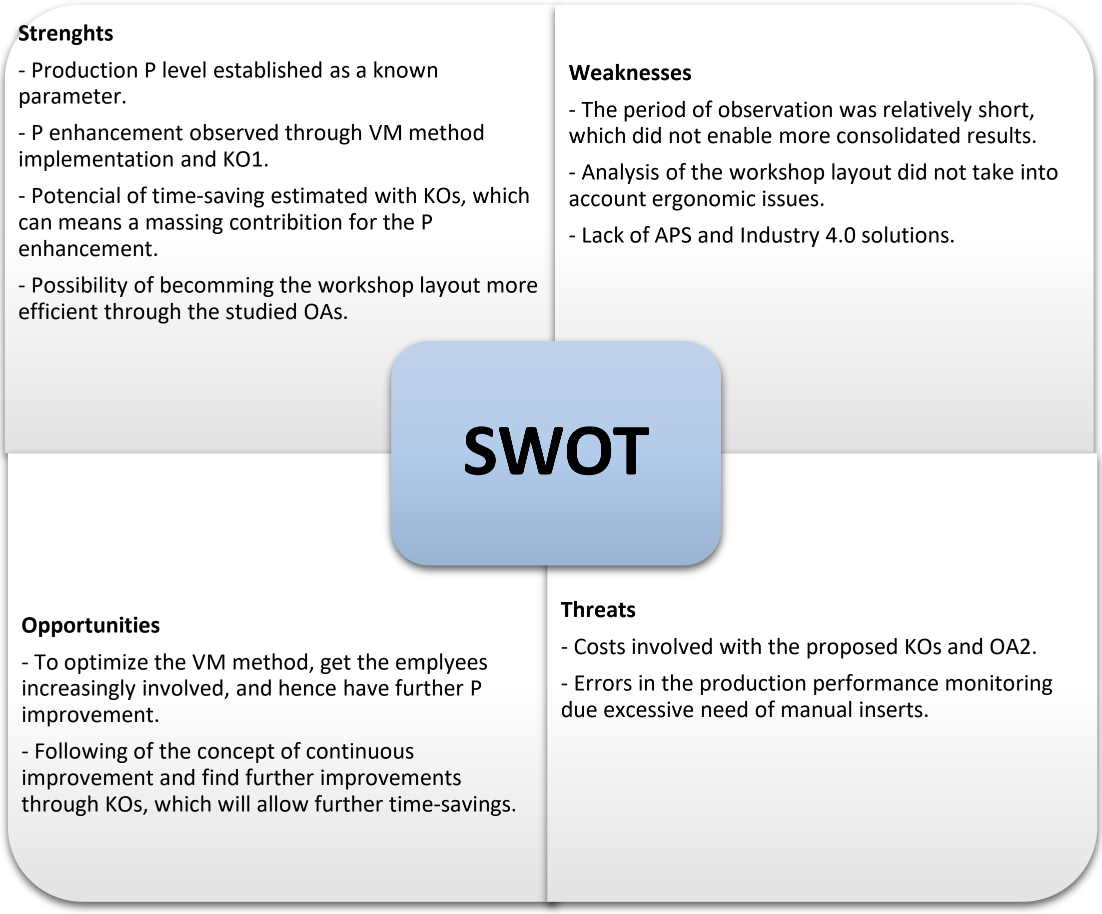


Figure 32 – SWOT analysis of the developed solutions.

CONCLUSIONS

5 CONCLUSIONS AND FUTURE WORKS

In this final chapter, the final conclusions are presented, as well as proposals for future works.

5.1 Conclusions

The main goal of this project, which was the assessment and improvement of the P production was reached. Through the implementation of VM, as well as KO1, the P level reached 59,1%, which compares with 43,7% as the highest performance observed on previous weeks. If compared with the first observed P level, which was 27,1%, it can be considered in fact a massive improvement. Scope for further improvement was left with KOs intended to be implemented and OAs proposed to enhance the efficiency of the workshop layout. Table 30 contains a detailed scrutiny of the defined objectives.

Table 30 – Checking of the objectives' accomplishment.

Defined goals	Observation	Remark
General analysis of the production department in order to characterize its WSs, activities performed and the workshop`s layout.	Regarding the different WSs, activities performed and its frequency and description of each location of the layout was made and presented in section 3.3.	✓
Quantification of IN in terms of time capacity.	It was established the standard value for WPTC (206 h) and created a spreadsheet solution that allows to dynamically, considering variations in WPTC due to official holydays and people absence.	✓
Establishment of measurement methods for the produced tools and executed services, in order to get the OUT.	First, it was concluded the study over the PTs, concretely to have an accurate PT for MUO as described previously. Furtherly, forms were created to be filled by the employees and, then, get the measurement of the production performance in new tools produced and services.	✓

Establishment of P index as a key performance indicator and proceed with its monitoring.	Observations of P started to be made in the week 26, with an observed P index of 27,1%.	
Assessment and implementation of strategies for P improvement and observing its effectiveness.	Production optimization methods were applied, such as Kaizen and VM. P improvement was observed with values 59,2% 52,1% and 58,3% when in previous weeks the highest value observed had been 43,7%. Further scope of improvement was left with KOs and workshop layout optimization.	

5.2 Proposals for future works

Next, a list of possible actions to be carried out in the future is left, allowing a continuous improvement process of the company.

- **Study of the production digitalization**

Most of the used methods requires a lot of manual inserts, such as forms for performance measurement or the spreadsheets, thus some technological solutions can be found and adopted in the context of planning, such as APS, or in the context of information flows in the era of Industry 4.0.

- **Study of Make to Stock (MTS) approach**

In fact, MTS approach is something that can lead to more products produced, hence P enhancement, however the introduction of this concept would demand a carefully study, because stocks might carry also high costs for the company.

REFERENCES AND OTHER SOURCES OF INFORMATION

6 REFERENCES AND OTHER SOURCES OF INFORMATION

alki TECHNIK GmbH. (2019). *Training Documents*.

alki TECHNIK GmbH. (2021). *alkitronic - HOME OF TORQUE POWER*. https://www.alkitronic.com/en/

Antoniolli, I., Guariente, P., Pereira, T., Ferreira, L. P., Silva, F. J. G. (2017). Standardization and optimization of an automotive components production line. Procedia Manufacturing, 13, 1120-1127. https://doi.org/10.1016/j.promfg.2017.09.173

Araújo, M., Amaral, G., Varela, L., Machado, J., & Trojanowska, J. (2017). Improving Productivity and Standard Time Updating in an Industrial Company – A Case Study. *Lecture Notes in Networks and Systems*, *20*, 220–228. https://doi.org/10.1007/978-3-319-63091-5_25

Azizi, A. (2015). Evaluation Improvement of Production Productivity Performance using Statistical Process Control, Overall Equipment Efficiency, and Autonomous Maintenance. *Procedia Manufacturing*, *2*(February), 186–190. https://doi.org/10.1016/j.promfg.2015.07.032

Bishop, D. A. (2018). Key Performance Indicators: Ideation to Creation. *IEEE Engineering Management Review*, *46*(1), 13–15. https://doi.org/10.1109/EMR.2018.2810104

Brundage, M. P., Bernstein, W. Z., Morris, K. C., & Horst, J. A. (2017). Using Graph-based Visualizations to Explore Key Performance Indicator Relationships for Manufacturing Production Systems. *Procedia CIRP*, *61*, 451–456. https://doi.org/10.1016/J.PROCIR.2016.11.176

Buchari, Tarigan, U., & Ambarita, M. B. (2018). Production layout improvement by using line balancing and Systematic Layout Planning (SLP) at PT. XYZ. *IOP Conference Series: Materials Science and Engineering*, *309*(1), 012116. https://doi.org/10.1088/1757-899X/309/1/012116

Campos, L. (2020). *ESTRUTURAÇÃO DO MODELO DE GESTÃO DE UMA NOVA UNIDADE DE PRODUÇÃO DO SETOR AUTOMÓVEL*.

Correia, D., Silva, F. J. G., Gouveia, R. M., Pereira, M. T., Ferreira, L. P. (2018). Improving manual assembly lines devoted to complex electronic devices by applying Lean tools. Procedia Manufacturing, 17, 663-671. https://doi.org/10.1016/j.promfg.2018.10.115

Costa, T, Silva, F. J. G., Ferreira, L. P. (2017). Improve the extrusion process in tire production using Six Sigma methodology. Procedia Manufacturing, 13, 1104-1111. https://doi.org/ 10.1016/j.promfg.2017.09.171

D.R. Kiran. (2019). *Production Planning and Control: A Comprehensive Approach* (B. Guerin & G. Capille (eds.)). Matthew Deans.

Darmawan, H., Hasibuan, S., & Hardi Purba, H. (2018). Application of Kaizen Concept with 8 Steps PDCA to Reduce in Line Defect at Pasting Process: A Case Study in Automotive Battery. *International Journal of Advances in Scientific Research and Engineering*, *4*(8), 97–107. https://doi.org/10.31695/ijasre.2018.32800

de Man, J. C., & Strandhagen, J. O. (2018). Spreadsheet Application still dominates Enterprise Resource Planning and Advanced Planning Systems. *IFAC-PapersOnLine*, *51*(11), 1224–1229. https://doi.org/10.1016/J.IFACOL.2018.08.423

Dias, P., Silva, F. J. G., Campilho, R. D. S. G., Ferreira, L. P., & Santos, T. (2019). Analysis and improvement of an assembly line in the automotive industry. *Procedia Manufacturing*, *38*(2019), 1444–1452. https://doi.org/10.1016/j.promfg.2020.01.143

Elahi, B. (2021). Manufacturing Plant Layout Improvement: Case study of a High-Temperature Heat Treatment Tooling Manufacturer in Northeast Indiana. *Procedia Manufacturing*, *53*, 24–31. https://doi.org/10.1016/j.promfg.2021.06.006

Ellwein, C., Elser, A., & Riedel, O. (2019). Production planning and control systems – a new software architecture Connectivity in target. *Procedia CIRP*, *79*, 361–366. https://doi.org/10.1016/J.PROCIR.2019.02.089

Erol, S., & Sihn, W. (2017). Intelligent Production Planning and Control in the Cloud - Towards a Scalable Software Architecture. *Procedia CIRP*, *62*, 571–576. https://doi.org/10.1016/j.procir.2017.01.003

Ferreira, S., Silva, F. J. G., Casais, R. C. B., Pereira, M. T., Ferreira, L. P. (2019). KPI development and obsolescence management in industrial maintenance. Procedia Manufacturing, 38, 1427-1435. https://doi.org/10.1016/j.promfg.2020.01.145

Freitas, A. M., Silva, F. J. G., Ferreira, L. P., Sá, J. C., Pereira, M. T., Pereira, J. (2019). Improving efficiency in a hybrid warehouse: a case study. Procedia Manufacturing, 38, 1074-1084. https://doi.org/10.1016/j.promfg.2020.01.195

Gfycat. (2018). *Best Epicyclic Gear GIFs | Gfycat*. https://gfycat.com/gifs/search/epicyclic+gear

Glegg, S. M. N., Ryce, A., & Brownlee, K. (2019). A visual management tool for program planning, project management and evaluation in paediatric health care. *Evaluation and Program Planning*, *72*, 16–23. https://doi.org/10.1016/j.evalprogplan.2018.09.005

Haryanto, A. T., Hisjam, M., & Yew, W. K. (2021). Redesign of Facilities Layout Using Systematic Layout Planning (SLP) on Manufacturing Company: A Case Study. *IOP Conference Series: Materials Science and Engineering*, *1096*(1), 012026. https://doi.org/10.1088/1757-899X/1096/1/012026

Islam, M. A., Abul, C., Rashed, A., & Hasan, J. (2017). PRODUCTIVITY IMPROVEMENT THROUGH THE APPLICATION OF SYSTEMATIC LAYOUT PLANNING TECHNIQUE. In *Review of General Management* (Vol. 25, Issue 1).

Jaca, C., Viles, E., Jurburg, D., & Tanco, M. (2014). Do companies with greater deployment of participation systems use Visual Management more extensively? An exploratory study. *International Journal of Production Research*, *52*(6), 1755–1770. https://doi.org/10.1080/00207543.2013.848482

Janjić, V., Todorović, M., & Jovanović, D. (2019). Key Success Factors and Benefits of Kaizen Implementation. *Engineering Management Journal*, *32*(2), 98–106. https://doi.org/10.1080/10429247.2019.1664274

Jansson, G., Viklund, E., & Lidelöw, H. (2016). Design management using knowledge innovation and visual planning. *Automation in Construction*, *72*, 330–337. https://doi.org/10.1016/J.AUTCON.2016.08.040

Joppen, R., von Enzberg, S., Gundlach, J., Kühn, A., & Dumitrescu, R. (2019). Key performance indicators in the production of the future. *Procedia CIRP*, *81*, 759–764. https://doi.org/10.1016/J.PROCIR.2019.03.190

KAISER+KRAFT. (2021). *EUROKRAFTpro Premium-Montagewagen: 4 Schubladen | KAISER+KRAFT Deutschland*. https://www.kaiserkraft.de/wagen/montagewagen/premium-montagewagen/4-schubladen/p/M7343/

Kamdi, P. R. P., Gedam, A., Dharmik, V., Mohadikar, C., & Purandare, A. (2020). TORQUE WRENCH VERIFICATION SYSTEM. *International Engineering Journal For Research & Development*, *5*(5), 4–4. https://doi.org/10.17605/OSF.IO/48XGN

Kang, N., Zhao, C., Li, J., & Horst, J. A. (2016). A Hierarchical structure of key performance indicators for operation management and continuous improvement in production systems. *International Journal of Production Research*, *54*(21), 6333–6350. https://doi.org/10.1080/00207543.2015.1136082

Khaled, K. M., & Abdulhakim, M. (2020). Proposal for torque multiplier calibration standard. *Measurement: Journal of the International Measurement Confederation*, *151*, 107239. https://doi.org/10.1016/j.measurement.2019.107239

Khaled, K. M., & Osman, S. M. (2017). Improving the new ISO 6789:2017 for setting torque tools – Proposal. *Measurement*, *112*, 150–156. https://doi.org/10.1016/J.MEASUREMENT.2017.08.032

Khariwal, S., Kumar, P., & Bhandari, M. (2021). Layout improvement of railway workshop using systematic layout planning (SLP)-A case study. *Materials Today: Proceedings*, *44*, 4065–4071. https://doi.org/10.1016/j.matpr.2020.10.444

Kurdve, M., Harlin, U., Hallin, M., Söderlund, C., Berglund, M., Florin, U., & Landström, A. (2019). Designing visual management in manufacturing from a user perspective. *Procedia CIRP*, *84*, 886–891. https://doi.org/10.1016/J.PROCIR.2019.04.310

Labelident. (2021). *Labelident BP730i, 300 dpi Desktopdrucker, TFT-LCD Display, Modell mit Abreißkante (BP730I)*. https://www.labelident.com/bp730i.html?___store=privatview&trid=DE_Shopping~BP730I~AdWords&gclid=EAIaIQobChMIkve2zf_T8gIVavx3Ch0OAgesEAQYASABE

gKMp_D_BwE

Lake, L. (2015). *What are key performance indicators (KPIs) and why are they important?.* http://marketing.about.com/od/

Li, W., Liu, K., Belitski, M., Ghobadian, A., & O'Regan, N. (2016). E-Leadership through Strategic Alignment: An Empirical Study of Small- and Medium-sized Enterprises in the Digital Age: *Journal of Information Technology*, *31*(2), 185–206. https://doi.org/10.1057/JIT.2016.10

Martins, D., Martins, D., Fonseca, L., Ávila, P., & Bastos, J. (2021). Lean practices adoption in the Portuguese industry. *Journal of Industrial Engineering and Management*, *14*(2), 345–359. https://doi.org/10.3926/jiem.3291

Martins, M., Godina, R., Pimentel, C., Silva, F. J. G., Matias, J. C. O. (2018). A Practical Study of the Application of SMED to Electron-beam Machining in Automotive Industry. Procedia Manufacturing, 17, 647-654. https://doi.org/ 10.1016/j.promfg.2018.10.113

MECHANICAL E-NOTES. (2017). *Epicyclic Gearbox: Components, Working Principle, Advantages, Disadvantages, and Applications [PDF]*. https://mechanicalenotes.com/epicyclic-gearbox/

Moeuf, A., Pellerin, R., Lamouri, S., Tamayo-Giraldo, S., & Barbaray, R. (2017). The industrial management of SMEs in the era of Industry 4.0. *International Journal of Production Research*, *56*(3), 1118–1136. https://doi.org/10.1080/00207543.2017.1372647

Moktadir, M. A., Ahmed, S., Tuj Zohra, F., & Sultana, R. (2017). Productivity Improvement by Work Study Technique: A Case on Leather Products Industry of Bangladesh. *Industrial Engineering & Management*, *06*(01). https://doi.org/10.4172/2169-0316.1000207

Moreira, A. A., Silva, F. J. G., Correia, A. I., Pereira, T., Ferreira, L. P., de Almeida, F. (2018). Cost reduction and quality improvements in the printing industry. Procedia Manufacturing, 17, 623-630. https://doi.org/10.1016/j.promfg.2018.10.107

mountz. (2019). *ISO 6789 and Torque Wrench Calibration: Establishing a Standard Calibration Regimen*. https://blog.mountztorque.com/iso-6789-and-torque-wrench-calibration-establishing-a-standard-calibration-regimen-slp/

Mulugeta, L. (2021). Productivity improvement through lean manufacturing tools in Ethiopian garment manufacturing company. *Materials Today: Proceedings*, *37*(Part 2), 1432–1436. https://doi.org/10.1016/J.MATPR.2020.06.599

Naik, S. B., & Kallurkar, S. (2016). A LITERATURE REVIEW ON EFFICIENT PLANT LAYOUT DESIGN. *INTERNATIONAL JOURNAL OF INDUSTRIAL ENGINEERING RESEARCH AND DEVELOPMENT*, *7*(2). https://doi.org/10.34218/ijierd.7.2.2016.005

Nakamura, K., Kaihatsu, S., & Yagi, T. (2019). Productivity improvement and economic growth: lessons from Japan. *Economic Analysis and Policy*, *62*, 57–79.

https://doi.org/10.1016/J.EAP.2018.11.002

Neves, P., Silva, F. J. G., Ferreira, L. P., Pereira, M. T., Gouveia, A., Pimentel, C. (2018). Implementing Lean Tools in the Manufacturing Process of Trimmings Products, Procedia Manufacturing, 17, 696-704. https://doi.org/10.1016/j.promfg.2018.10.119

Ogushi, K. (2020). The testing evaluation of several digital torque wrenches by using a torque wrench tester. *ACTA IMEKO*, *9*(5), 189–193. https://acta.imeko.org/index.php/acta-imeko/article/view/IMEKO-ACTA-09 %282020%29-05-40

Oluyisola, O. E., Bhalla, S., Sgarbossa, F., & Strandhagen, J. O. (2021). Designing and developing smart production planning and control systems in the industry 4.0 era: a methodology and case study. *Journal of Intelligent Manufacturing 2021*, 1–22. https://doi.org/10.1007/S10845-021-01808-W

Pablo, J., Cadavid, U., Lamouri, Samir, Grabot, Bernard, Pellerin, Robert, & Fortin, A. (2020). *Machine learning applied in production planning and control: a state-of-the-art in the era of industry 4.0*. https://doi.org/10.1007/s10845-019-01531-7

Pinto, B., Silva, F. J. G., Costa, T., Campilho, R. D. S. G., Pereira, M. T. (2019). A Strategic Model to take the First Step Towards Industry 4.0 in SMEs. Procedia Manufacturing, 38, 637-645. https://doi.org/10.1016/j.promfg.2020.01.082

Pinto, G., Silva, F. J. G., Fernandes, N. O., Casais, R. B., Baptista, A., Carvalho, C. (2020). Implementing a maintenance strategic plan using TPM methodology. International Journal of Industrial Engineering and Management, 12(3), 192-204. http://doi.org/10.24867/IJIEM-2020-3-264

Pişec, I. F., & Pop, A. (2018). Contribution for increasing the manufacturing companies productivity using a tracking and planning production program. *MATEC Web of Conferences*, *184*, 03006. https://doi.org/10.1051/MATECCONF/201818403006

Prajapat, N., Waller, T., Young, J., & Tiwari, A. (2016). Layout Optimization of a Repair Facility Using Discrete Event Simulation. *Procedia CIRP*, *56*, 574–579. https://doi.org/10.1016/j.procir.2016.10.113

Priyaadarshini, R. G., Kumar, V. R. S., & Rajlakshmi, S. A. (2018). Study on lean thinking among MSMEs in the Machine tool sector in India. *IOP Conference Series: Materials Science and Engineering*, *310*(1), 012091. https://doi.org/10.1088/1757-899X/310/1/012091

Rosa, C., Silva, F. J. G., Ferreira, L. P. (2017). Improving the quality and productivity of steel wire-rope assembly lines for the automotive industry. Procedia Manufacturing, 11, 1035-1042. https://doi.org/ 10.1016/j.promfg.2017.07.214

Rosa, C., Silva, F. J. G., Ferreira, L. P., Campilho, R. (2017). SMED methodology: The reduction of setup times for Steel Wire-Rope assembly lines in the automotive industry. Procedia Manufacturing, 13, 1034-1042. https://doi.org/10.1016/j.promfg.2017.09.110

Rosa, C., Silva, F. J. G., Ferreira, L. P., Pereira, M. T., Gouveia, R. (2018). Establishing Standard Methodologies To Improve The Production Rate Of Assembly Lines Used For Low Added-Value Products. Procedia Manufacturing, 17, 555-562. https://doi.org/10.1016/j.promfg.2018.10.096

Saad, S. M., Bahadori, R., Jafarnejad, H., & Putra, M. F. (2021). Smart Production Planning and Control: Technology Readiness Assessment. *Procedia Computer Science*, *180*, 618–627. https://doi.org/10.1016/J.PROCS.2021.01.284

Shojaei, M., Ahmadi, A., & Shojaei, P. (2019). Implementation productivity management cycle with operational Kaizen approach to improve production performance (Case study: Pars Khodro company). *International Journal for Quality Research*, *13*(2), 349–359. https://doi.org/10.24874/IJQR13.02-07

Shukla, H. M. (2018). Implementation of Kaizen and 5S in Plastic Pipe Manufacturing Unit. *International Journal of Applied Science and Engineering*, *6*(1). https://doi.org/10.30954/2322-0465.1.2018.2

Silva, F. J. G., Ferreira, L. P. (2019). Lean Manufacturing: Implementation, Opportunities and Challenges. Nova Science, NY, USA. ISBN: 978-1536157253.

Silva, J., Silva, F. J. G., Campilho, R. D. S. G., Sá, J. C., Ferreira, L. P. (2021). A model for productivity improvement on machining of components for stamping dies. International Journal of Industrial Engineering and Management, 12(2), 1-17. https://doi.org/10.24867/IJIEM-2021-2-279

Sivaraman, P., Nithyanandhan, T., Lakshminarasimhan, S., Manikandan, S., & Saifudheen, M. (2020). Productivity enhancement in engine assembly using lean tools and techniques. *Materials Today: Proceedings*, *33*, 201–207. https://doi.org/10.1016/J.MATPR.2020.04.010

Sniehotta, P. (2017). *PNEUMATIC WRENCH GEARBOX DEVELOPMENT FOR TIGHTENING TORQUE OF 6000 NM*.

Soltanali, H., Khojastehpour, M., & Torres Farinha, J. (2021). Measuring the production performance indicators for food processing industry. *Measurement: Journal of the International Measurement Confederation*, *173*(August 2020). https://doi.org/10.1016/j.measurement.2020.108394

Sousa, E., Silva, F. J. G., Ferreira, L. P., Pereira, M. T., Gouveia, R. M., Silva, R. P. (2018). Applying SMED methodology in cork stoppers production. Procedia Manufacturing, 17, 611-622. https://doi.org/10.1016/j.promfg.2018.10.103

Steenkamp, L. P., Hagedorn-Hansen, D., & Oosthuizen, G. A. (2017). Visual Management System to Manage Manufacturing Resources. *Procedia Manufacturing*, *8*, 455–462. https://doi.org/10.1016/J.PROMFG.2017.02.058

Suhardi, B., Juwita, E., & Astuti, R. D. (2019). Facility layout improvement in sewing department with Systematic Layout planning and ergonomics approach. *Cogent Engineering*, *6*(1). https://doi.org/10.1080/23311916.2019.1597412

Sundar, R., Balaji, A. N., & Satheesh Kumar, R. M. (2014). A review on lean manufacturing implementation techniques. *Procedia Engineering*, *97*, 1875–1885. https://doi.org/10.1016/j.proeng.2014.12.341

Tayal, A., & Singh Kalsi, N. (2021). Review on effectiveness improvement by application of the lean tool in an industry. *Materials Today: Proceedings*, *43*, 1983–1991. https://doi.org/10.1016/J.MATPR.2020.11.431

ur Rehman, A., Ramzan, M. B., Shafiq, M., Rasheed, A., Naeem, M. S., & Savino, M. M. (2019). Productivity Improvement Through Time Study Approach: A Case Study from an Apparel Manufacturing Industry of Pakistan. *Procedia Manufacturing*, *39*, 1447–1454. https://doi.org/10.1016/J.PROMFG.2020.01.306

Usuga Cadavid, J. P., Lamouri, S., Grabot, B., & Fortin, A. (2019). Machine learning in production planning and control: A review of empirical literature. *IFAC-PapersOnLine*, *52*(13), 385–390. https://doi.org/10.1016/j.ifacol.2019.11.155

Vieira, J., Deschamps, F., & Deivid Valle, P. (2021). *Advanced Planning and Scheduling (APS) Systems: a Systematic Literature Review*.

Vukelic, G., Vizentin, G., & Masar, A. (2019). Hydraulic torque wrench adapter failure analysis. *Engineering Failure Analysis*, *96*, 530–537. https://doi.org/10.1016/J.ENGFAILANAL.2018.11.010

Weber, M.-A., Jeske, T., Lennings, F., & Stowasser, S. (2017). Framework for the Systematical Design of Productivity Strategies. *Advances in Intelligent Systems and Computing*, *606*, 141–152. https://doi.org/10.1007/978-3-319-60474-9_13

Xu, J., Zhao, Y., & Chen, K. (2020). Development of a High-precision Digital Display Torque Wrench. *Journal of Physics: Conference Series*, *1626*(1), 012138. https://doi.org/10.1088/1742-6596/1626/1/012138

Yemane, A., Gebremicheal, G., Meraha, T., & Hailemicheal, M. (2020, March 1). *Productivity Improvement through Line Balancing by Using Simulation Modeling*. Journal of Optimization in Industrial Engineering; QIAU. https://doi.org/10.22094/JOIE.2019.567816.1565

Zarbo, R. J., Varney, R. C., Copeland, J. R., D'Angelo, R., & Sharma, G. (2015). Daily management system of the Henry Ford production system: QTIPS to Focus Continuous Improvements at the Level of the Work. *American Journal of Clinical Pathology*, *144*(1), 122–136. https://doi.org/10.1309/AJCPLQYMOFWU31CK

ANNEXES

7 ANNEXES

The following annexes are attached to this work:

- **Table with WPTCs per week**
- **Tabel with unitary PTs of the tools**
- **Order 2021/40721**
- **Order 2021/40733**
- **Form for registration of produced tools**
- **Form for registration of produced services**