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Project

Master’s Degree of Mechanical Engineering – Industrial Production

Application of LEAN methodology to support projects improvements in a die casting industry

Liliana Marina Ferreira de Sousa

Leiria, *September of 2014*

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Project of Master's Degree performed by orientation of Doctor Irene Sofia Carvalho Ferreira, Professor of Superior School of Technology and Management of Institute Polytechnic of Leiria in Portugal and Doctor Rainer Schillig, Professor of the University of Aalen in Germany.

Leiria, *September of 2014*

"It is not the strongest nor the most intelligent of the species that survives, but the one that is most adaptable to change."

Charles Darwin

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Abstract

The main goal of this project is to define waste, measure and eliminate it, inherent to the production of aluminium die casting parts on the company *Schüle Druckguss* in Germany. In order to eliminate waste, a set of improvement projects were carried out focusing on the production in the different halls of the company. For that purpose, Lean thinking and tools were used as supporting methodology. It is important to highlight that these projects include issues like the organization of the workplace, the optimization of the workload for the worker, programing transport routes and minimize inventory of raw material and finish goods.

Towards to achieve the previous goals, it was necessary to observe operations and procedures, measure time, detect bottlenecks or critical tasks and test different scenarios, aiming to reduce the most wasteful activities. Referring to the workplace organization, the solution achieved consists on the application of a colored marking system on the floor to define the transport way and the place for the material.

Regarding the workload of the worker, it was optimized given the worker, in the new procedure, more tasks, mostly due to the introduction of automation of controlling process. About the routes for the truck coming from the daughter company in Slovakia, it was changed and some wasteful activities reduced, obtaining a minimization of 15% of the time spent on these activities per day. Note that human and material resources were also saved with the new proposal.

Furthermore, the necessary quantity of inventory referent to one product was calculated the economic quantity order and minimized costs in 34%. For the finish goods it was proposed a new layout for the boxes, in order to be transported more quantities, according with customers 'demand. Finally, it was studied a product and its variations, that is die casted on the daughter company in Slovakia and machined in Germany, in order to change its production to a continuous line in Germany. Thus, it was included on the Die Casting Island (DCI), three external processes, minimizing the time in transportation and using fewer workers than the actual situation.

The current project is focused on continuous improvement, providing a low cost approach and performs the main goal which is to achieve the best practices within the organization.

Key-Words: Lean thinking, VSM, die casting, autonomation, logistic.

Resumo

O principal objectivo deste projeto é definir desperdícios, medir e eliminá-los, de acordo com a produção de peças de alumínio fundidas na empresa *Schüle Druckguss*, na Alemanha. No âmbito de eliminar desperdícios, um conjunto de projetos de melhoria foram realizados com foco na produção nos diferentes pavilhões da empresa. Neste sentido, o pensamento e ferramentas Lean foram usadas como metodologia de suporte. É importante salientar que estes projectos incluem temáticas como a organização do espaço de trabalho, optimização da carga laboral para o trabalhador, programação da rota nos transportes e minimização do inventário de matéria-prima e produto acabado.

No sentido de alcançar os objetivos propostos, foi necessário observar operações e procedimentos, fazer medições de tempo, detectar alvos ou tarefas criticas e testar diferentes cenários, de forma a reduzir as atividades responsáveis pela maioria do desperdício. Relativamente á organização do espaço de trabalho, a solução encontrada corresponde á aplicação de marcas no chão para definir a zona de transporte e o local destinado ao material.

Relativamente á carga laboral do trabalhador, foi optimizada atribuindo ao trabalhador, num novo procedimento, mais tarefas, maioritariamente devido á implementação de um processo automático de controlo da peça. Em relação á rota do camião que transporta o material da Eslováquia para a Alemanha, foi alterada e algumas actividades que geram desperdício reduzidas, obtendo uma diminuição de 15% do tempo de actividades do camião por dia. É de salientar que os recursos humanos e materiais foram também reduzidos, considerando a implementação da melhoria.

No que se refere á quantidade de inventário necessária para um produto, foi calculada a quantidade económica de encomenda e diminuídos os custos em 34%. Para o produto acabado foi sugerido um formato de caixa para que pudesse ser transportada mais quantidade, de acordo com a procura do cliente. Finalmente, foi estudado um produto e as suas variantes, que são fundidos na empresa filial na Eslováquia e maquinados na Alemanha, pretendendo alterar a sua produção para uma linha contínua na Alemanha. Assim, foram incluídas na ilha de fundição três processos externos, diminuindo tempos de transporte e seriam necessários menos trabalhadores, em relação á situação actual.

O presente projeto realça a melhoria contínua, proporcionando abordagens de baixo custo e atinge o objectivo principal que é aplicar as melhores práticas na empresa.

Palavras-chave: pensamento Lean,VSM, fundição,automatização,logistica.

Übersicht

Das Hauptziel dieses Projektes ist es Verschwendung, bei der internen Produktion von Aluminium-Druckgussteilen beim Unternehmen Schüle Druckguss in Deutschland zu definieren, sie zu messen und zu eliminieren. Um Verschwendung zu beseitigen wurde eine Reihe Optimierungsprojekte durchgeführt, die den Fokus auf die Produktion in den verschiedenen Hallen legen. Für diesen Zweck wurden der "Lean" Gedanke und seine Werkzeuge als Methoden verwendet. Wichtig ist hinzuzufügen dass, diese Projekte einschließlich Themen, wie Organisation des Arbeitsplatzes, Optimierung der Arbeitsschritte des Mitarbeiters, Entwurf der Transportwege und Reduzierung der Bestände für Roh- und Fertigteile umfassen.

Um, die obengenannten Ziele zu erreichen, war es notwendig Abläufe zu beobachten, die Zeiten aufnehmen, kritische Prozesse bzw. Bottlenecks zu finden, verschiedene Optimierungsszenarien zu testen mit dem Ziel Aktivitäten mit Verschwendung zu beseitigen. Bezüglich der Arbeitsplatzorganisation, beruht die Lösung in Anwendung eines Farbmarkierungssystems, um die Transportwege und Stellflächen für das Material zu definieren.

Angesichts der Optimierung der Auslastung des Maschinenbedieners ist dieser nun in der Lage, durch Verschiebung der visuellen Prüfung in die automatisierte Fertigungszelle, flexibler in der Bedienung mehrerer Fertigungszellen zu sein. Bezüglich des neuen Fahrroute des LKWs vom Tochterunternehmen Schüle Slovakia konnten nicht – werthaltige Aktivitäten gesenkt werden und somit eine Zeiteinsparung von 15% erreicht werden. Zusätzlich konnte Arbeitsaufwand und Ressourcen eingespart werden.

Außerdem wurde die optimale Höhe der Bestände eines Produkttyps berechnet und diese ergaben eine Kostenreduzierung von 34%. Schließlich ergab die Untersuchung bestimmter Produkttypen, die in der Slowakei gegossen und in Deutschland bearbeitet werden, an einem Ort zu einem geschlossenen Prozess zu verbinden. Somit wurde auf der Druckguss Island, drei externe Prozesse, die Minimierung der Zeit im Transport und Verwendung von weniger Arbeitskräfte als die tatsächliche Situation enthalten.

Dieses Projekt unterstreicht die kontinuierliche Verbesserung, die eine niedrige Kostenansatz und erreicht das primäre Ziel ist, die besten Praktiken in der Gesellschaft gelten.

Stichworte: Lean Denken, VSM, Druckguss, Automatisierung, Logistik.

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List of Acronyms

CT – Cycle Time

D – Demand

DCI –Die Casting Island

DCM – Die Casting Machine

EOQ – Economic Order Quantity

FIFO – First In, First Out

FG – Finish Goods

FW – Foundry Worker

GB – Grid Boxes

HC – Handling Costs

JIT – Just In Time

LLC – Large Load Carrier

LT – Lead Time

LW – Logistic Worker

MGL – Machine Group Leader

NVA – Non-Value Added

O – Operator

PDCA – Plan-Do-Check-Act

PL – Production Line

PM – Process Manager

PT – Process Time

QCD – Quality-Cost-Delivery

RA – Raw Aluminum

RM – Recycled Material

RC – Reorder Costs

RP – Raw Part

SDG – *Schüle Druckguss GmH*

SP – Storage Place

SSK – *Schüle* Slovakia

SLC – Small Load Carrier

SMGL – Sub Machine-Group Leader

TL – Team Leader

TPM – Total Productive Maintenance

TPS – Toyota Production System

TQC – Total Quality Control

TT – Transport Time

USA – United States of America

VA – Value Added

VSM – Value Stream Mapping

WH – Warehouse

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1. Introduction

1.1 Framework and goals

"The most important factors for success are patience, a focus on long-term rather than short-term results, reinvestment in people, product, and plant, and an unforgiving commitment to quality." – Robert B. McCurry, former Executive V.P., Toyota Motor Sales (Liker, 2004).

The excerpt aforementioned refers to the first of fourteen principles that make "The Toyota Way", an ideology that have been capture the attention of organizations. The concept Toyota Production System (TPS) was born in Japan in 1940 as a philosophy established by Taiichi Ohno, the second President of Toyota Motor Corporation. This philosophy is based on tools, technics and continuous improvement, with the golden rule of eliminating waste (Liker, 2004) (Toyota).

Companies are seeking for a competitive advantage through its competitors. The market is thorough of offers and the goal is to achieve the best practices to provide exactly what the customer wants: the best product quality in the right time and amount, with the lower price.

Schüle Druckguss GmbH (SDG) is a provider of pre-finished die casted parts for automotive industry, pneumatic systems and gas heating markets. The company is continuously improving its performance focused on providing the best solutions for the customer and cost efficient production.

The definition of waste is based on the activities which create value or do not create value for the customer. Therefore, the focus is on reducing and eliminating these non-value added activities, responsible for high lead times, leading to a successful organization.

Throughout the present study, the main goal is to eliminate waste inherent to the production, upgrade the workload for the workers, improve the material flow and optimize the amount of inventory. Furthermore, the logistic of transports will be mentioned, including truck organization and routes. Besides, there are studied the possibilities of change one production that is divided by transport and inventory, in a continuous line procedure.

Therefore, it is necessary to collect data and analyze it, in order to get results with the aim of optimize the work, always leading to waste elimination.

On course to achieve improvements, it is indispensable to use features based on Toyota Production System (TPS), such as 5S's, and Value Stream Mapping (VSM). The Lean thinking will be the light motif of this study, in order to look for the details of the work and upgrade it.

1.2 Contents of the study

Chapter one introduces the purpose of this project, as well as the main goals and methodology applied. On chapter two can be found the state of the art relative to Lean production and described its tools that will be used along this project. The case of study will be presented on chapter three, including the definition of the problematic on the distinct topics of this project.

Furthermore, on chapter four, there are represented the projects improvements and the tools of Lean methodology applied on the course to achieve results. Considering the results, the forecasts are expressed, in order to obtain profits.

Finally, on chapter five is represented a brief conclusion of the results obtained on the previous chapter as well as suggestion for future projects to be implemented on the company.

2. State of the art

Currently, the competitiveness between organizations is high, as well as the manufacturing exigencies imposed by their customers. Therefore, in order to meet customers' requirements, companies seek for high quality products, with low cost resources and efficiently procedures.

Lean philosophy intents to achieve the best practices into the organization, as improving workplaces, methodologies and implementing systems in order to support the worker and continuous improvement of internal operations. Hereby, the number of organizations that use Lean methodology is increasing over the time, registering in Europe an adherence higher than 50% in 2008 (ACE, 2008).

2.1 Theoretical Approach

In 1891, the Japanese Sakichi Toyoda invented a wood handloom and improved it for some years, achieving the creation of an automatic power loom (Toyota, 2002). Furthermore his invention had a system that stopped the power loom whether there was an error. This system is known as *Jidoka*, the Japanese term that means "building in quality". Throughout his creation he founded a textile company named Toyoda Automatic Loom Works. Afterwards emerged an interest on automobile industry, and he and his son, Kiichiro Toyoda, went in United States of America (USA) to study Fords' production (Liker, 2004).

In USA, Henry Ford was pioneer of the "flow production", making a sequence of processes with an assembly line in the end of the production, which later was called mass production (Institute, 2009). Subsequently to the World War I, this manufacturer system controlled the automobile industry, by producing big and standardized batches of products (Womack, et al., 1990).

Following the technologic growing, Kiichiro Toyoda sold the patent of the power looms and invested on the foundation of Toyota Motor Corporation, in 1930. Within the feedback from USA, he realized that on the supermarkets there was used a reposition system according with customer's purchase. Therefore he created the Just-in-time (JIT) principle that consists on supply the right amount exactly when it is required (Liker, 2004).

After the World War II, his successor, Eiji Toyoda, together with Taiichi Ohno, who was graduated in mechanical engineering, realized that the concept of mass production used in USA was not applicable to Japans' economic situation (Womack, et al., 1990). Furthermore, the challenge of produce cheap and more different cars with high quality showed up (Liker, 2004).

Taiicho Ohno was qualified as assessment chief of Toyota, creating the Toyota Production System (TPS), a philosophy based on two pillars abovementioned: *Jidoka* and JIT. In contrast with Fords' manufacturing system, where it was normal to repair defective products, Ohnos' rules consisted on immobilizing the production and finding the origin of the problem. Introducing this technique to the manufacturing system, it was noticed the reduction of failures and the company was worldwide considered as the one with less car defects (Womack, et al., 1990).

Toyota was known as the best worldwide automobile seller and it becomes a philosophy used by several companies around the world, not just in manufacturing but also in logistic and other areas (Institute, 2009). In fact, it has been recognized that TPS is a cheap way to improve business, with a creative mind and a focus on waste elimination.

2.2 Lean Philosophy

Toyota Motor Corporation is known for being a family business leaded within the TPS philosophy. This philosophy implies to get the hands dirty, think with an innovative mind and focus on societies' contribution (Liker, 2004). On this environment, the term Lean was emerged, by the researcher John Krafcik, since this system, in comparison with mass production, looks for the utilization of fewer resources (Womack, et al., 1990).

The major goal of Lean philosophy is to short the time from the demand of the customer to the delivery of the product or service, which is called "lead time". Regarding this concept, there is also included on Lean terms the *takt* time concept. It represents the amount of time that must be elapse between two consecutive unit completions in order to meet the demand, taking into account the net time available to work. Therefore, the *takt* time needs to be respected and reduced, in order to get more profits (iSixSigma, 2014).

With the aim of waste elimination and best quality product achievement, Lean methodology encloses a set of tools and techniques. Within this concept, it is possible to observe on figure 1 the contents of the house of TPS (Systems2win, 2003).

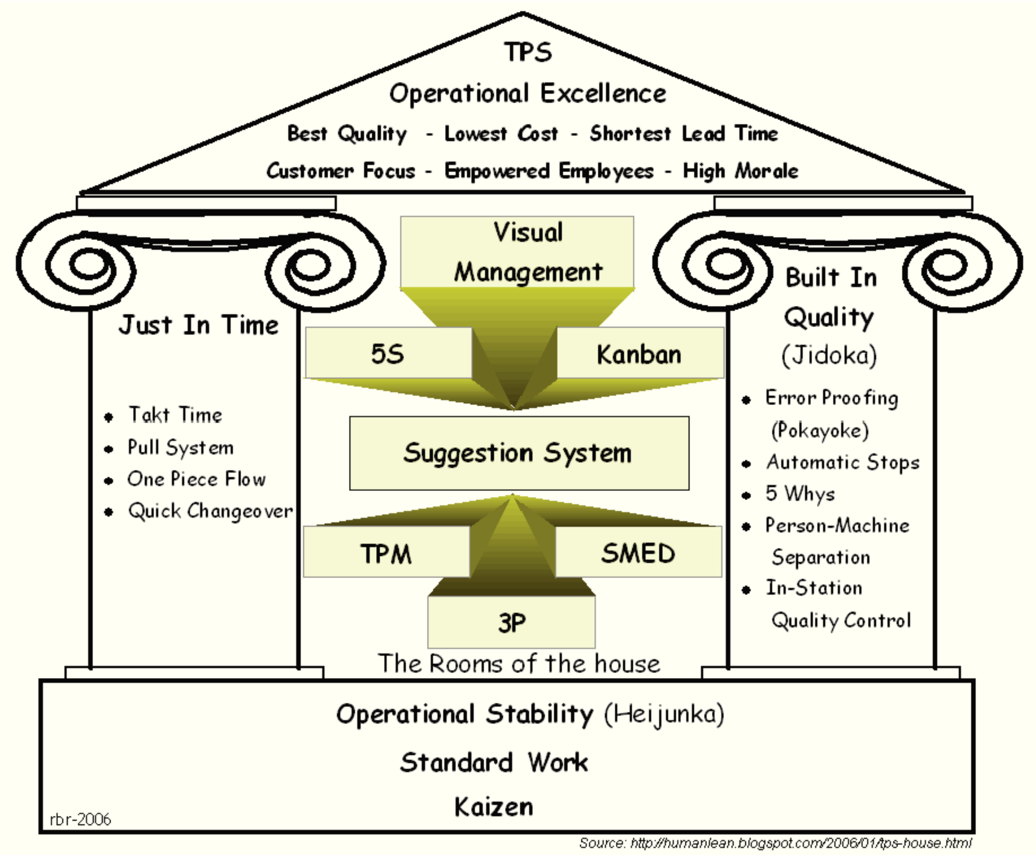

Figure 1 - House of Toyota Production System (Systems2win, 2003).

The TPS house structure represented on figure 1 has an import interpretation, considering *Kaizen*, standard work and *Heijunka* as the basis of the house. The two pillars of the house are the Just-In-Time (JIT) and *Jidoka* philosophies, both created within Toyodas' family by Kiichiro Toyoda and Sakichi Toyoda (Liker, 2004).

Heijunka is a Japanese term for "levelization", which on this context refers to "level out the production". In other words, this principle advocates the reduction of quantity and variety of products that are kept in inventory instead of correspond to customer's request. This principle grounds the pull systems that will be referred forward on this chapter (Liker, 2004) (Shook, et al., 2014).

Concerning the order of the customer, JIT principle intends that the right product has to be delivered in the correct amount, on the exact required time. In order to reach this goal, it is necessary to plan the *takt* time to complete a product according with its order, create pull systems, quick changeover times and continuous flow, using one-piece-flow principle (Liker, 2004).

Towards to the second pillar of TPS House, *Jidoka* is the principle of stop the production while a problem occurs, raising the quality of the product. The techniques used are based on mistake-proof systems like *Poka-Yoke*, *andon*, and problem-solving systems, such as “5 Whys” and Plan-Do-Check-Act (PDCA) cycle (Liker, 2004).

A continuous improvement methodology intents to highlight some aspects as human efforts, communication, team work and others, to achieve long term benefits to the organization. Therefore, it involves the whole members of an organization, from the top managers to the operators, including suppliers (Imai, 1997).

Known as a “low-cost approach to improvement”, *Kaizen*, the Japanese term for “continuous improvement”, requires going in *Gemba*, which means “real place” in Japanese. The approach of “go to *Gemba* first” seeks to identify the root cause of the problem, by asking “Why” five times. While the origin of the problem is found and countermeasures are applied, the next step for innovation is testing to standardize. Figure 2 shows the innovation in quality of a product/process over the time, comparing situations with and without *Kaizen* methodology (Imai, 1997).

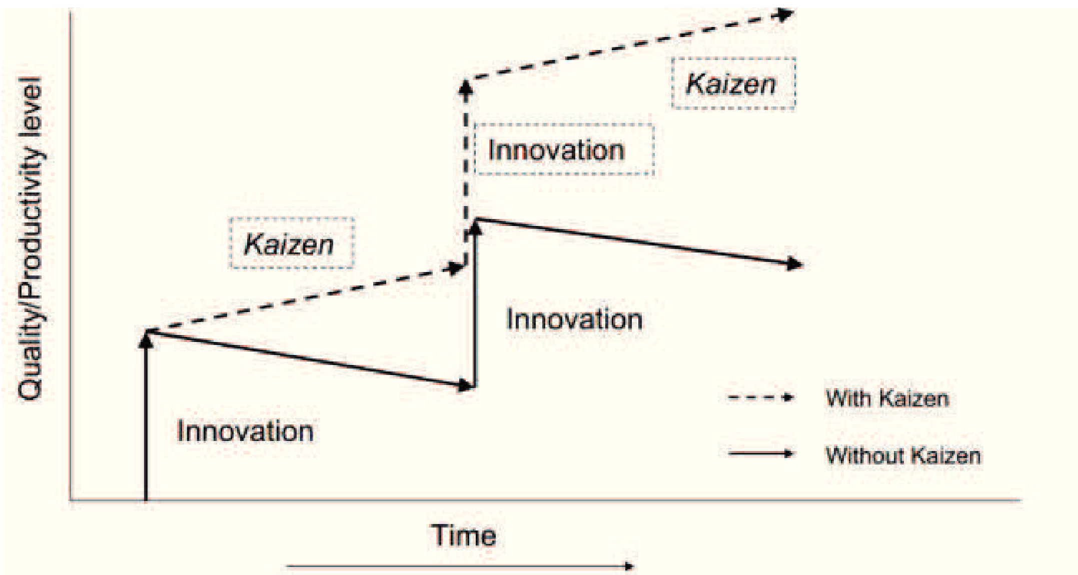

Figure 2 - Innovation deployment over the time, with and without *Kaizen* (Gumelar, 2013).

As a main strategy, *Kaizen* focuses on Quality-Cost-Delivery (QCD), assigning the same level of significance to all of them. QCD priority is the satisfaction of the customer, where quality refers not only to the product, but process; the cost is considered from the design until the service hereafter the sold good; and the delivery of the finish good has to be on the exact quantity in the right time (Imai, 1997).

2.3 DEFINITION OF WASTE

Waste or *Muda*, in Japanese, is everything that doesn't create value for the customer, instead it consumes resources (Womack, et al., 1996). As value-added activities is intent everything that the customer pays for, then the remaining events are considered non-value-added or waste (Williams, et al., 2012). Therefore it is fundamental to define value on the early phase of a project, thereby the waste is easily detected and bottlenecks can be found.

The general description of waste (*Muda)* can also be completed with *Muri* and *Mura. Muri* (Overburdened) is classified as strenuous, which is a task or a process that overload the resources available, leading it to a limit. The variability in quality, cost or delivery is known by *Mura* (Unevenness) (Williams, et al., 2012) (Imai, 1997). These three ways of waste constitute a system, the three M's, represented on figure 3.

Figure 3 - Three M's for wasteful activities, according to Lean methodology (Liker, 2004).

Taiichi Ohno defined seven types of *Muda*, eminent to the production, as the following (Harry, et al., 2010) (Manufactus, 2014) (Imai, 1997):

1. **Overproduction**

Whether there is production without order, it implies use of resources without being needed, consequently raises the inventory and transport of goods. Besides these two last aspects, excessive production causes the other types of waste mentioned bellow.

2. **Waiting**

Waiting is an evident cause of waste, while a worker or equipment is stopped it is not creating any value, instead is wasting time that could be productive. Consequently it causes delays on processes and mitigates the lucrativeness of a product.

3. **Transport**

Carrying products for long distances or do not planning transport routes, generates long lead time, and requires more human and material resources.

4. **Over-processing or incorrect process**

In case that a process provides a better quality or extra activities that are not requested, it is wasting resources unnecessarily. On the other hand if a project design is not well-planed, concerning the right steps and tools, it will cause a weak production.

5. **Excess of inventory**

It is considered waste a large amount of products stored without a plan or reason. Excess of inventory is a way to hide problems, like quality defects, and requires more resources as well as logistic work, transport and storage space. Furthermore, the product quality decreases over the time, so as long as finish goods are stored, and it becomes obsolete while delivered to the customer.

6. **Unnecessary movement**

The motion of a worker as moving things constantly, searching for tools, walking around or checking inventory, consumes time and efforts. This can be a result of unused standards on the workplace or unplanned processes.

7. **Defects**

The customer does not pay for defective products, so every bad part is an obvious waste of resources. Also reworking on a part or verifying it represents a loss of time and efforts.

Afterwards, Womack and Jones (1996) defined the unused employee knowledge as the eighth type of waste. Once that an employee deals continuously with a process, his or her knowledge could bring suggestions for improve it (Liker, 2004).

Commonly, within a process it is possible to determine only 5% of Value Added (VA) activities, considering the other activities as Non-Value Added (NVA), as figure 4 shows.

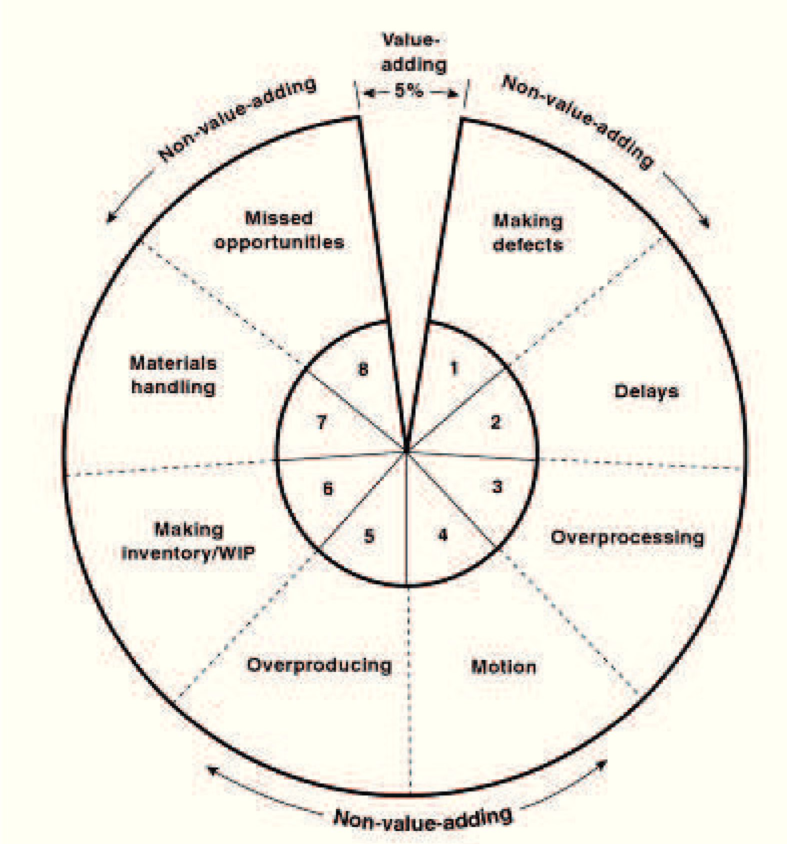

Figure 4 - The eight wastes (Harry, et al., 2010).

2.4 LEAN TOOLS

Over this subchapter, some Lean techniques will be presented. These techniques were used to concretize the proposed improvements exhibited on the course of this project. It is also important to highlight that Lean philosophy was essential to get a commonsense thinking and a continuous improvement approach among the organization.

2.4.1 ONE- PIECE-FLOW PRINCIPLE

Ford manufactured large lot sizes and on his system there were manufactured more than one unit per step, just on the assembly line it was processed one unit at a time. Toyota manufacturing system produces small lot sizes, with the methodology of manufacture one unit per process that flows from one production cell to the other, without middle inventory, also called "buffer". This methodology is called one-piece-flow and is a way to improve quality and eliminate inventory between steps (Liker, 2004).

If a problem emerges on the production line, it has to be solved at the moment and the production stops, so there is no chance that this mistake continues to the next process. Furthermore, it forces workers to solve problems inherent to the production, raising their skills, expertise and motivation to do the job.

A one-piece-flow manufacturing system needs to be design according with the *Takt* time of that product. It means that if the customer demands a unit every minute, every minute a unit has to be ready, regarding the time available for machines and workers (Liker, 2004). Therefore, in contrast with the conventional production that creates inventory, "buffers", there is the one-piece flow production, with a single unit going through a set of processes without waiting times. This comparison is represented on figure 5 (ALD Vacuum Technologies, 2010).

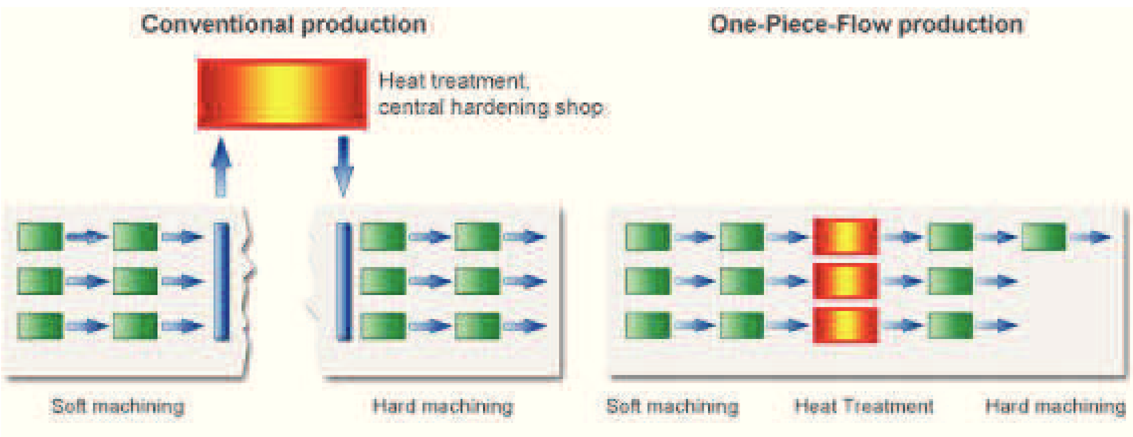

Figure 5 - Conventional production and one-piece-flow production (ALD Vacuum Technologies, 2010).

2.4.2 PULL SYSTEMS

Within Lean philosophy, the production follows the demand of the customer so, it is the customer who decides the quantity of products to be manufactured. This is called "pull production system", once that is the customer who pulls the production and not the opposite. On the other hand, there is the "push production system" that consists in manufacture as much as possible independent on the customer demand, based on forecasts. This situation is a typical approach used in mass production, where there is not a plan for the production and where it is produced as much as possible, which leads to large amounts of inventory (Imai, 1997).

Considering the pull system adopted by Toyota, Taiichi Ohno went further and created a methodology called Kanban that means "sign" (Liker, 2004). Kanban is a visual system, based on real data, for replenishment of products and control of the material flow (Vatalaro, et al., 2003). Therefore, the interchangeability between processes becomes easier, considering that kanban gives the recurrent information about what is needed and in which quantity (Ohno, 1988).

A pull production uses both *kanban* systems: "Conveyance *Kanban*" and "Production *Kanban*". The first term can be also called "Withdrawal *Kanban*", which refers to a card that flows with the items to a process until it is done and after comes back to the previous process to be attached to the next ones. Referring to "Production *Kanban*" or "Signal *Kanban*", it consists in a signal to order recipients with the units needed for the further process, symbolized with a triangle (Sugimori, et al., 1977).

Figure 6 represents an example that uses both *Kanban* systems abovementioned, used on a production, with a buffer of 1,5 days between "Stamping" and "Welding + Assembly". When it is necessary replace the material on the buffer, a signal is sent to the Stamping process for reply to this request (Shook, et al., 2014).

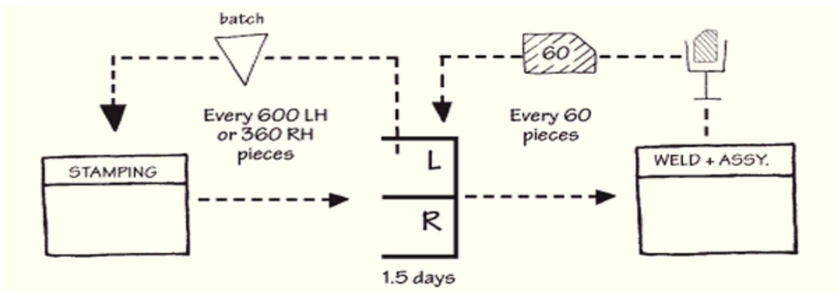

Figure 6 - Example of application of a Signal *Kanban* (triangle) and a Withdrawal *Kanban* (card) (Shook, et al., 2014).

Regarding the pull system methodology, the "First In, First Out" (FIFO) principle collaborates for its optimization, by replacing a unit on a line when another unit, remaining at first on this line, is used. Fundamentally, this principle consists on order items, from the first produced to the last, using first what was produced first, and fill the empty space adding items to the last position. While this principle is applied on inventory, it prevents the degradation and loss of quality of the finish goods by sending to the customer the material with a longer storage time (Shook, et al., 2014).

Figure 7 shows a pull system using FIFO principle. When a lane with material is full, the providing processes should stop until it is required (Shook, et al., 2003).

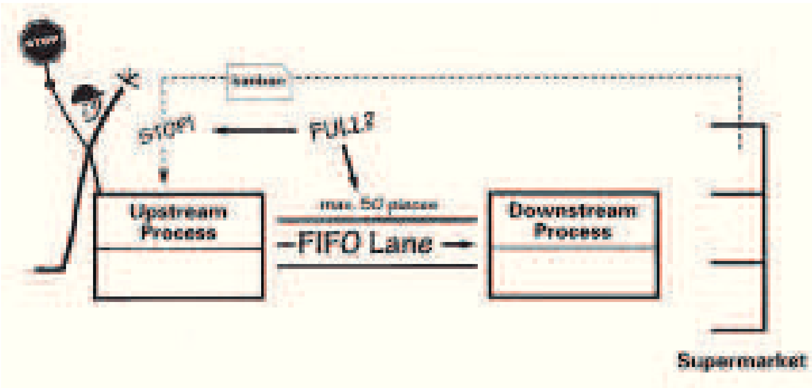

Figure 7 – First-In-First-Out principle (Shook, et al., 2003).

2.4.3 PDCA CYCLE AND STANDARDS

Concerning the way for improvement, there are techniques as Plan-Do-Check-Act (PDCA) cycle, Total Productive Maintenance (TPM) and Total Quality Control (TQC). TQC is a system to identify, control and improve procedures, regarding cost and delivery, but mainly focused on product quality. Nevertheless, there is also the concern about the equipment quality and preventive maintenance, a system called Total Productive Maintenance (TPM), which main focus is improving equipment performance (Imai, 1997).

PDCA is an endless cycle, also named Deming cycle, which starts to establish goals and sketch ways to accomplish it (Plan). Therefore this plan has to be implemented (Do) and its results verified (Check). In conclusion, the project must be prosecuted (Act) and standards created. On figure 8 it is possible to observe the PDCA cycle sustained by standards, following a continuous improvement toward to innovation (Imai, 1997).

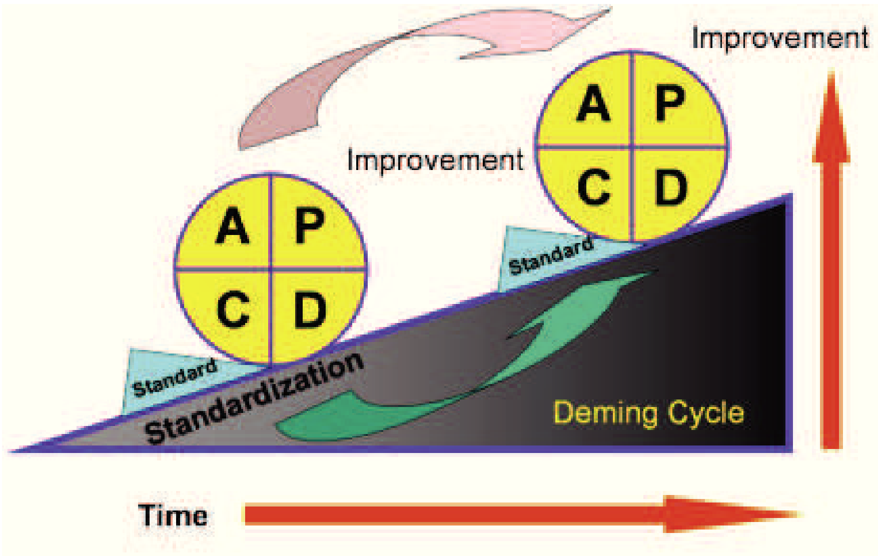

Figure 8 - PDCA or Deming cycle to achieve improvement along the time (Management, 2009).

In respect to continuous improvement, it is necessary to establish standards to maintain the best practices within an organization. Whether there are no standards, deviations from the normal situation occur and the probability of appear defects is higher. Furthermore, if the best practices for a procedure are not standardized, the efforts for improving will be vainly (Liker, 2004).

2.4.4 5S PRINCIPLE

Concerning the importance of a workplace organization and the appliance of a standardized work, the 5S principle supports the achievement of these aspects. This methodology comes from five Japanese words, which definition and order is represented below (Liker, 2004) (Imai, 1997):

1. *Seiri* – Usefulness

The first step is to establish order on the workplace by define the items necessary for a process and keep it in accessible place to be used. The tools, machines, defect parts or other objects that are not needed, should be taken away from the area. The criterion used is if it the item is not required for the further thirty days, then it must be relocated outside the working area.

2. *Seiton* – Orderliness

After selecting only the necessary objects, it is indispensable to label these objects with name and address, and define a correct place for them. Therefore, with the identification and right place for the things, it will make tasks easier and faster, and raise the performance of the work. An example is the application of markings on the floor to define the right place to sort a pallet or a tool box.

3. *Seiso* – Cleanliness

As soon as a workplace is cleaned, it motivates people to work on this environment, is safer to walk around and easier to detect anomalies on the equipment. Considering this, in this stage of 5S's it can be implemented routine procedures to keep the workplace clean.

4. *Seiketsu* – Maintenance

Regarding the three steps abovementioned, it is fundamental to create systems to maintain the good practices established. In order to support this maintenance, it can be used tools as informative papers, check lists, among others, seeking for a high performing organization on the workplace. Nevertheless, without setting standards and commitment from workers, this stage will not be accomplished.

5. *Shitsuke* – Discipline

While the previous steps are applied and the best practices prosecuted, it requires for systematization. For this reason, this last step of 5S's is considered the most difficult to implement taking in account the usual customs of people on the workplace and the resistance to change their routines.

With a focus on the methodology described, there are different ways to support people to achieve the best practices. Figure 9 represents an example of an informative resource to implement 5S principle on the workplace.

Figure 9 - 5S's Principle (Quality foundation, 2008).

2.4.5 PROBLEM SOLVING SYSTEMS

Regarding *Jidoka* pillar, it emerges the concept of "automatic stop" to pause production while a problem appears. Thus, machines are able to detect a problem and transmit this information to the workers so they can solve it quickly (i.e. procedure entitled "automation with a human touch") (Ohno, 1988). Therefore, the root cause of the problem has to be found instead of implement a temporary solution, by applying countermeasures to avoid recurrence (Japan Management Association, 1989).

2.4.5.1 DEFINE ROOT CAUSES

In order to solve a problem it is fundamental to identify it and analyze its inherent data to get hypothesis of its occurrence. Therefore, it is used a Cause-Effect diagram to define probable motifs, ordered by different groups which are connected to each other. These categories are known as the 5M's for Men, Machine, Material, Method and Measures. Considering these groups, it is possible to add another one: "Mother nature", which refers to the environment (Pande, et al., 2000).

Moreover, this tool can either be called fishbone or *Ishikawa* diagram, which allows the whole visualization of the main problem and its hypothetic causes (Lighter, et al., 2000). An example of a fishbone diagram and its correlated categories can be seen on figure 10.

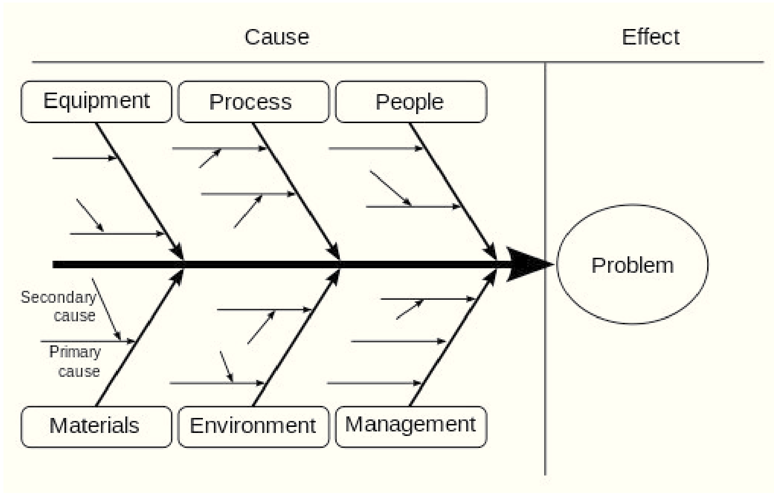

Figure 10 - Fishbone diagram (Comindwork, 2014).

2.4.5.2 DATA ANALYSIS

Hereby, improvement processes requires defining which data should be measured, collecting and analyzing it. There are diverse types of tools used on the analysis of the data, depending on its characteristics and what has to be studied. Pareto Chart is an example of these tools that sorts data in a descending order, contradicting with a crescent curve, and shows that 20% of the causes are originating 80% of the problems. Thus, it can easily be found a bottleneck (Pande, et al., 2000).

It is represented on figure 10 a Pareto Chart of a pizza delivery process, considering that 20% of the reasons, which are “undercooked”, “overcooked” and “not enough topics”, were 80% of the complains of the customer.

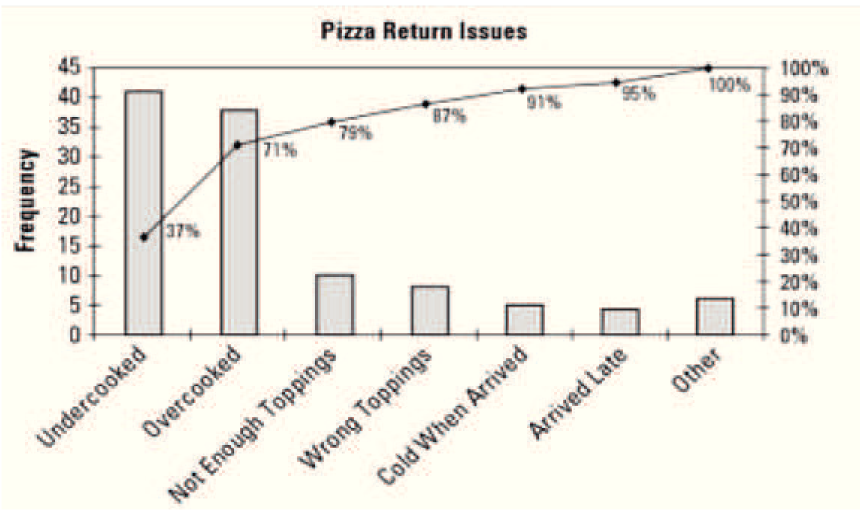

Figure 11 - Pareto Chart (Wallace, et al., 2007).

2.4.5.3 MISTAKE-PROOF SYSTEMS

There are techniques aiming to bring problems to surface and avoid mistakes, such as *Poka-Yoke* and *andon* systems. Considering the principle of interrupting a process whether a problem occurs, it is used the *andon* system, the Japanese word for "lamp". An example to prosecute the *andon* system is the application of light systems on the manufacturing process to warn the worker while there is a problem, by turning the red light on. Therefore the production stops, and it is compulsory that the workers involved on the production solve the abnormality (Japan Management Association, 1989). On figure 12 it is possible to visualize how this procedure works.

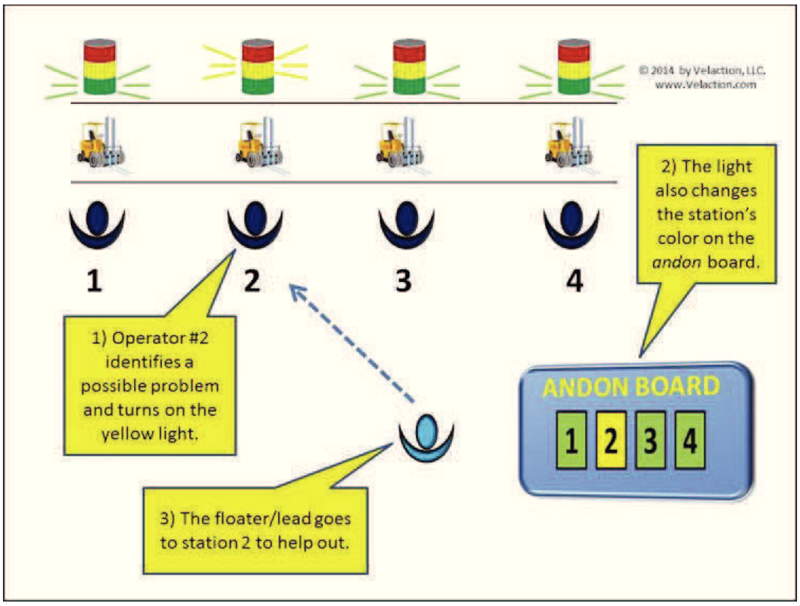

Figure 12 - *Andon* System (Velaction, 2009).

In this case represented on figure 12, the operator 2 find an abnormally and light on the yellow alarm, which give a signal to the *andon* board. Then the group leader knows that has to go in the production station 2 to support on solving the problem.

Toward to solve abnormalities on the work place, the engineer Shigeo Shingo created a tool named *Poka-Yoke* that means "mistake-proofing". Originally, this system was created to assist workers to avoid mistakes. Although, its main goal is to improve quality in all the levels of the production, reducing substantially the appearance of abnormalities (Shimbun, 1988).

As a mistake proofing, this system does not give any chance to make errors. An example is demonstrated bellow on figure 13.

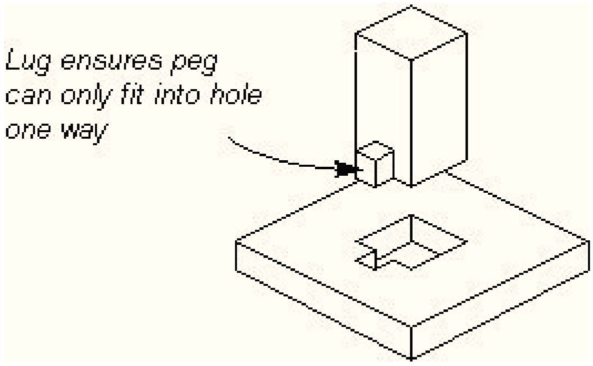

Figure 13 - *Poka-Yoke* System (David Straker, 2002).

2.4.6 VALUE STREAM ANALYSIS

Among other tools used in Lean, Value Stream Mapping (VSM) aims to visualize all the material and information flows, from the demand of the customer to the shipping. Therefore, VSM intends to describe the material flow and showing the waste inherent to the production (Liker, 2004).

VSM was originally used in Toyota with the name of “material and information flows”, which later was placed by James Womack and other authors, as “value stream” (Martin, et al., 2014). This tool can be applied to study the current state in order of waste elimination and future state to see the outcome of the improvements enforced (Nash, et al., 2008).

Before delineating a VSM, the *takt* time has to be calculated, making the relation between the daily number of units required by the customer and the daily available time of production. Equation 1 shows how to calculate the *takt* time (Shook, et al., 2003).

$$Takt\ Time = \frac{\text{available working time per day [seconds]}}{\text{customer demand per day [units]}} \qquad (1)$$

In VSM, each box contains the process and its data, such as Cycle Time (CT), capacity of the process, available time of the machine or worker and other pertinent data that can be added. These boxes are connected by arrows, simulating the movement of the material flow (Liker, 2004). Under each box and arrow, there is a timeline, which contains the respective time that takes for processing one unit and move it to the next step. In the end of the timeline it is represented the “total cycle time” or “Process Time” (PT), the “travel distance” along the process or “Transport Time” (TT), and “Lead Time” (LT) that is the sum of PT and TT (Nash, et al., 2008).

Relative to the drawing of a VSM, it must be used standard symbols to make it universally understandable, as it can be seen on figure 14.

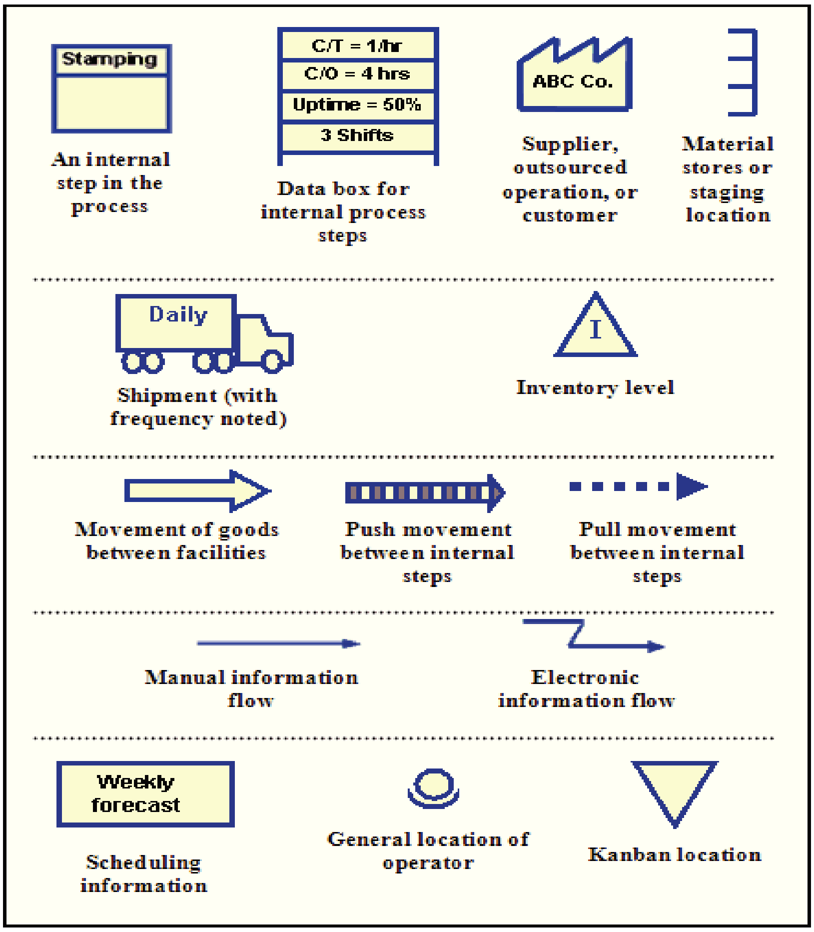

Figure 14 - Value Stream Mapping Symbols (QualityTrainingPortal, 2004).

Regarding the symbols represented above, and based on the data obtained by following products on working area, the next step is to drawn the VSM that can be visualized on figure 15.

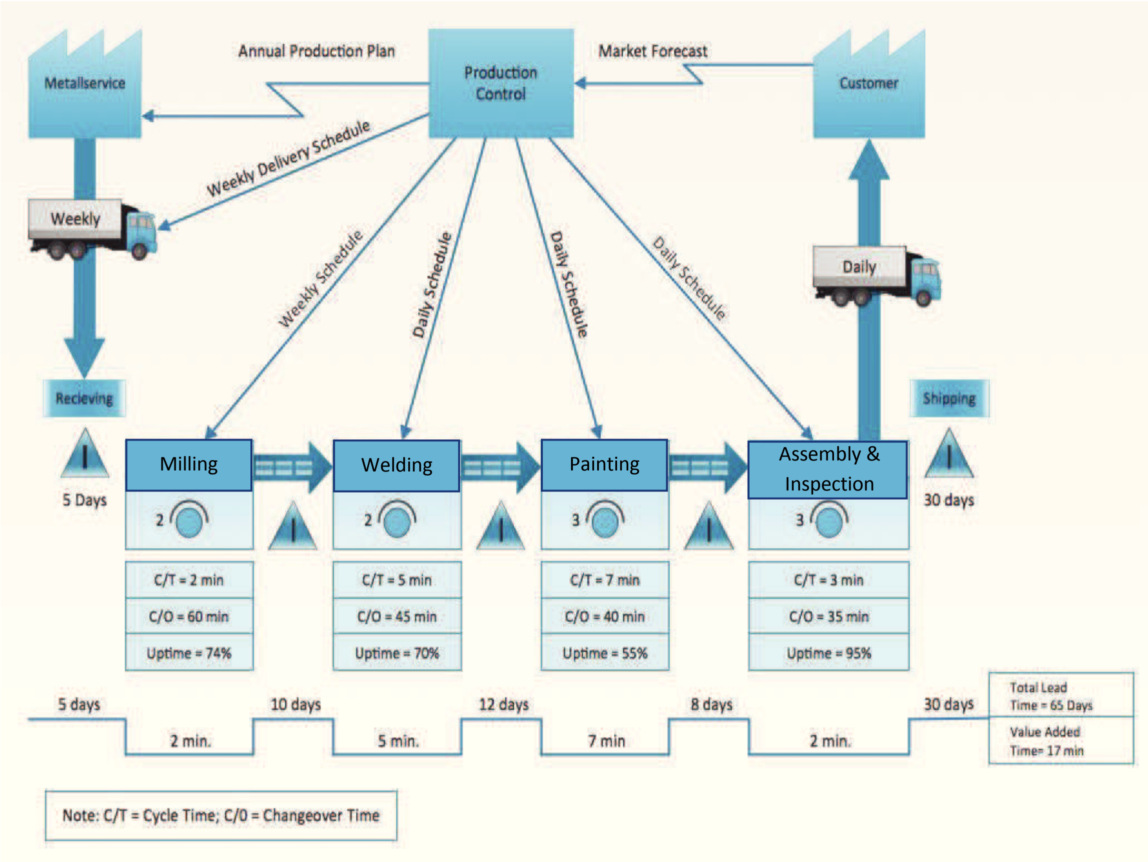

Figure 15 - Value Stream Mapping example (ConceptDraw, 2013).

On the example represented by figure 15, the processes Milling, Welding, Painting and Assembly correspond to value added time, and the inventory between processes is the non-value added time. On the process "Assembly & Inspection" the cycle time is 3 minutes, but the value added is 2 min, once that inspection of the products is considered waste. In the end the product Lead Time is 65 days and the time that the customer is willing to pay is just 17 min.

Concerning this tool, it is possible to visualize the whole procedure and take countermeasures regarding waste extinguishment.

3. Case of Study

The present project consists on the application of the Lean Thinking within the organization. The case of study is the company *Schüle Druckguss GmbH*, situated in Schwäbisch Gmünd, Germany. Along this chapter, will be mentioned the different production halls of the organization and more over the daughter company in Slovakia. The sub chapters represent analysis of different aspects as hall organization, workload for the operator and truck routes, among others. Therefore, it will be presented proposals in order to improve all the system involved on the production.

3.1. The company

The foundation of *Julius Schüle*, companys' first name, was in 1951 in *Schwäbisch Gmünd*, Germany and it was specialized in injection molding for the production of tools. In 15 years the production raised and the warehouse area was expanded to 4 000 m^2, giving job to 150 employees. Later it moved on to a new administrative building and it was constructed a new building for manufacturing and another hall, summing a total area of 10.000 m^2.

In 1999 the new company's name changed to *Julius Schüle Druckguss GmbH* and it was founded a daughter company in Poprad, north of Slovakia, named *Schüle* Slovakia s.r.o., with 25 employees. The number of employees of *Schüle* daughter's company was expanded to 180 in 2 years.

The German company expanded its area by constructing a new production and logistic hall to replace the old buildings and rented "*Schenk* Hall" with 1 600 m^2, raising the area of production. In 2012 the company acquired a new building called "Automotive Hall" with 7.500m^2 and registered 250 employees in Schwäbisch Gmünd and 380 employees in Poprad.

At the moment, the company has in total 600 employees and manufacture products mainly for automotive industry, but also pneumatic and gas heating markets. There are manufactured products as pumps, steering, valves and gears for the abovementioned markets. The company has thirty die-casting islands and manufacturing lines, characterized by its automation.

Furthermore, the company has a quality control system, energy management and recycling plans implemented. The customers of *Schüle Druckguss* are Mercedes Benz, Bosch, ZF and Festo, among others. Figure 16 shows the logo of the company.

Figure 16 - Logo of the company.

3.2. Presentation of the problematic

Considering that companies are seeking for innovation, the implementation of low cost solution is the way for get more profits without investment, in which the focus is to make more with the existing resources. Therefore, a set of problematic situations, as well as potential improvements areas, were analyzed through Lean perspective in order to better define the best Lean tool for that purpose. Each situation is then detailed, in order to better defining the problematic, analyzing the data gathered and suggesting improvements.

Based on that, a set of projects' improvements will be presented regarding problematic situations on the production, where the methodology and techniques used, as well as the countermeasures, will be described in detail on chapter four.

3.2.1. *Schenk* Hall

Schenk is the name of the hall rented by the company *Schüle* to manufacture four types of products. There are three shifts and each one has one Machine Group Leader (MGL), one Sub Machine Group Leader (SMGL) and four operators (O). The Logistic Worker (LW) is just present on the first two shifts, once that is not necessary for the third shift, or "night shift". The workload of the LW and the Operator will be studied further on this sub-chapter. The structure of employees on this hall is represented on figure 17.

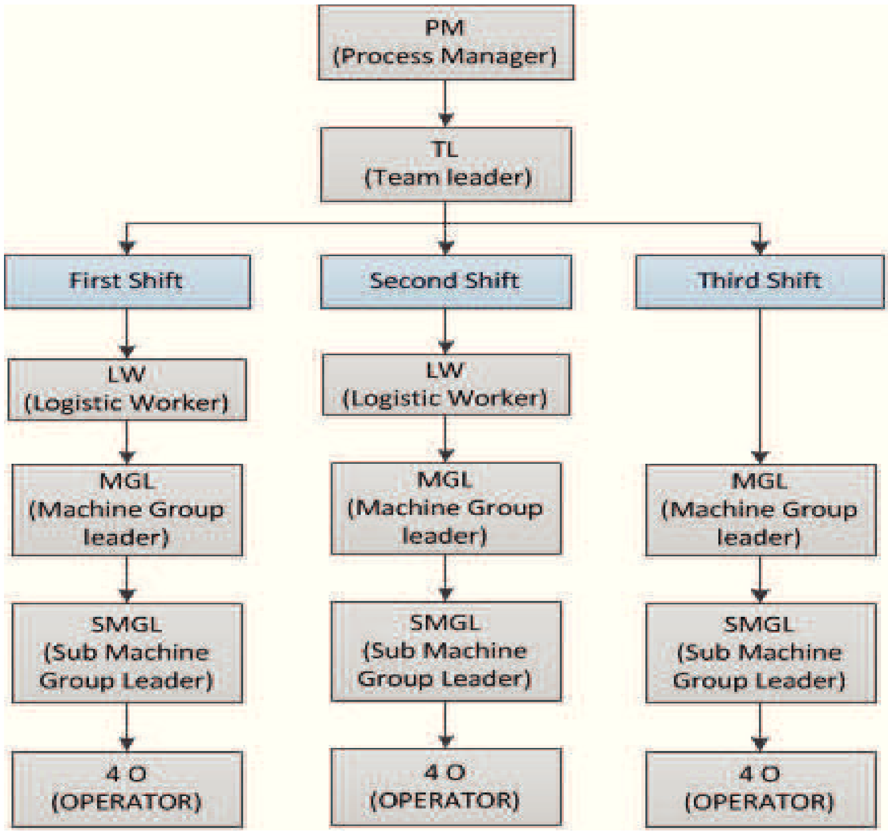

Figure 17 – Hierarchy in *Schenk* Hall.

The *Schenk* Hall has eight lines of automatized production that manufacture four different products: “New AMT Cover”, “New AMT Housing”, “Housing CP 14” and “GM Delta”. Figure 18 shows the products and the correspondent name.

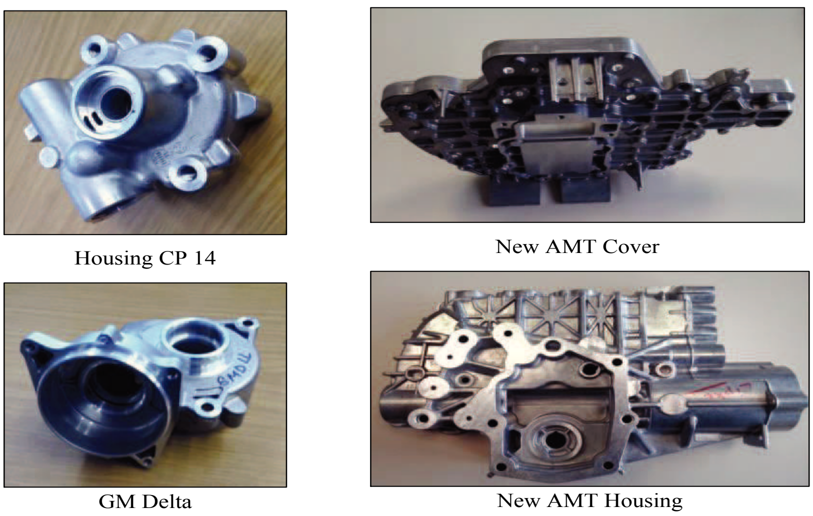

Figure 18 – Products manufactured in *Schenk* Hall.

Considering the products represented above, there are two Production Lines (PL) for manufacture the New AMT family, one for the Housing and another for the Cover; two PLs for the GM Delta and three PLs for the Housing CP14. The layout of the PLs relative to these products can be visualized on Annex I, including another PL for the product CP 14, which is not working yet.

This hall does not have so much available space and the problematic is the material flow on the workplace. Towards to optimize the material flow, specifically the transportation of pallets between warehouse and production lines, it was necessary to study the workplace organization first. Therefore, a project improvement focusing on *Schenk* Hall was carried out aiming to optimize the material flow, by the analysis of workload for the workers and workplace organization.

3.2.2. Automotive Hall

Automotive Hall is the newest of the company where are produced, in two lines of production, the "Topf" product. This product encompasses different operations, from the die casting process to the machining. Figure 19 represents this product that will be produced for the next seven years. In the future there will be implemented more lines for this product production, which justifies all the efforts to optimize its manufacturing process.

Figure 19 – Product "Topf".

The goal of this project is to optimize all the procedure inherent to this product, aiming to reduce the lead time by determining bottlenecks and improving the production by waste elimination. Given the fact that the inventory inherent to the raw material and finish goods of this product is high, it is decided that the main focus of this project will be inventory reduction.

3.2.3. Logistic of transports

Regarding the restructuration of the company in the future, one of the matters to be improved is the logistics. In the actual situation, the logistic worker faces some difficulties, while loading or unloading the trucks. Besides, the truck that comes from the daughter company in Slovakia has a long route between halls and its inherent activities take too much time. The challenge here is to optimize the activities inherent to this truck that every day transport material between Slovakia and Germany.

3.2.4. Daughter company in Slovakia

The daughter company of *Schüle Druckguss GmbH* (SDG), in Schwäbisch Gmünd, was founded 15 years ago in Poprad, Slovakia, with 25 employees and its name is *Schüle* Slovakia *s.r.o.* (SSK). Nowadays, SSK has in total 400 employees and in the production area the employees are working in two shifts per day of 12 hours each, with 45 minutes of break. The manpower is cheaper than in Germany so it's possible to get competitive advantage even considering the distance of 1078 Km between these companies.

In SSK there are produced aluminum die-casting parts which are sent to SDG every day to be machined. Based on that, the objective of this project is to convert the actual production, divided by 13h of travel, in a closed process by moving the Production Line (PL) from SDG to SSK. To do that, the new process must start with the production of die casting parts and end with the production lines, where the product is machined. There are 12 different PL that have products being manufactured continuously and some of these products are changed according to the customer demand. This is true for the four variations of Gearbox Cover, where the main focus here will be only on the Gearbox Cover PL7.

The basis for the production is a contract, with a yearly prediction, about the quantity of components that the customer requires, including a safety number. Usually every week, the customer sends the demand to the sales department in SDG that communicates to the sales department in SSK, which orders the Raw Aluminum (RA) alloy, depending on the product. In the best scenario this procedure takes 3 days, since customer's demands until the product starts to be manufactured. There is also the case where it is necessary the intervention of the Process Leader to make the production plan, and it lasts longer according to the time for the changeover of the die casting tool.

Gearbox Cover PL7

The product Gearbox has different variations and it is manufactured according with the demand of the customer. In this subchapter it will be studied the variation PL7 (Figure 20), which is die casted in SSK and transported to SDG, where is machined in Automotive Hall.

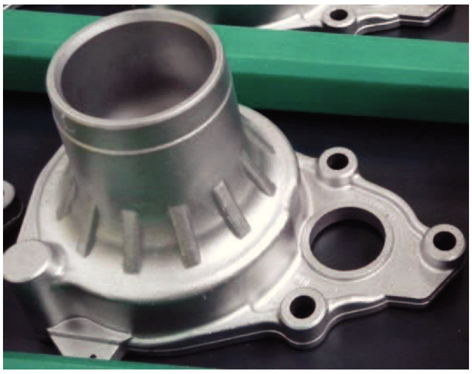

Figure 20 – Gearbox Cover PL 7.

The procedure starts in SSK receiving the Raw Aluminium (RA), which comes from different points in Europe, as France, Spain, Hungary, Austria, England and Slovakia. It is considered an average of 1.250 Km of distance, which corresponds to 15 hours driving. The RA is unload from the truck to the Warehouse (WH), by the Logistic Worker (LW), and from the WH to the foundry where is setting the furnace.

Considering the different type of products, there are also different aluminium alloys and three furnaces, which are cleaned in the end of every shift. Inside of the furnace there are 1.000Kg of aluminium melted every hour, in the proportion of 60% of RA and 40% of Recycling Material (RM). This RM is the fragment formed by the distribution channel of the mould and it is separated from the moulded parts on the cutting station, in the Die Casting Island (DCI). These fragments are placed on the conveyor by the robot, and moved to a container identified with the alloy type as figure 21 shows. There is an operator responsible to move the full container from the DCI to the Foundry area, so these fragments can be melted over again.

Figure 21 – Container with the recycled material, identified with number and color of aluminium alloy.

There is a light system used for the furnace, which turns on the green light, so the Foundry Worker (FW) knows the aluminium is molten and ready to be transported. On the wall is standing another light system for the Die Casting Machine (DCM), which blinks when it is running out of material.

The FW is responsible for transport the molten aluminium with a forklift, in a pot with 600 Kg of capacity, from the furnace to the impeller and after to the DCM. The impeller is a treatment process that purifies the liquid aluminium by injecting gaseous nitrogen in the material. The rotation that the impeller induces on the molten aluminium causes the agglomeration of the impurities by chemical reactions and brings the impurities to the surface. The FW extracts the impurities to a container and transports the pot with the pure molten aluminium to the DCI (Christophe Leroy Ph.D., 1991).

In this case of study, the DCI includes the die-casting machine, a checking station and a cutting station, although it is also possible to include stamping and shot peening processes inside of the DCI. On figure 22 it is possible to see the elements of the DCI and figure 23 comprises all this processes and simulates the material flow on DCI.

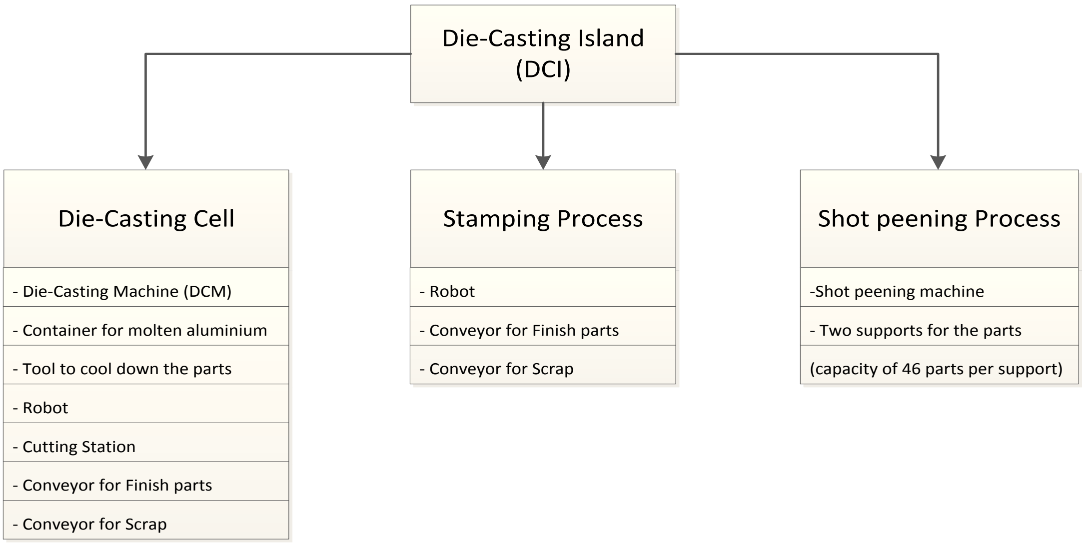

Figure 22 – Scheme with the processes of the Die-Casting Island.

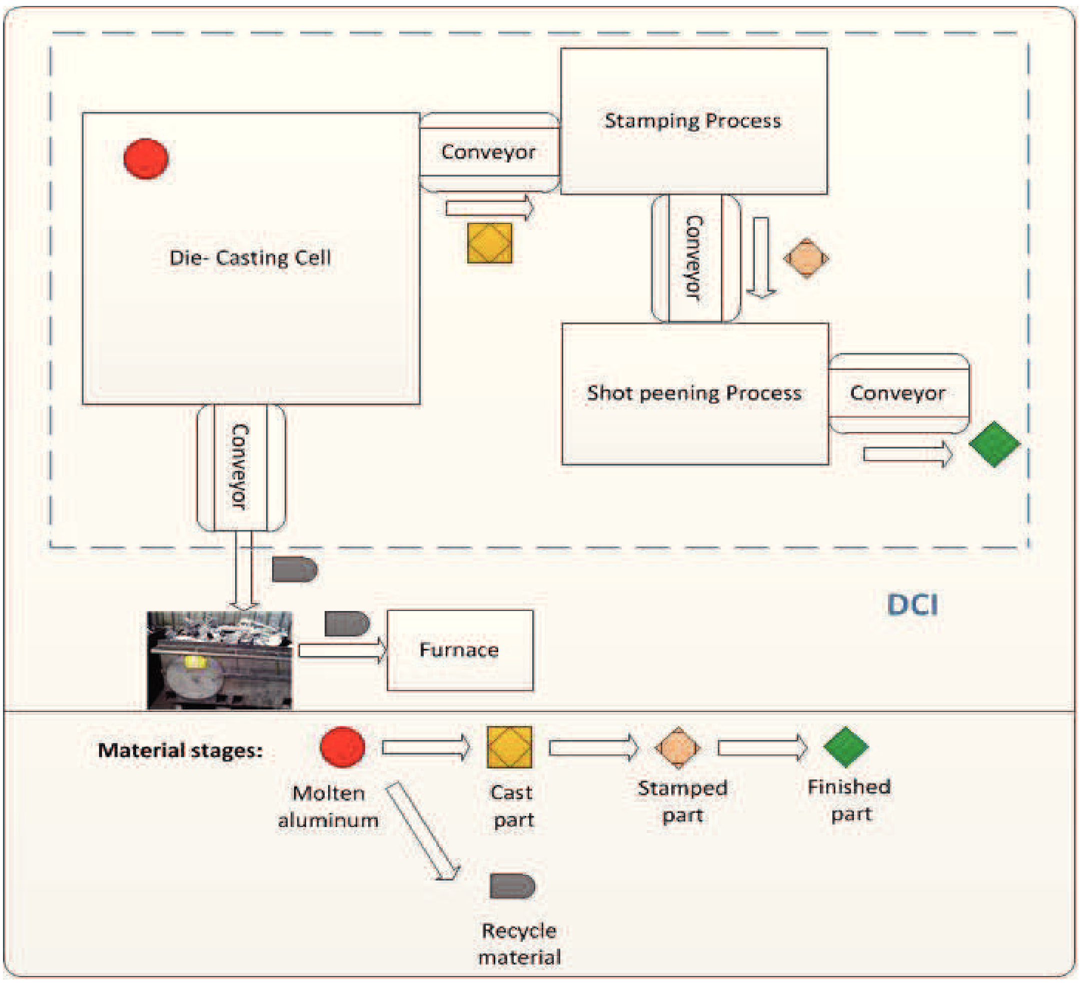

Figure 23 - Layout of a Die Casting Island.

On figure 24 it is represented the four moulded Gearbox Cover PL7 parts, which are the result of one shot of 3,4Kg of molten aluminium.

Figure 24 – Product structure after the die-casting process.

Afterwards the robot unloads the part from the conveyor to the Stamping process and puts it in another conveyor for the next step. The machine responsible for make the Stamping process on the part is represented on figure 25.

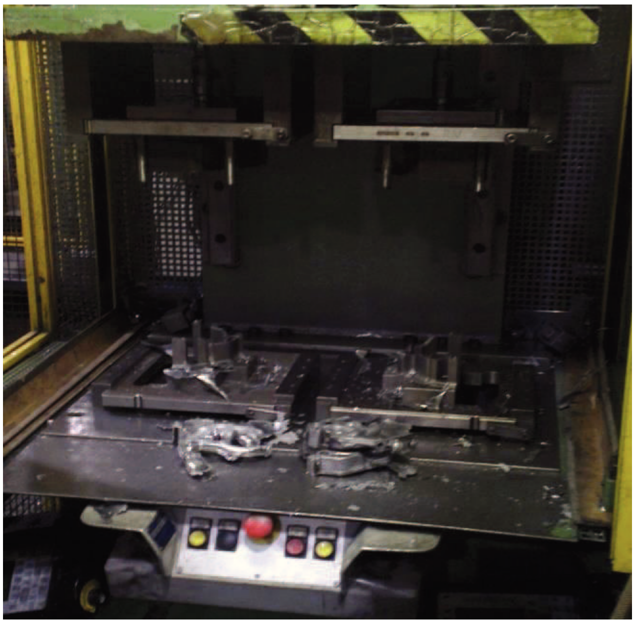

Figure 25 – Stamping machine.

In the end of the conveyor, the operator takes the part and makes the debarring process with an automatic tool and loads it in the box. There is a second operator that picks up the part from the box and loads on the support of the shot peening machine, represented on figure 26. Shot peening is a process that induces compression stress, using stainless steel cylinders on the part's surface for surface treatment (Technologies, 2013). This machine produces 46 parts per cycle, while the operator is loading the parts on the second support.

Figure 26 – Shot peening machine with the two supports outside.

As soon as the process is finished, the operator signs the ready units with a marker and loads into the Grid Box (GB), after that, the second support goes inside and the process continues. Once the GB is full, the operator transports it to the Warehouse (WH), thus the unit is ready to be delivered to SDG. In the WH the First-In-First-Out principle (FIFO) is applied, writing the day and month of production on the pallet, ordered by product, as figure 27 represents.

Figure 27 – Grid boxes organization using FIFO principle.

It is possible to observe on figure 27, the GBs are organized from the one which was produced first on the top and will be the first one to be taken, to the last one produced on the bottom.

After the transport to SDG, in Automotive Hall, the Logistic Worker (LW) transports the GB directly to the place near the Production Line (PL). The operator has to transport the GB near the conveyor, to load the parts and make the checking process after the machining. The checking process includes two steps: visual checking of the part and cleaning with the vacuum machine. The operator puts the part on the pallet and transports near the storage, so the LW can make the packing process and the pallet is ready to be sent to the customer.

4. Carrying out of projects improvements

During this chapter will be presented the analysis and results according to the problematic described on the last chapter, in order to: optimize material flow and improve organization on *Schenk* Hall; optimize manufacturing process of "Topf"; optimize the logistics' activities of the truck coming from Slovakia; and redefinition of Gearbox Cover PL7 production.

4.1. *Schenk* Hall

As it was mentioned before, the first improvement project was carried out aiming to optimize material flow in this area. To do that, workload of the workers and the material's flow were studied and a set of actions proposed, which will be described in the following chapters. At the same time, since the workplace organization of the work area in *Schenk* Hall was not organized, which was particularly problematic, and there is not so much available space, this aspect will be also analyzed.

4.1.1. Material Flow: "Housing CP 14"

The problematic presented was relative to the product "Housing CP 14", once that will be added, in a close future, another Production Line of this product. In order to understand all the steps that the product passes through, it was studied the material flow. Figure 28 represents materials' flow of this product, beginning on the supplier of the Raw Aluminum (RA) and finishing with the delivery of Finish Goods (FG) to the customer.

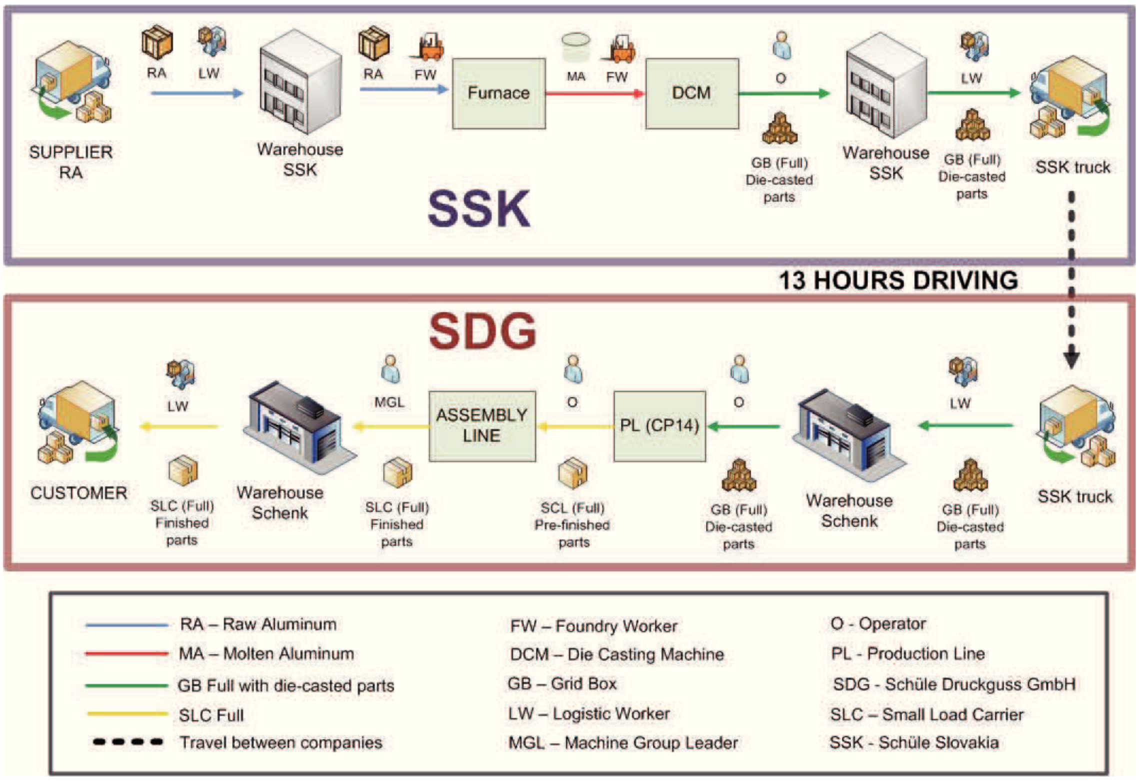

Figure 28 - Material flow of the product Housing CP 14.

As it can be observed, the die casting process is done in SSK and the machining of the part is done in SDG. The focus will be on this last process, in SDG, and the material flow in detail within this company is represented on Annex II.

Afterwards it was necessary to drawn the Value Stream Mapping (VSM) of this procedure referent to the current product, which was analyzed considering SSK as the supplier. The VSM is the best way to visualize the whole situation and detect possible targets for waste elimination. On this case, the transport between steps is the target, once that the material flow is not organized, which is a great possibility to improve. Therefore, it was necessary to understand how this transport works and consequently, determine the workload for the workers involved on the material flow. The gathered VSM is represented on figure 29.

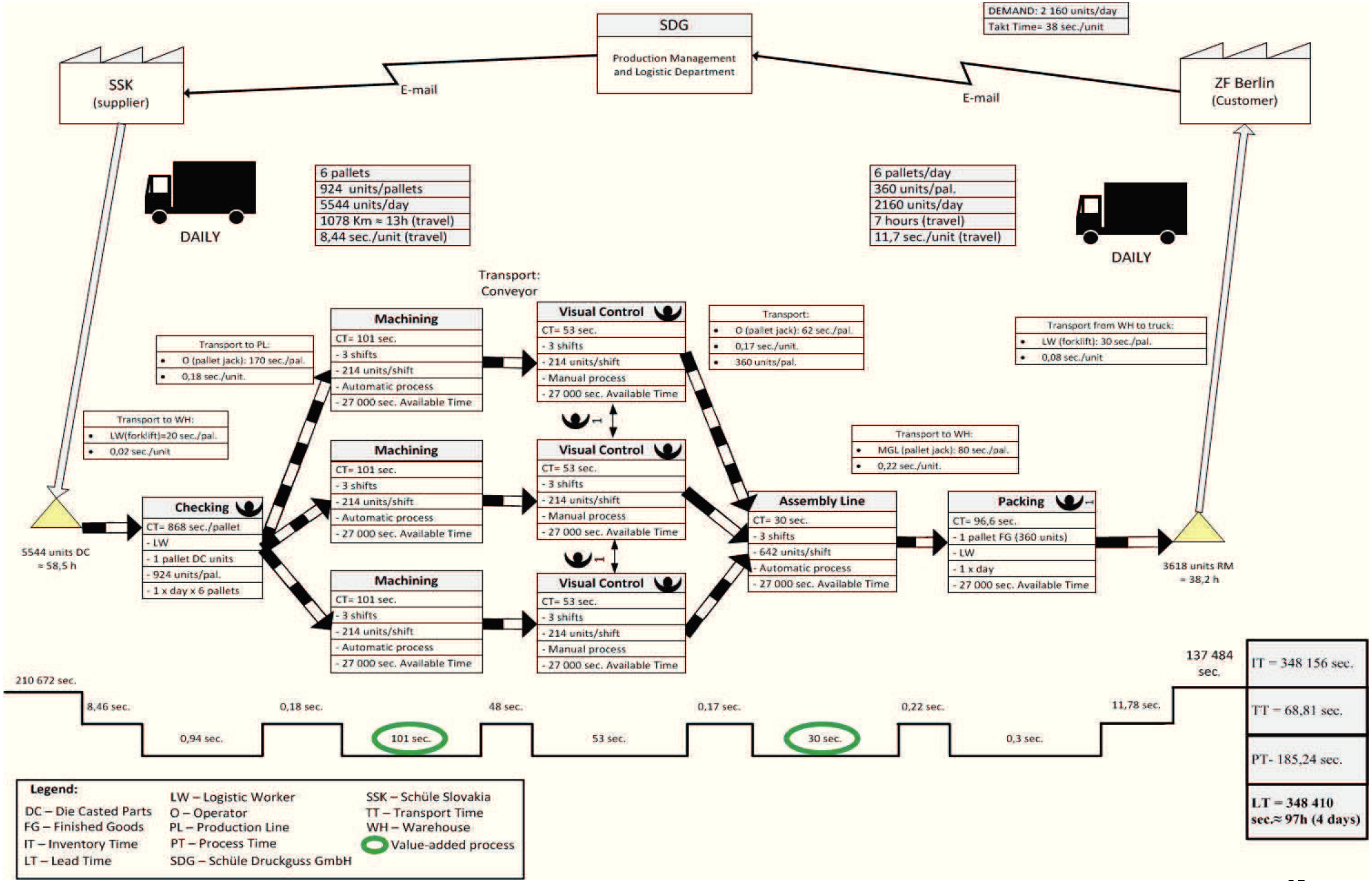

Figure 29 – Value Stream Mapping of Housing CP14 of *Schüle* in Germany.

While observing the VSM it is possible to see that it takes four days for one part to pass through all the chain and the value added is just 131 seconds.

4.1.2. Workload for the worker

There are four operators in the hall, to work in seven machines per shift, and they are able to work in all the machines, producing different products. Afterwards, the time for the tasks of the workers needs to be measured to see the percentage of workload per shift. This percentage was determined according with the available time per shift, which means that 27.000 seconds corresponds to 100% of workload per worker.

Operator

Along this sub-chapter it will be studied product "Housing CP14" due to the previously described reasons. Referring to operators, it was defined the tasks per machine for one shift, considering that the present product has three Production Lines (PL). Table 1 represents the list of tasks for the worker in one PL of "Housing CP 14", determined using an average value of three measurements on different shifts. Thus, it was calculated according to the amount produced per shift, which is 214 units per PL, considering 924 units of raw material inside one Grid Box (GB) and 360 units on the Small Load Carriers (SLC).

Table 1 – Time measurement of "Housing CP14" for the tasks of one operator in one production line.

O (Operator)				
Step	Tasks [1 Production Line]	Time/step [sec]	Time/shift [sec.]	Calculation
1	Transport GB empty to Warehouse	72	16,7	924 units/214 units=4,3 Shift/GB
2	Transport GB full to production line	85	19,8	924 units/214 units=4,3 Shift/GB
3	Load on the conveyor	3	642	3 Sec./unit; 214 units/shift
4	Control of the part	34	7276	214 units/shift
5	Load on the SLC	3	642	214 units/shift
6	Marking parts	1	214	214 units/shift
7	Transport SLC full to assembly line	9	5,3	[360 units/SLC] /[214 units/shift]=1,7shift/SLC
8	Transport SLC empty to PL	72	42,4	[360 units/SLC] /[214 units/shift]=1,7shift/SLC
9	Superficial examination	180	1350	1x every hour
10	Extended examination	900	1800	2 x shift
11	Transport aluminium shavings to the container	180	180	1 x shift
		TOTAL:	**12.188 sec./ PL/ shift**	

In order to get the time per shift that the operator spends to load the SLC, it was measured 3 seconds per unit and multiplied for the capacity of production per shift, which is 214 units. According with this, the operator spends 642 seconds per shift doing this task on one PL. In total there are 12.188 seconds per shift of workload for the operator on one PL, in 27.000 seconds available, which corresponds to 45 % of workload per shift. Once that this product is produced in three machines and there are two operators to work on them, the workload per operator is 67,5 %.

Regarding the list of tasks abovementioned, it was necessary to determine the main causes of waste of time, inherent to the workload of the operator. Thus, it was made a Pareto analysis that consists on find out the 20% of causes that are responsible for 80% of the waste, referring to the tasks that take the majority time of workload for the operator. Figure 30 represents this analysis using the Minitab program.

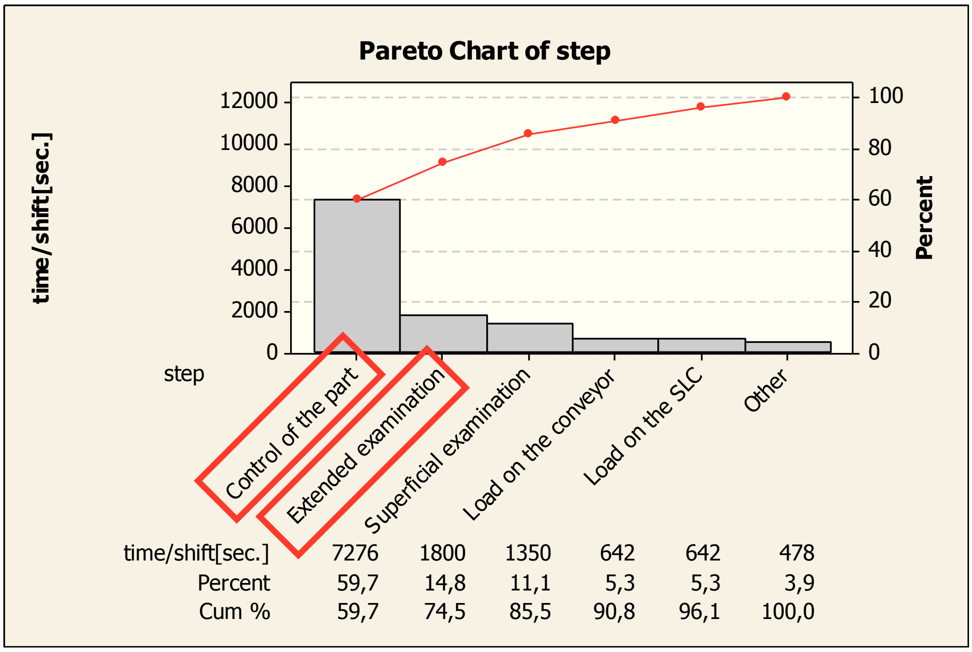

Figure 30- Pareto analysis of the time for operators' workload on "Housing CP14".

Throughout the Pareto analysis it is possible to observe that the tasks signed are the two causes for 80% of operators' workload, per shift. Therefore, the tasks selected as "Control of the part" and "Extended examination", are the focus for improvement.

Considering the "Control of the part", it will be studied in detail and represented as the bottleneck of this study. Therefore it is necessary to identify all the small steps inherent to the control and measure each one. On Annex III there are represented in detail all these steps, and on Annex IV can be found the 10 measurements of time for two workers in each step. The steps 3 and 4 were measured together because the operators make the task simultaneously. The result, considering the average, is represented on table 2.

Table 2 – Average of steps' measurement for the control task made by the operator.

Step	Task	Time [sec.]
1	Measure the hole of the part with a cylindrical tool	2,7
2	Clean with an spiral automatic machine	3,3
3	Make a visual control and take off aluminium sharps with a tool	19,8
4	Clean with a vacuum machine and check with a flashlight	
5	Make a endoscopy test in three different points of the part	7,9
	TOTAL:	**34 sec.**

The control of the part is the task that takes more time. Thus, if it can be automatized in order to make it faster and save human resources, it will be an important improvement. Regarding that, it is crucial to find out if it is possible to include this step inside the PL as an automatized process, by measuring the Cycle Time (CT) of the robot and the processes itself. The lead time of the PL for one part is 101 seconds, and figure 31 represents the cycle time of the stations and movements of the robot for one part, considering that these processes work in parallel.

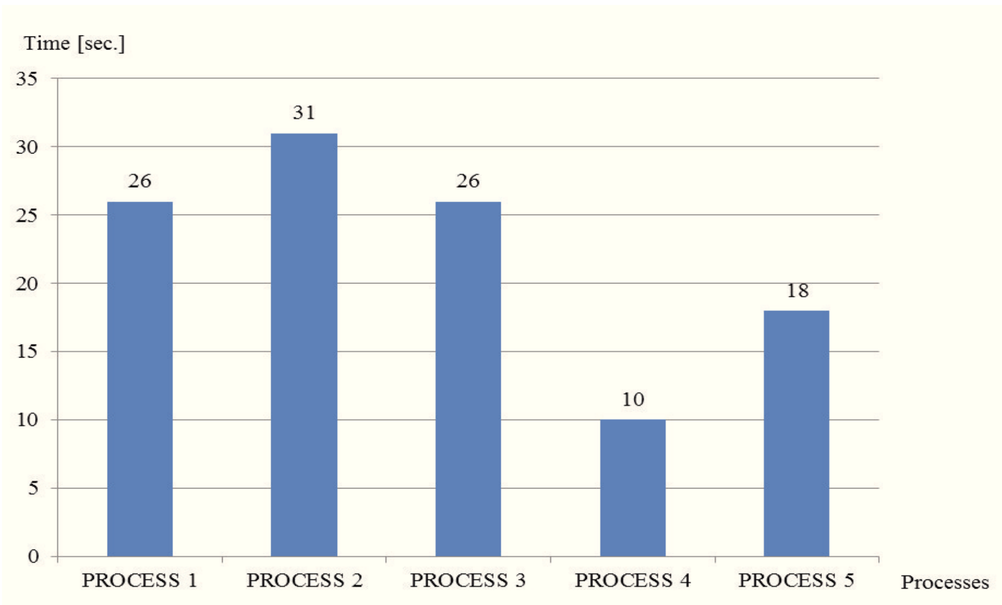

Figure 31 - Cycle time of the product Housing CP14, referent to the machining.

As figure 31 shows, the higher cycle time is 31 seconds, which means that the cycle time for the control of the part cannot be higher; otherwise it would make a delay on the cycle time of the PL and consequently a bigger lead time. Therefore, it was made a contact with a possible supplier, presenting all the steps for the control of the part, including cycle times. The proposal made was a cycle time of 15 seconds per part for a checking station that would work in parallel with the other processes and should not take longer than the higher cycle time aforementioned.

Furthermore, it was considered that in the future there will be four PLs and if the actual situation continues with a manual control with 2 workers, they just can operate on this PL. For a future situation with an automatized control, the same workers can operate in four PLs of Housing CP14, as well as to make other tasks. The percentage of time saved per shift with this improvement can be seen on table 3.

Table 3 – Time saved with the automatized control for the product Housing CP 14.

	Time/ Step [sec.]	Time/ Step/ Shift [sec.]	% Task/Shift	Workload/ Shift [sec.]	% Total Workload/ Shift	Operators for 4 Machines
Manual control	34	7276	60%	12188	181%	2
Automatized control	15	3210	40%	8122	120%	2
Total time saved	19	4066	20%	4066	60%	

As a conclusion, with the automation of the control process, the total workload per shift for one operator would be 60% (120% for two operators), which means that both can do other tasks in 80% of time left. Therefore, it will reduce the lead time on 34 seconds per part, once that the process will be done in parallel with other processes inside the PL. Furthermore, the investment on the automatic process will be recovered in one year, when compared with a cost for employing one worker.

In order to understand if it is possible, with an automatized control, both operators work in other product, it was made the same procedure for the product GM

Delta. This procedure was made considering that there are two PL and one operator, for work in both lines, as it can be seen on Annex V. The results are represented on table 4.

Table 4 – Actual scenario, with a manual control, for the products: Housing CP 14 and GM Delta.

Actual Scenario - Manual Control				
Products	Time/ unit	Workload/ product	Total workload	Number of operators needed
CP 14 (4PL)	34 sec.	181%	253%	3
GM Delta (2 PL)	20 sec.	72%		

The actual situation shows that will be the necessity of three operators to work on the six PLs, considering that is required 253% of workload per shift. On the other hand, the result of the Pareto analysis for GM Delta defines the control of the part as a bottleneck since it takes 20 seconds per part for visual checking and clean with the vacuum machine. Thus, it was considered that with an automatized control for this product it would take half of the time compared with the operator, which means 10 seconds, regarding the study made above.

Furthermore, on the actual situation is considered 72% of workload for one operator that works on two PLs of GM Delta and with the automatized control it would decrease to 49% (see Annex 4). Thus, it is possible that in a future Scenario with the control of the parts automatized, two operators can handle six PLs in total: four PLs of Housing CP 14 and two PLs of GM Delta. The proposal results can be seen on table 5.

Table 5 – Future scenario, with an automatized control, for the products: Housing CP 14 and GM Delta.

Future Scenario				
Products	Time / unit	Workload/ product	Total workload	Number of operators needed
CP 14 (4PL)	15 sec.	120%	169%	2
GM Delta (2 PL)	10 sec.	49%		

Machine Group Leader and Logistic Worker

It was considered that the workload, for the Machine Group Leader (MGL), Sub-Machine Group Leader (SMGL) and Logistic Worker (LW), includes all the products. Basically, the MGL and SMGL have the same tasks, as maintenance of the machines and operate on the assembly line of the product "Housing CP14", which is specified in detail on annex VI. The LW has to load and unload the trucks, sort the material on the warehouse and make all the procedures inherent to the material, likewise label the boxes, introduce the information on the system, amongst other tasks that can be found on Annex VII.

Therefore, the result of the workload for MGL and SMGL is 22,8% per each, even though they have the same tasks, they need to be available to solve problems inherent to the production.

Referring to the LW, there are two shifts. On the first shift, the LW has the majority of workload, instead on the second shift the LW goes to another hall when the tasks in *Schenk* hall are finished. On this case, the workload is different and it can be seen on Annex VII. Figure 32 represents the workload for the LW worker, in both shifts.

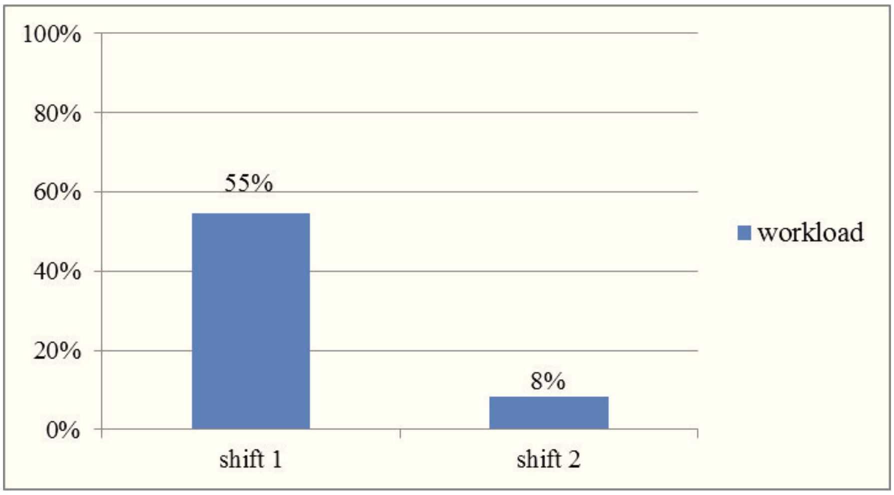

Figure 32 - Workload for the Logistic Worker in both shifts.

4.1.3. Transport of material

Regarding the results determined for all the workers of the hall, and remembering that the main goal is to optimize the material flow and the workload of the workers, the proposal is to share the transport of material between workers. Firstly, it was measured the transport between warehouse and the different production lines, actually made by the operators. It was considered that the PLs of New AMT Cover and New AMT Housing are the closest ones to the Warehouse, PL 1 of GM Delta comes next, after the PLs of Housing CP 14 and the farthest one is the PL 2 of GM Delta (see Annex I). For the GM Delta product, it is differentiated PL1 and PL2, once that the variation of transport time is significant.

The transport of the pallets is made by the operator that drives, with a pallet jack, the Grid Boxes (GB) empty, from the PL to the Warehouse (WH), and come back in the PL with a GB full with raw parts. When there is a pallet of a Small Load Carrier (SLC) full with finish goods, on the PL, the operator drive it to the WH and bring a pallet of SLC empty back in the PL. These steps were measured dependent on the product, once that the capacity of production varies, and it can be found on Annex VIII.

Relative to the measurements done about the transport of pallets by the operator, figure 33 represents this scenario as the actual one.

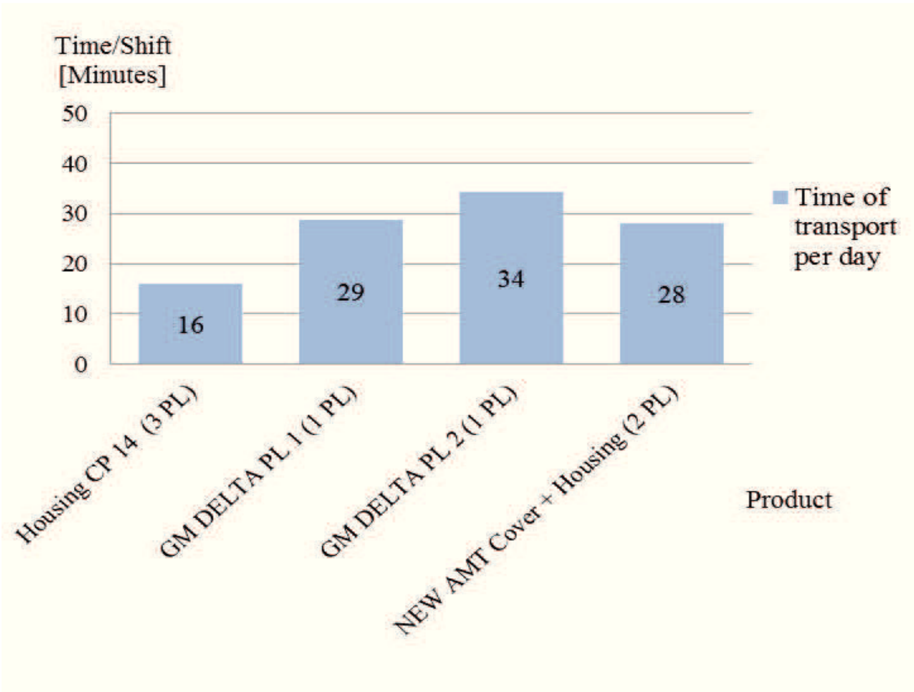

Figure 33- Operators' transport times per day, including all the products.

Considering figure 33 above, it is important to underline the fact that the operator transports the pallets with a pallet jack. In spite of this, the LW can transport the pallets with an electric forklift that is faster than the pallet jack. The proposal is that the PLs of New AMT and PL1of GM Delta, since are near the warehouse (see Annex 1) and the access for the forklift is possible, the transport will be totally done by the LW.

The space available is limited, so it was determined a place in the middle of the trajectory between WH and PLs, as the only place available to place the pallets for the other PLs. Referring to the PL2 of GM Delta and PLs of Housing CP14, it should be done from the Warehouse to the area near the assembly line by the LW and the operator drives from there to the station with the pallet jack. Figure 34 represents this area that was measured and prepared in order to place pallets, by organizing tools and equipment standing there without a defined place.

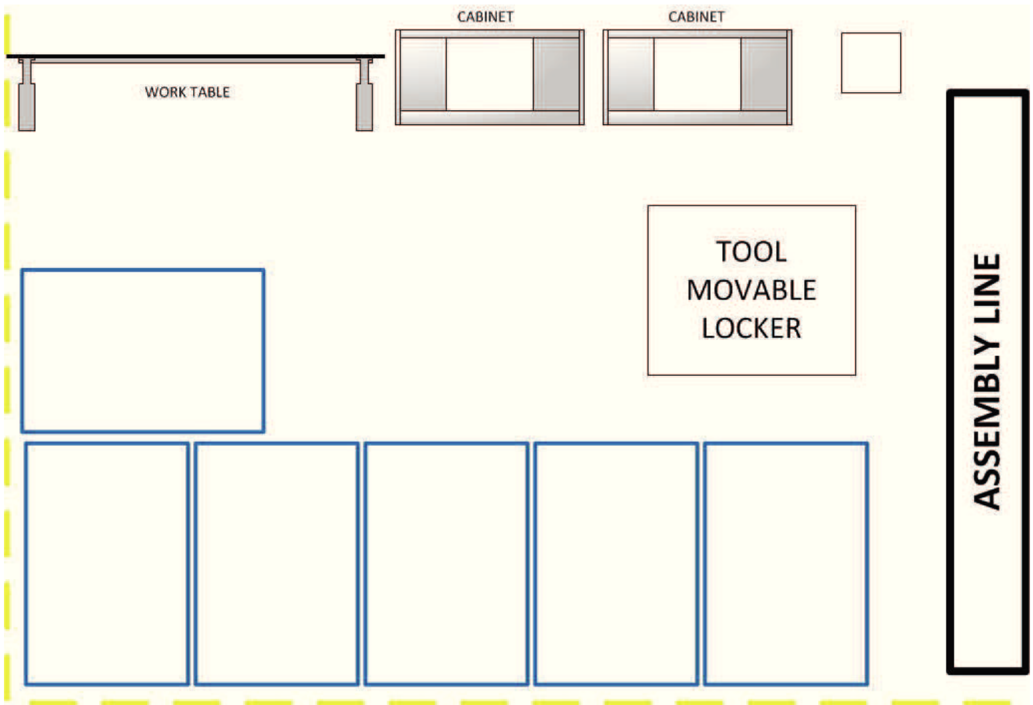

Figure 34 - Layout for the area to place the pallets, near the assembly line.

It is noticed by observing figure 34, that the color marking system was implemented on this improvement. Thus, the LW can transport the material needed for the production lines and bring back the pallets that belongs to the Warehouse.

On Annex VIII, it can be found the measurements and the assumptions about these improvements referent to the operator and LW, as well as the workload for the LW after the improvements. These assumptions are based on the fact that the LW can drive 30 meters in 20 seconds with the electric forklift and the operator drives the same distance in 27 seconds with the pallet jack. Thus, the LW takes less 26% of the time to make the same trajectory, adding the advantage that can transport two pallets in one drive. The results gathered for the transport shared between operator and logistic worker can be seen on figure 35.

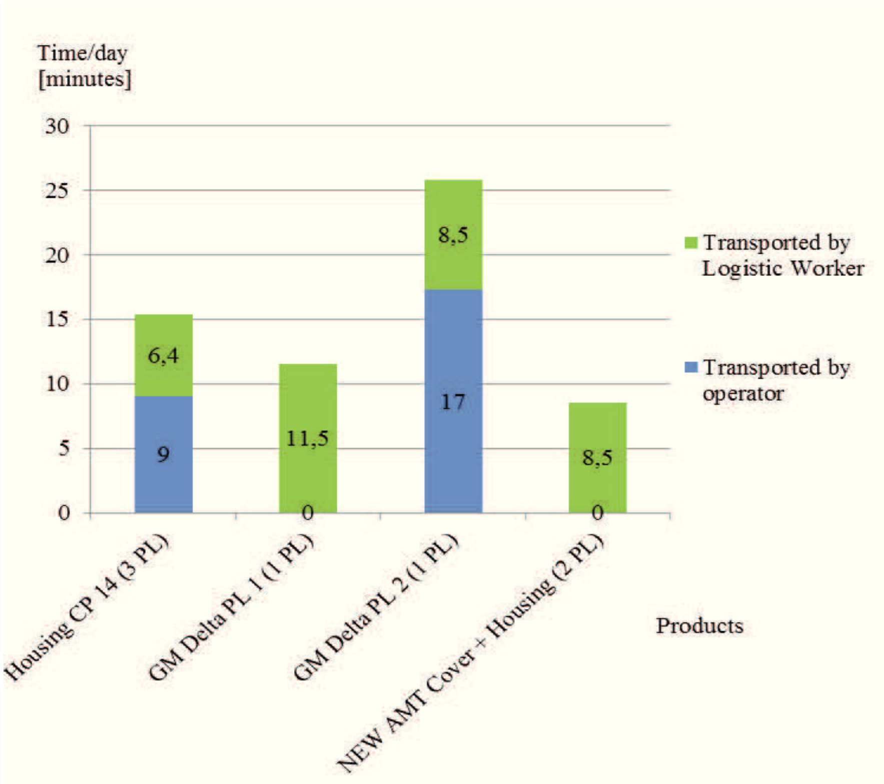

Figure 35 – Time for transport of material made by operator and logistic worker in a future situation.

Even though the workload for the LW will increase 2% (consult annex VIII), the final results are satisfactory and can be found on table 6 below.

Table 6 – Pallets' transport, before and after the improvement.

Pallets' transport	Time / day [minutes]
Transport by operator	107 min.
Transport by operator and Logistic worker	61 min.
Time saved:	**46 min. (43%)**

As it can be observed, the results are significant, the workload is shared between workers, and it will save 46 minutes in transport per day. Concerning that there are just two shifts for the LW, on the other shift the transport is made by the MGL or SMGL, who are also able to drive the electric forklift.

4.1.1. Workplace organization

Regarding the 5S Principle mentioned previously on chapter 2, *Seiton*, the Japanese word for orderliness, refers to set order on the workplace. Thus, the work area in *Schenk* Hall was not organized, without defined position to place the pallets and other items, even though walking around was difficult, considering that there is not so much available space. Figure 36 shows a set of pictures of *Schenk* Hall organization before implementation of improvements.

Figure 36 - *Schenk* Hall organization before improvements.

An organization like figure 36 shows is chaotic for the way that the pallets are sorted; there is no standard applied. Therefore, the purpose is to improve this situation, by implement a floor marking system. This method consists on drawn marks on the floor, using yellow to delineate the transport way and blue to fix a place for the pallets. There are also red marks for placing pallets transported by the Logistic Worker, topic that was studied previously.

In order to achieve the required organization of the workplace, firstly it was necessary to get a map of the entire hall and sketch a possible layout, as figure 37 shows.

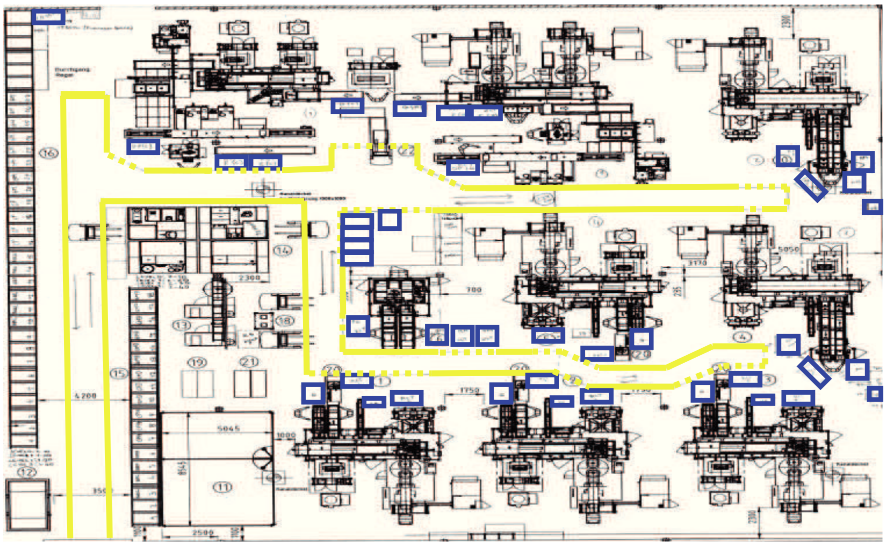

Figure 37 – Layout of *Schenk* Hall with a floor marking system.

On figure 37 it is possible to observe the standard layout for the pallets, considering that there are two types: Grid Boxes (GB) to transport the Raw Parts (RP) and Small Load Carrier (SLC) that transports Finish Goods (FG).

Considering the implementation of defined places for the material, it will keep the workplace organized and the most important, it will take less time for the worker to do the job. The images bellow on figure 38, show the floor markings made with colored tapes, as a test run.

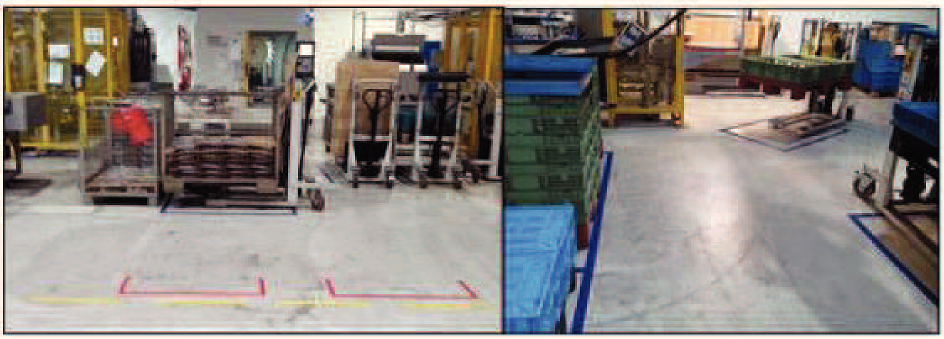

Figure 38 - Floor marks to place grid boxes, on the left side, and small load carriers, on the right side.

Referring to the transport way, it was limited by the yellow mark, thereby there is no hesitation about the way to follow, while transporting pallets between warehouse and production line. One example of this application is represented on figure 39.

Figure 39 - Yellow marks on the floor for the transport way.

While the logistic worker packs the pallets with finish goods, he does it for more than one at the same time; hence the pallets need to be disposed on a line. Besides, he has to prepare the pallets with FG in an organized line, for posteriorly be shipped. Hereby, it was implemented limits, on the place where the LW makes the packing and on the area for placing FG, as it is represented on figure 40.

Figure 40 - Blue marks on the floor to bound pallets area before packing (left) and after (right).

Even though the floor marking system was planned, there is always space to improve or some better suggestion to consider. While there are more than one valid hypothesis for define the place to sort a pallet, both have to be considered and studied in order to find the best one.

On GM Delta Production Lines (PL), after the machining, the operator has to make a visual checking, clean and place the Finish Goods on the Small Load Carrier (SCL). While that the SLC is full, the operator has to grab another two boxes, place it on the pallet and come back to the initial position. Therefore, there are two hypotheses for this set of tasks. On one hand there is option "A" that consists in placing the SLC near the workplace and go around it to grab the boxes. On the other hand there is option "B", in which the SLC is distant from the PC, however the operator can pass in between. These options were tested and can be visualized on the scheme of figure 41.

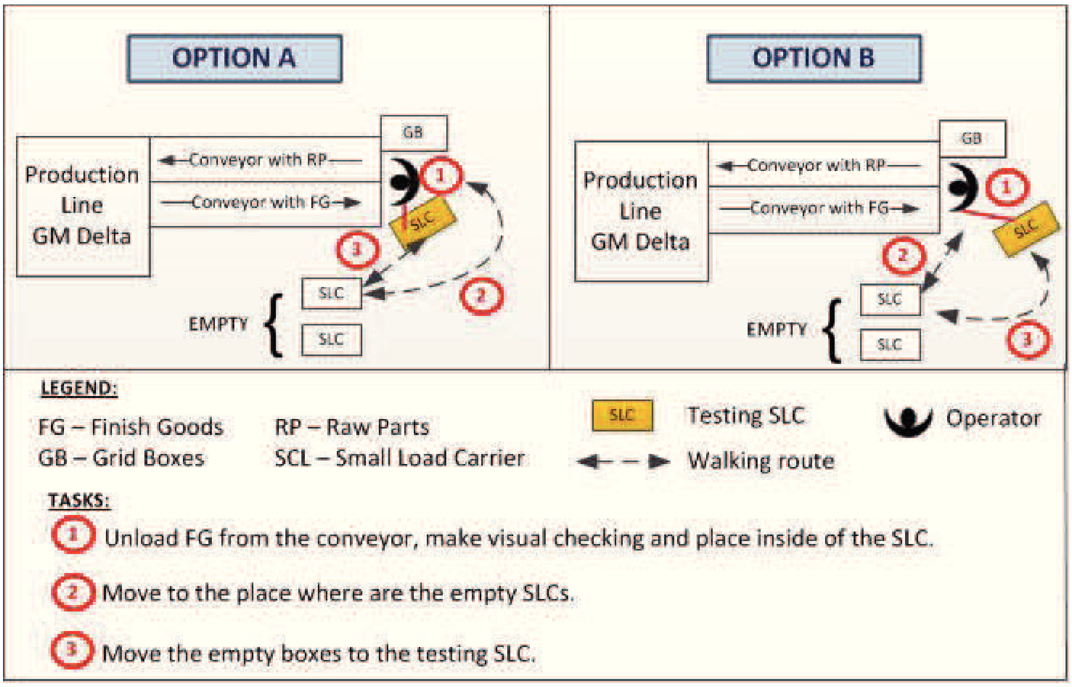

Figure 41 – Scheme representing two options for place the pallets in GM Delta production line.

Regarding the options represented on figure 41, it was studied the time spend during the previous tasks. Hereby the focus was to find out if the operator spends more time walking around the SCL (option A) or loading parts on the conveyor (Option B).

This analysis was made by measuring the time that the operator takes to load one part on the SCL (task 1) and moves to grab the empty boxes and place it on SLC (task 2 and 3). The operator needs to grab two empty boxes every 30 parts loaded on the SLC, thus, this was considered one cycle. The analysis is resumed on table 6.

Table 7 – Analysis of the time necessary for the tasks 1 and 2/3, considering Option A and Option B.

	Option A Time [sec.]	Option B Time [sec.]
Task 1	24	48
Task 2/3	46	32
Total time	70	80

As a result, option B takes more 10 seconds than option A, per cycle. Although there are produced 308 parts per shift, which means 10 cycles that in the end of the shift corresponds to more than 1 minute. Since the variation is not so significant, considering option B, in which the pallet is distant from the station, there is a concern about the free space. Whereby, to move material around the pallet becomes difficult, once that the space for motion is not so much. On conclusion, the best is option "A", where the SCL is near the PL, as it is possible to observe on figure 42.

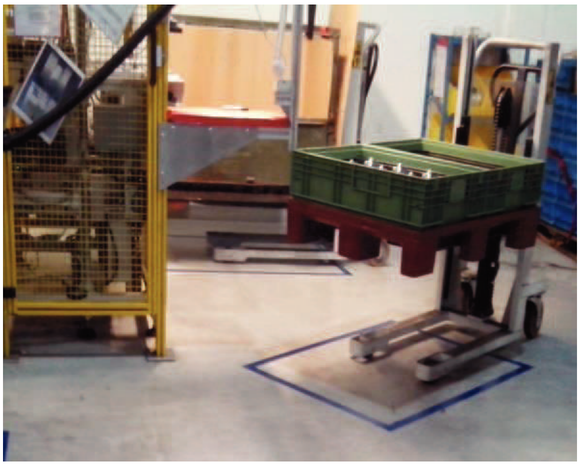

Figure 42 – Marking system for the Small Load Carrier on GM Delta production line.

Thus, it was made an informative document in order to explain all the procedure to the workers and there is also a space where they can write suggestions. This document is focused on the New AMT PLs for a test and can be consulted on annex IX.

Returning to the theoretical approach, supported by 5S's principle, the focus was then on the organization of the workplace. After the implementation of the marking system, it emerged another situation that was the workplace for the LW. The place where the LW works is situated on a shelf of the warehouse near the local where the forklift is charged, which means is not safe to work in an area of 2,5 m^2 of this local.

Thus, the tools that the LW uses are not near the workplace for that reason, and are under the shelf of the warehouse; thereon it is not comfortable to achieve the tools all the time. On figure 43, this scenario can be visualized.

Figure 43 – Workplace of the logistic worker.

The local around the equipment for charge the forklift is marked with a tape yellow and black that signs the area where nothing can be standing on. The tools that the LW needs, as the labels for the pallets, material for packing and other items, can be visualized on figure 44.

Figure 44 – Place for the tools of the logistic worker.

Deliberating the situation, the proposal is to find a place for the logistic worker, to do the job easier and be more motivated. Behind the shelves of the warehouse there are two rooms, which are not being used and belong to the owner of the hall, and one of these rooms could be the perfect place for the logistic worker. To guarantee that this option works, it was planned a layout for this room (see figure 45).

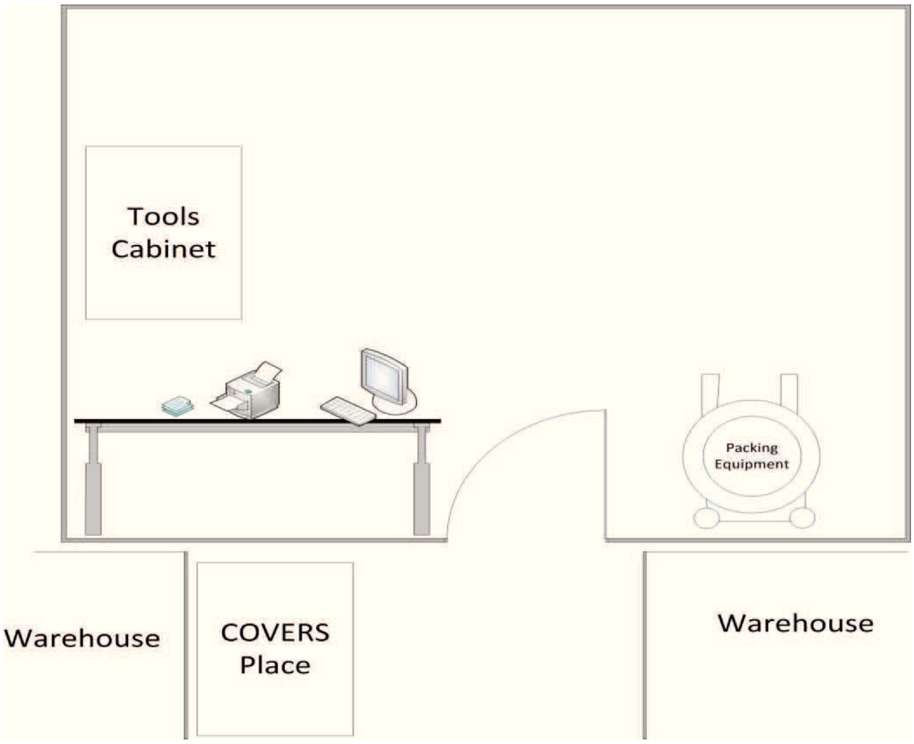

Figure 45 – Layout for the room of the logistic worker.

Summarizing, the room should have all the tools inside a cabinet, organized on the shelves and the packing equipment that did not have a defined place before. On the entrance of this room, are placed covers of the pallets of Small Load Carriers (SLC). Even though the SLCs are different per product, the covers for the pallets are the same, except for the New AMT products. While the SLC empty is transported to the Production Line (PL), its cover is left on the area near assembly line, and when the SLC is full and transported to the warehouse, the cover is placed by the LW again. The covers are used to be placed in the area near the assembly line, which is now occupied with the pallets, after the improvement on transport of material. Afterwards, the new place for the covers of pallets is represented on figure 45, presuming that the logistic worker will transport the SLC, can take out the cover and leave it there. When the SLC is back in the warehouse, ready to be packed, the LW can place the cover again on it and further make the packing process.

4.2. Optimization of the "Topf" production regarding inventory waste

4.2.1. Raw material

Assuming that "Topf" is the only product on this hall that is die casted and manufactured on a continuous line, and that it will be produced for the next seven years, its production lines will increase. At the moment, there are two Production Lines (PL) and each one produces 1.230 units per day.

The safety inventory for Raw Aluminium (RA) is 60 tons and the company orders the supplier every week 25 tons or 50 tons, presuming that the truck is full with 25 tons. The material comes from all Europe, dependent on the cost. Thus, the main focus is to reduce the costs inherent to the storage of the RA, and for this it is necessary to discriminate the area occupied. Admitting that one storage place can sort 1 batch of aluminium, that weights around 650 Kg, there are 93 storage places for the safety inventory abovementioned (50 tons). Table 8 represents the costs referent to all the storage area for RA, considering 130 places available for the storage of 85.000 Kg and a price of 5€ per square meter, adding to this price 5% of interest rates.

Table 8 - Information about storage of raw aluminium.

Raw Aluminium (RA)	
1 Storage Place (SP)	0,4 m^2
Area occupied (130 SP)	52 m^2
Cost/month	260 €
Interest rate/month (5%)	13 €
Total cost/month	**273 €**
Total cost/year	**3 276 €**

Presuming that per week it is necessary 28 tons of RA to produce and the safety inventory allows producing two weeks without receiving material from the supplier, the question is why that safety inventory is so high. The most important reason is because the production cannot risk stopping. Although, it is necessary to optimize this safety quantity, according with some economic features. The Economic Order Quantity (EOQ) is calculated bellow, using features as Reorder Costs (RC), the Demand (D) of the customer and Holding Costs (HC), through equation 2 (Waters, 2003).

$$EOQ = \sqrt{\frac{2 \times RC \times D}{HC}} \leftrightarrow \qquad (2)$$

$$\leftrightarrow EOQ = \sqrt{\frac{2 \times 50\,000€ \times 1\,426\,880\ Kg}{\frac{0{,}04€}{Kg}}} \leftrightarrow EOQ = 1\,888\,704\ Kg/year$$

The result for the EOQ represents the necessary quantity of material, in Kilograms (Kg) per year to produce in two PL, which means that the EOQ per week is about 37 tons of material. In the equation 2, the demand of the customer (D) is 728.000 units per year that means 1 426 880 Kg per year, since one unit needs 1,96 Kg of RA to accomplish the demand. Referring to the cost per order (RC), regarding that one order is 25 tons, 2€ per Kg, including the material and transport costs, which means 50.000€ per order. Other feature to consider is the HC that refers to the costs of the place for one unit of inventory for a year, including the interest rate, price for the area and obsolescence. This last factor is not applicable on this case of study, although the other factors, calculated on table 8, represent 0,04€ per Kg in one year, knowing that the total price per year for the storage of 85 000 Kg is 3.276€.

Thus, using the reference abovementioned, there would be saved costs for the inventory storage and additional costs as logistic work and transportation. The results are expressed on table 9.

Table 9 – Result of the costs saved with the inventory improvement.

	Actual	Improvement
Quantity	60 tons	39 tons
Total cost/ year	3.276 €	2.170€
Costs saved/ year	1.106 € (34%)	

As a result, it was saved 34% of the inventory costs per year, for the raw material of the product "Topf".

4.2.2. Finish goods

Regarding that there are 15 shifts per week and the production per shift and per machine is 430 units, in the end of the day there are 2.580 units of finish goods to send to the customer. In addition, on Saturday there are 2 shifts that produce 1.720 units. The demand of the customer per week is 14.000 units and there are 620 units of finish goods in the storage in the end of the week. Every day of the week there is a truck to ship 2.640 units and an additional truck on Friday for the shipment of 800 units. Assuming that the truck can transport 66 Large Load Carriers (LLC) and each one transports 40 units, the last truck transports 20 pallets so it is not full.

Presuming that the goal is to reduce costs of inventory and every waste inherent to it, the proposal is that the LLC can store more units inside. Towards to accomplish this improvement it was studied the actual layout within the LLC that has three levels with inlays. On the upper level there are stored 10 units with the parts laid down, and on the other two lower levels there are 15 units per each and the parts are standing, as it can be seen on figure 46, bellow.

Figure 46 – Product "Topf" stored on the Large Load Carrier.

The main focus will be reorganizing the structure represented on figure 42, in order to place more parts inside. This restructuration involves changing the inlays, which ensures that the parts are not in contact while the transport is done. The first step is to measure the box, and the part which has a diameter of 9,32 cm. It was added 1 cm to the diameter as tolerance, concerning the space for the inlays, and drawn with the right dimensions on the program Microsoft Visio. This drawn consists in positioning the parts in a way that minimize the space occupied and more parts can be stored inside, as figure 47 shows.

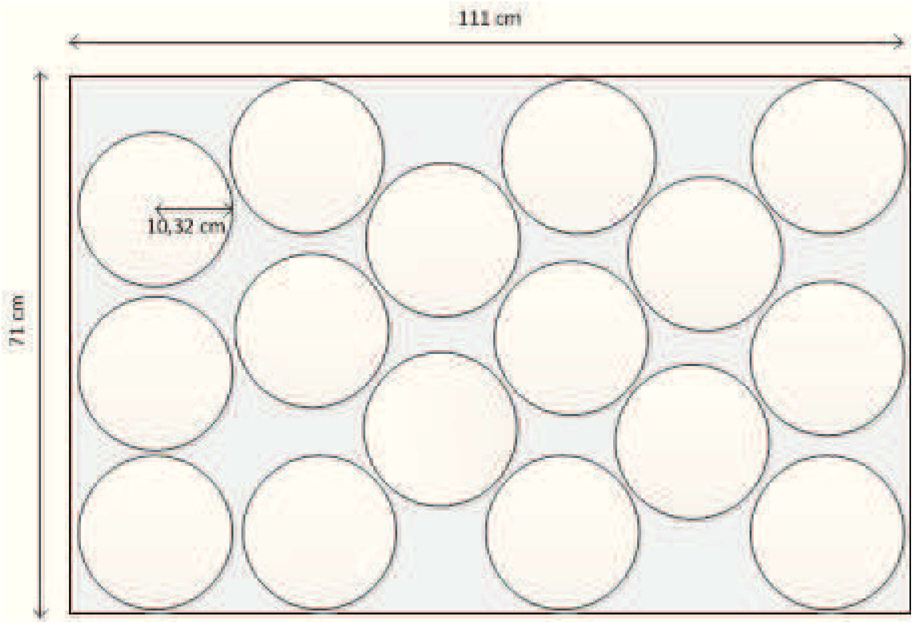

Figure 47 – Proposal of a new layout for place the parts inside the Large Load Carrier.

Concerning the new layout, there is one more part placed on one level and two more parts per LLC, which means 42 units. Further, it is crucial to know if it is possible to make the improvement without cause any damage for the parts, presuming that are more compacted inside the box. So it was made a prototype of two inlays for make the test run and see if the parts suffer some type of deformation. This prototype can be visualized on figure 48.

Figure 48 – New prototype of the inlay for the product “Topf”.

This new prototype of inlays was made with the actual inlays by modifying the shape and connecting with adhesive tape. Concerning the actual inlay, it is foldable and easy to place inside the LLC, so the new inlay has to attend also to this expectation. Figure 49 shows the inlays, the actual and the improved one.

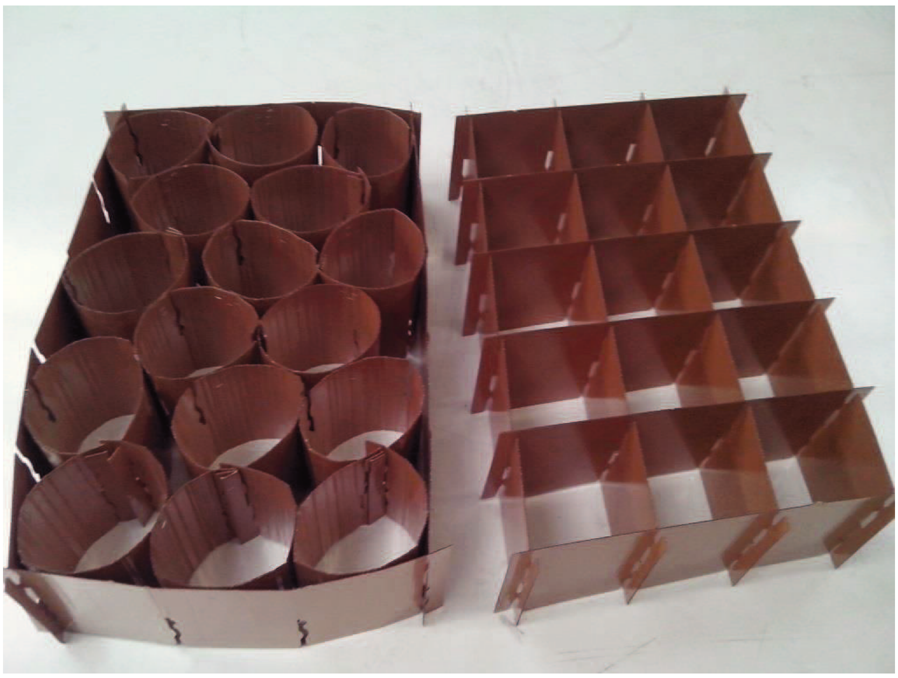

Figure 49 - Improved inlay, on the left and actual inlay, on the right.

It was considered that the parts cannot be in contact with each other or the box itself, so it was made thinking about all of these features. Afterwards, this pallet with a new layout was transported along 2.156 Km, which distance is much longer comparing with the customer, in order to realize if the parts have some anomalies. Obviously, there were used parts with defect for this test and it was measured on examination equipment before and after the transport, to see the difference.

As a result, it was verified a deformation of one part in the middle and a variation relative to the first measurement, on other parts. Although it is important to notice that this was a dabbler inlay, constructed by hands, which make it not reliable. Thus, a contact with the supplier was made with intend of making a real prototype that can be really tested and finally prove if this layout is reliable or not. Concerning this contact, it was presented the proposal of structure for the inlays and a required a budget, to discover if it is worth the investment.

Attending to customer demand, it was studied the actual scenario and an improved scenario, which result is represented on the table 10, bellow.

Table 10 – Delivered amount per week of the product “Topf” in the actual and improved scenario.

Delivery Per day	Actual (40 units/ LLC)				Improvement (42 units/ LLC)			
	1st truck		2nd truck		1st truck		2nd truck	
	LLC	units	LLC	units	LLC	units	LLC	units
Monday	66	2 640			66	2 772		
Tuesday	66	2 640			66	2 772		
Wednesday	66	2 640			66	2 772		
Thursday	66	2 640			66	2 772		
Friday	66	2 640	20	800	66	2 772	4	140
Total delivered: 14.000 units/week								

Afterwards, the second truck, necessary to ship the product on Fridays would transport just 4 pallets, which is not a beneficial option at all. On the other hand, while the customer is flexible, the demand could be organized per month with an amount of 56.000 units or 1.333 LLC per month. Thus, every day a truck full and in a window of two weeks, send an additional truck with 36 LLC that corresponds to the amount that is in inventory. Considering 4 weeks, with one shipping per day, in one month can be accomplished the demand and inventory eliminated. This outcome can be observed on table 11.

Table 11 – Delivery to the customer per week, considering the improved situation.

Delivery per week	Improvement (42 units/ LLC)			
	1st truck		2nd truck	
	LLC	units	LLC	units
Week 1	330	13860		
Week 2	330	13860	36	1512
Week 3	330	13860		
Week 4	330	13860	36	1512
Total delivered per month: 58.464 units				

As it is possible to see, the total delivered to the customer is more than the demand, but on this way it would be possible to minimize the costs for inventory and transport. Considering that, each transport costs 300€, in one year there are 312 transportations and the total cost is 93.600€. On the proposed improvement solution, it would be necessary 286 transportations, less 8,4% and the company would save 7.800 € per year.

4.3. Logistic of transports

The logistic department of the main hall is the responsible for all the material that arrives and shipped on the company. There is a place, on main hall, where the trucks load and unload the material. There are two Logistic Workers (LW): one working with the forklift, while the other is on the storage. When it is necessary and there are a lot of trucks, both workers can operate with forklift.

Actually, the situation on main hall is chaotic and the focus is to improve this situation, by finding the root cause. Basically, the issue is the job provision of the LW, which is compromised by people walking around on the workplace while the transport of material, trucks coming at the same time, amongst other causes.

Therefore, in order to identify the main causes of a poor logistic organization, it was defined a diagram cause-effect or fishbone diagram (see figure 50).

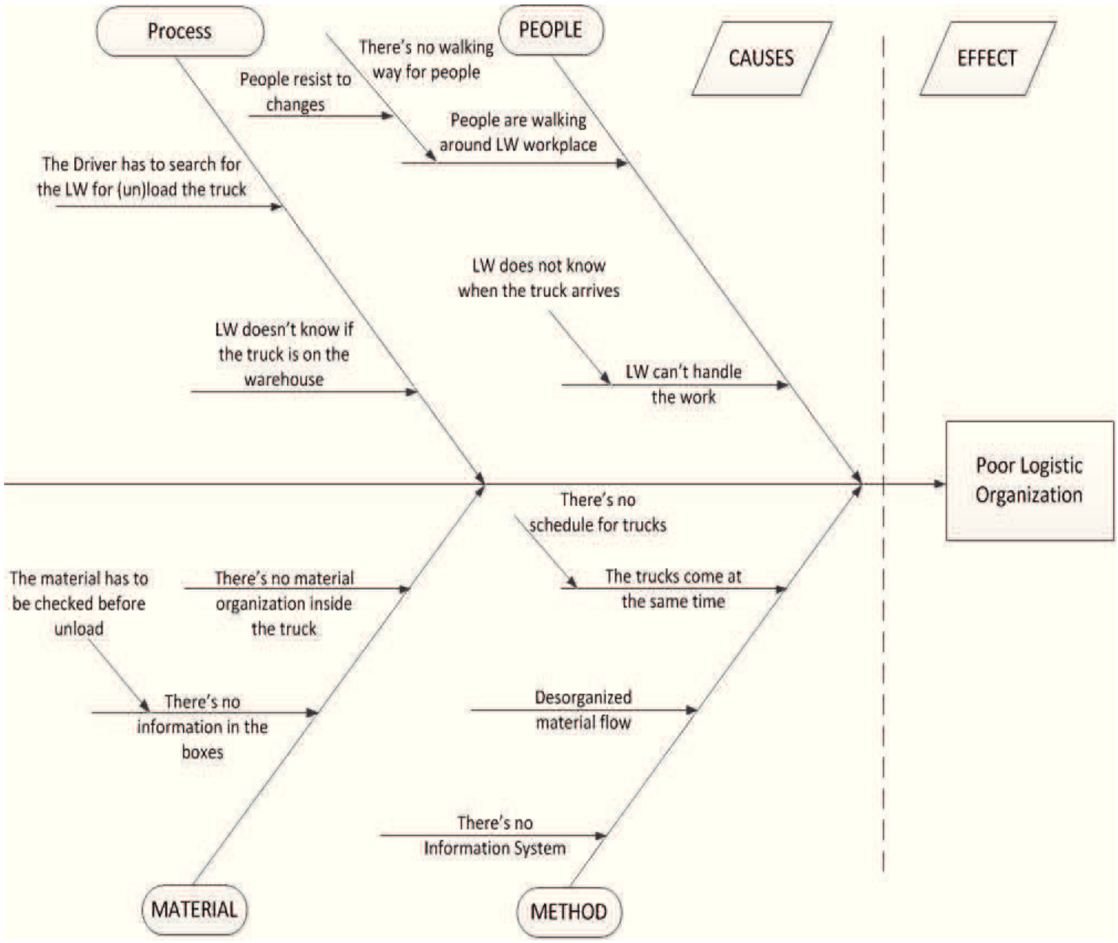

Figure 50 - Fishbone Diagram to represent the poor logistic organization.

Concerning this diagram, it is possible to realize the circumstances that logistic department faces. One of them is the category "people" on the fishbone diagram. Since people is walking around the place where the LW has to transport the material, the suggestion is to implement a walking way for people and the solution proposed is illustrated on figure 51.

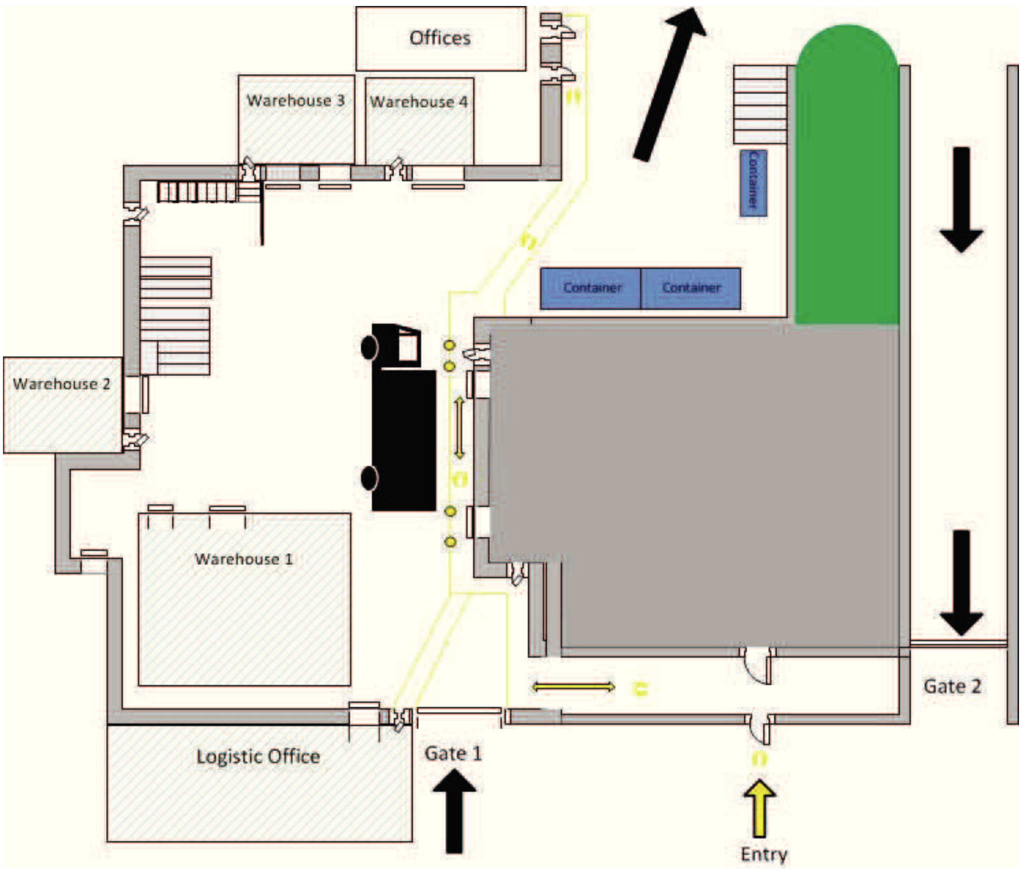

Figure 51 - Part of the plant of main hall where the trucks (un)load.

Therefore, while there is a walking way for people, between entry and the offices, and it is respected, one problem is solved. Referring to the unorganized situation for the trucks, once that there is no information system, the suggestion is to implement a device that can notify the LW, regarding the existence of one truck to (un)load, while working on the storage. This device can be a pager as figure 52 shows.

Figure 52 – Pager. (Pas14)

4.3.1 Logistic transport for the truck from Slovakia

Concerning the interchangeability of material between Propad, in Slovakia (SSK) and Schwäbisch Gmünd, in Germany (SDG), the transport between these two companies has to be improved. This transport of Raw Parts (RP), which are stored inside of Grid Boxes (GB), from SSK to SDG is made every day. The truck that comes with GB full and brings back the GB empty to SSK, will be now called as "SSK truck".

SSK truck has to unload in three different places of the company: Main Hall, *Schenk* Hall and Automotive Hall. Usually, the sequence between these places follows this order. After unloads the material, the truck comes back again in the first station, which is Main Hall, to load material.

The time relative for all the activities made in each hall was measured, through of 10 measurements and the result (i.e. the average of measurements) is represented on figure 53.

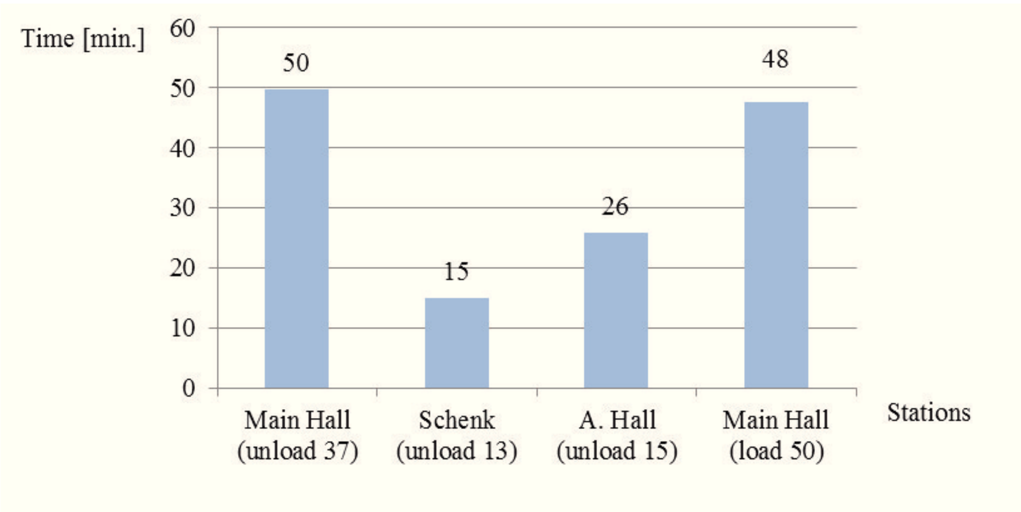

Figure 53 – Time for load and unload each truck on the halls.

As it is possible to see on figure 53, it takes more than two hours to load and unload the truck. Furthermore, the activities in each hall were defined and measured, considering the time that the truck is waiting on the entrance, the task of open and close the truck, load ,unload, driving, organize pallets on the Warehouse (WH) and sort pallets. These steps are discriminated in percentage on figure 54.

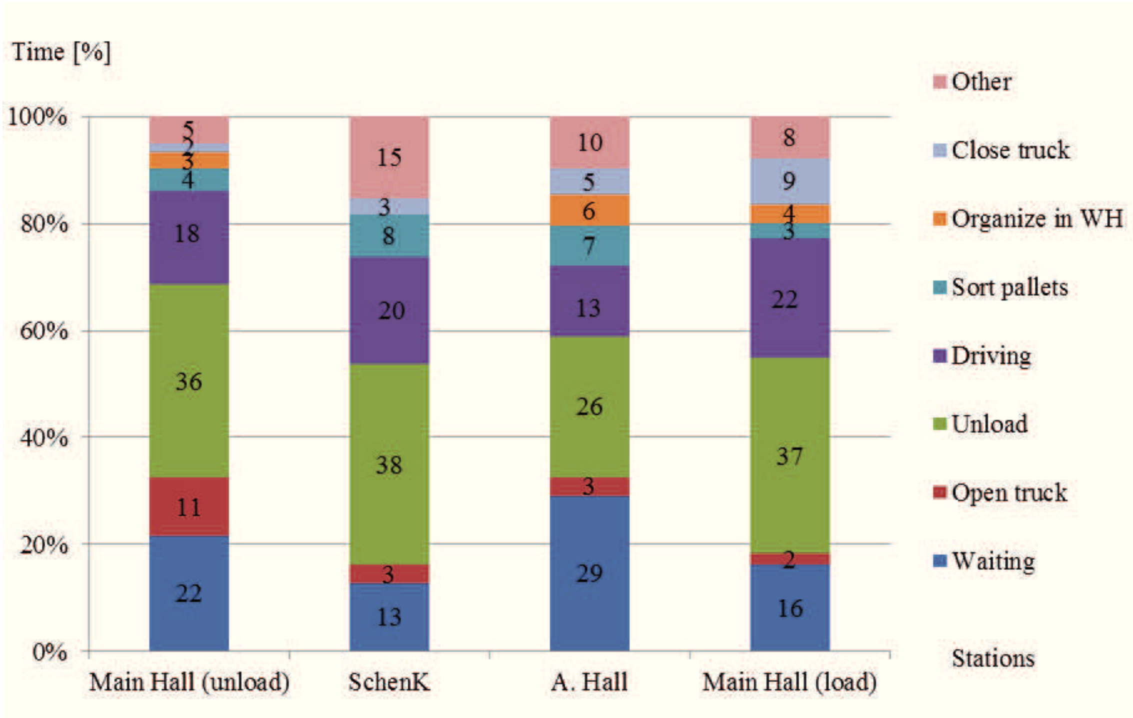

Figure 54 – Percentage of activities of the truck from *Schüle* Slovakia, in each hall.

As it is illustrated, the feature "others" represents activities that are not standard, such as picking up the phone, talking and do other tasks that does not belong to the current situation. Therefore, the focus was on the feature "sort pallets", which happens when the LW has to unload material and load it again in the truck because does not belong to the hall. This situation occurs because the GB are all the same, even though the material inside is different, so it is easy to make mistakes. Considering that, it is recognized that this aspect is an evident waste of time, human and material resources encompassing 5% of total activities time (figure 55).

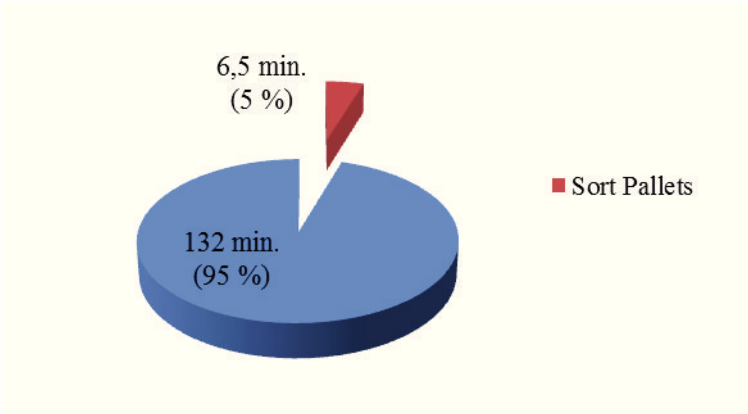

Figure 55 – Percentage of time used for the step “sort pallets”.

Thus, the elimination of the activity “sort pallets” induces the elimination of 5% of the actual time spent in all the procedure. Towards to this elimination, it was created a system to mark the pallets according to the hall that it belongs and adding the product name. This is a color system in which yellow corresponds to Automotive Hall, green to Main Hall and blue for *Schenk* Hall. The grid boxes, with the colored marks are represented on figure 56.

Figure 56 – Color system to mark the grid boxes with the raw parts.

Afterwards, it was measured the time while the truck is driving between stations, which can be seen in a scheme represented on figure 57.

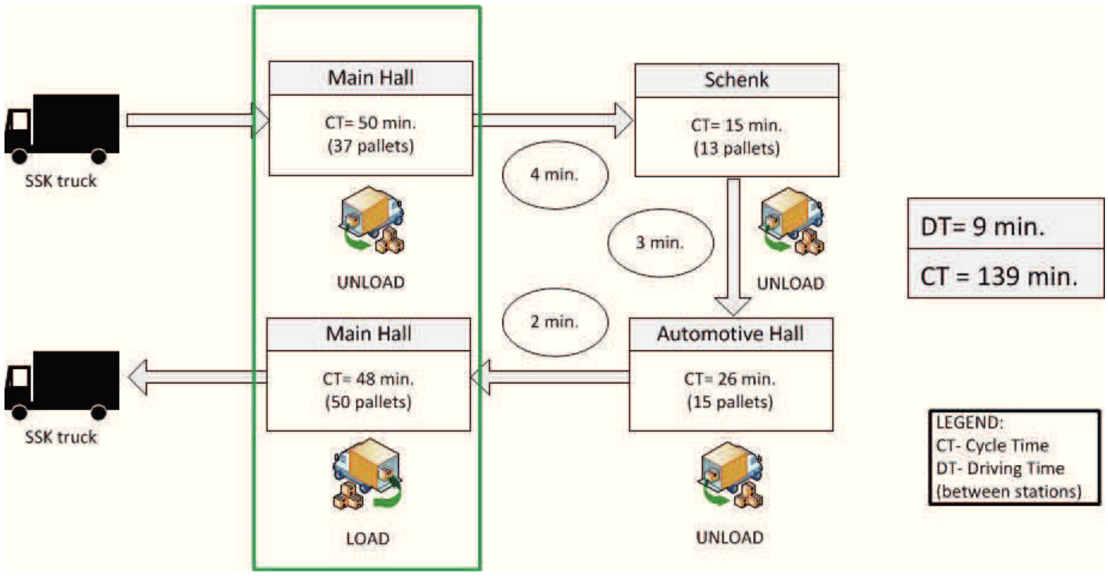

Figure 57 – Actual route of the truck from *Schüle* Slovakia**.**

The SSK truck goes twice to the same point, which is a waste of time, regarding that the truck has to unload material in all the halls and load just in the Main Hall. The suggestion is to go first in *Schenk* Hall, following to the Automotive Hall and in the last station, which is Main Hall, unload and load material. Then, the route should look like the scheme represented on figure 58.

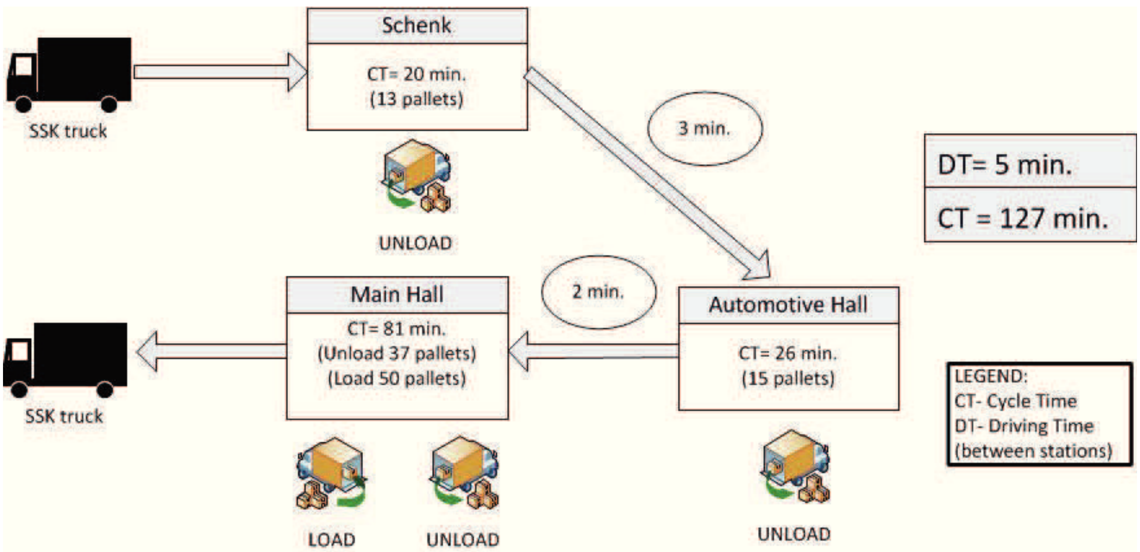

Figure 58 – New route for truck from *Schüle* Slovakia.

Furthermore, it was defined a place for the pallets inside of the truck, according with the improved route, which is represented bellow of figure 59.

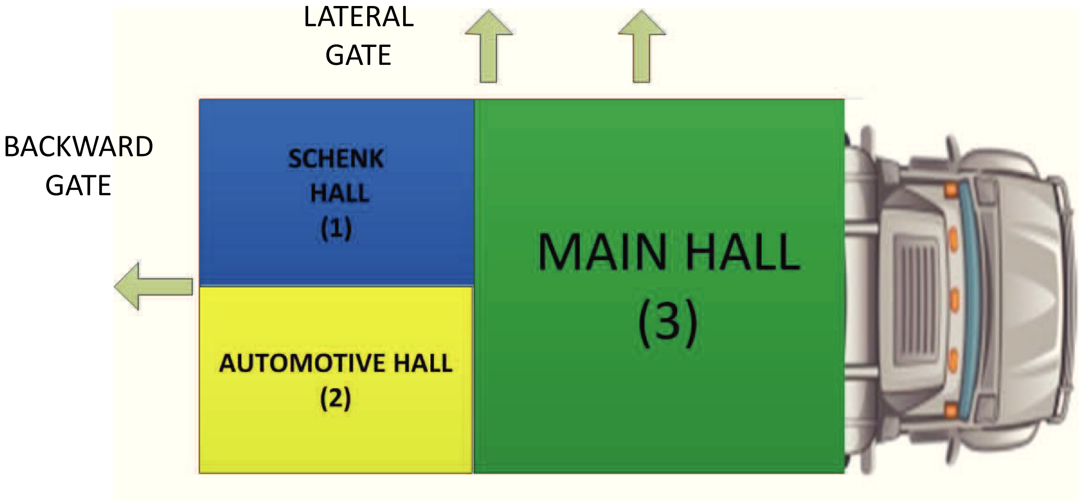

Figure 59 – Organization of the boxes inside the truck.

Thus, the driver can open the backward gate or the lateral gate that the boxes are placed on the right position, in order to unload first *Schenk* Hall, after Automotive Hall and finally Main Hall.

The time saved with these improvements can be seen on table 12.

Table 12 – Result of the time saved with the improvements.

Time/day [Minutes]	Workload	Driving	TOTAL
Actual	139	9	148
Improvement	121	5	126
Time saved	**18**	**4**	**22 min. (15%)**

Concerning the results shown above, the total reduction on time per day was 22 minutes, or 15% of the total time. Even more than time, there are human and material resources saved with these improvements.

4.4. Redefinition of Gearbox Cover PL7 production

Toyota production system uses the Value-Stream Mapping as a tool to analyze the material and information flows, distinguishing value-added from non-value added activities, in order of find root causes of the waste and eliminate it (Mike Rother, 2008).

The current project makes the waste of time the main focus of study, within the analysis of the workload for the operator; it was measured the time as a way to achieve the main goal, which is waste elimination.

4.4.1. Time analysis

There are two Production Lines (PL) to machining Gearbox PL7, another two PL's to machining Gearbox Cover 674 and on the fifth PL there are interspersed the production of the other two variations of Gearbox Cover: 477 and 478. Every PL has one robot and there are three operators to work on these five machines.

It is represented in table 13 the time measurement per shift, for operator's tasks, considering three different products being manufactured on five PL's. This measurement aims to analyze the operator's workload per machine and studying the actual situation for three types of products: PL7, 674 and 477.

Table 13 - Measurement of the workload for the operator, per product, considering 1 production line.

		Gearbox 674 (1 PL)			Gearbox PL7 (1 PL)			Gearbox 477 (1 PL)		
Step	List of tasks	Time/step [sec.]	Time/shift [sec.]	Calculation	Time/step [sec.]	Time/shift [sec.]	Calculation	Time/step [sec.]	Time/shift [sec.]	Calculation
1	Transport Empty GB from PL to WH	62	59	262units/shif; 275units/GB); 0,95GB/shift	62	74	395units/shift; 329units/ GB; 1,2 GB /shift	62	69	268 units/shift; 240units/ GB; 1,12 GB /shift
2	Transport Full GB from WH to PL	43	41	262units/shif; 275units/GB); 0,95GB/shift	43	52	395units/shift; 329units/ GB; 1,2 GB /shift	43	48	268 units/shift; 240units/ GB; 1,12 GB /shift
3	Transport Empty SLC near the PL	30	66	262units/shif; 120units/SLC; 2,2 SLC /shift	30	99	395units/shif; 120units/ SLC; 3,3 SLC /shift	30	67	268 units/shift; 120units/ SLC; 2,23 SLC/shift
4	Transport Full SLC from PL to WH	53	117	262units/shif; 120units/SLC; 2,2 SLC /shift	53	159	395units/shif; 120units/ SLC; 3,3 SLC /shift	53	118	268 units/shift; 120units/ SLC; 2,23 SLC/shift
5	Load part in the conveyor	3	786	262 units/shift	3	1185	395 units/shift	3	804	268 units/shift
6	Vacuum cleaning and visual control	15	3930	262 units/shift	11	4345	395 units/shift	14	3766	268 units/shift
7	Put part in the blister packs	3	786	262 units/shift	3	1185	395 units/shift	3	804	268 units/shift
8	Marking the part	1	262	262 units/shift	1	395	395 units/shift	1	268	268 units/shift
9	Put the covers on the boxes	18	197	4 in 1 step [18/4/6=0,75]	18	296	4 in 1 step [18/4/6=0,75]	18	201	4 in 1 step [18/4/6=0,75]
10	Move boxes' covers near conveyor	14	157	4 in 1 step [14/4/6=0,6]	14	237	4 in 1 step [14/4/6=0,6]	14	161	4 in 1 step [14/4/6=0,6]
11	Prepare Box to put FG	19	210	4 in 1 step [19/4/6=0,8]	19	316	4 in 1 step [19/4/6=0,8]	19	214	4 in 1 step [19/4/6=0,8]
12	Add info paper to the boxes	11	480	1 box=6 units	-	-	-	11	491	1 box=6 units
13	Walking between stations	5	110	12 parts per cycle; 22 x shift	5	165	12 parts per cycle; 33 x shift	5	115	12 parts per cycle; 23 x shift
Total workload/shift [sec.]:		**7201**			**8508**			**7126**		

It is known that in SDG there are three shifts per day, eight hours per shift and thirty minutes of break for each shift. Therefore, the previous calculation was made according to the available working time for one operator, which is 27.000 seconds per shift, yet excluding the breaking time. The result of the measurement is visible in Table 14, including the percentage of workload per product referring to one shift.

Table 14– Result of the calculation of total workload per operator for five Production lines.

	Products		
	Gearbox 674 (2 PL)	Gearbox PL7 (2 PL)	Gearbox 477 (1 PL)
Workload/shift [sec.]:	7201	8508	7126
Workload/Operator/PL [%]:	26,7%	31,5%	26,4%
Workload/Operator/product [%]:	53,3%	63%	26,4%
Total workload for 5 Production Liness/operator :	**143%**		

Considering that one operator can work 100% of the time per shift (excluding break time), it is possible to verify through the calculation that two operators can work in five machines. Then, there is 143% defined time per shift for all machines, which means 71,5% of workload per operator. The workload per operator is increased and human resources for this production are saved, once that one operator can handle 2,5 machines.

4.4.2. Value Stream analysis

Regarding the procedure abovementioned in this chapter, it is possible to make the Value Stream Mapping (VSM) in spite of visualize the information to forecast the closed process of the product PL7. The quantity of material needed per unit for the die casting process is 0,85 Kg, thus, with one pot of molten aluminium (600Kg) it is possible to make 705 units. In this case, it is necessary to consider that 60% of this

0,85Kg is RA so, if 1 batch of RA weights 650Kg and it is necessary 0,51Kg of RA to make one part, there are 1.274 units in 1 batch of RA.

Through the review of figure 60, which represents the VSM correspondent to the production in SSK, and figure 61 that shows the procedure in SDG, it is possible to see the whole operation. Figure 62 exhibits the external VSM of all the process from the customer's demand to the respective delivery.

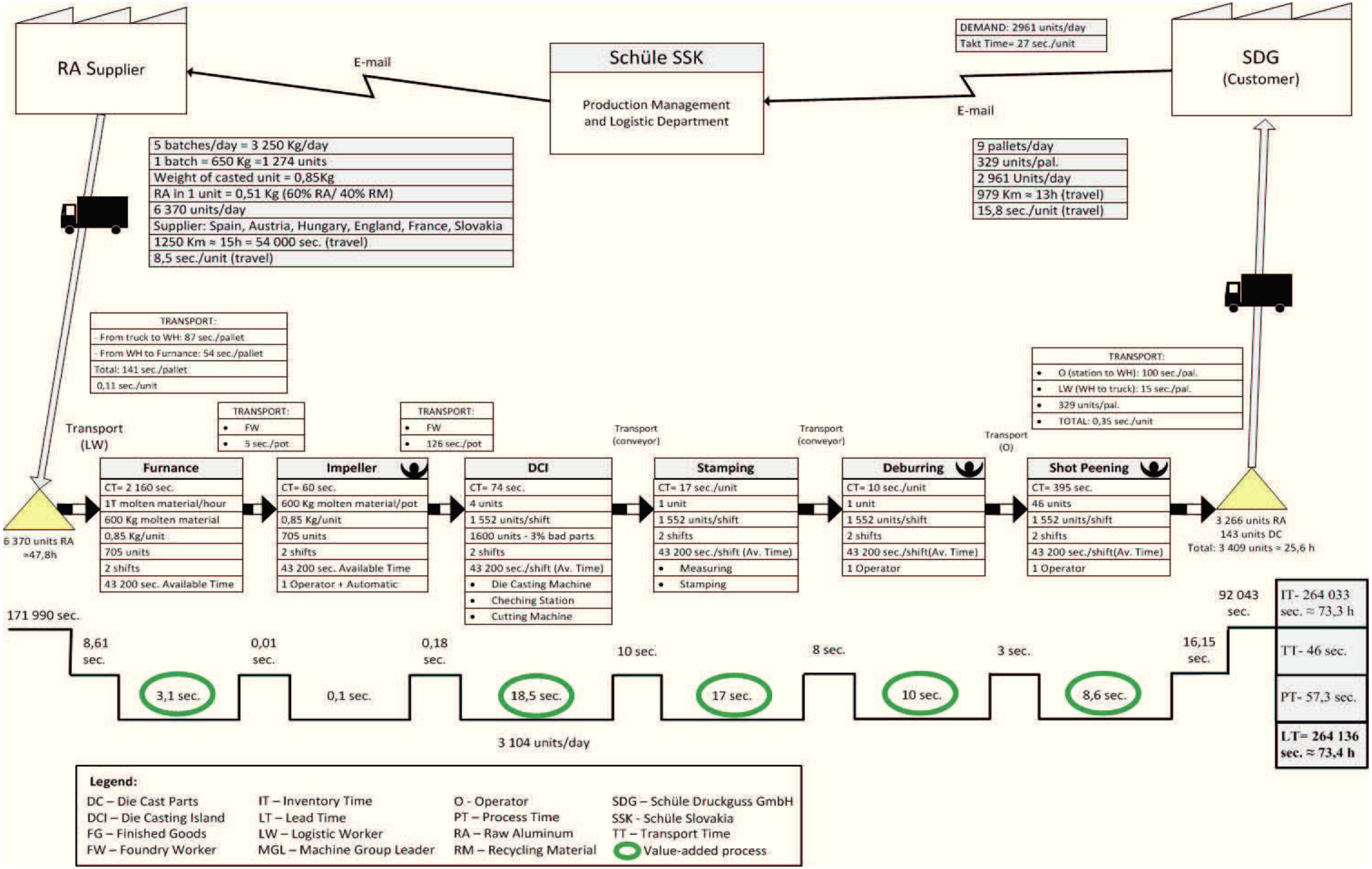

Figure 60 - Value Stream Mapping of the Gearbox PL7 in *Schüle* Slovakia.

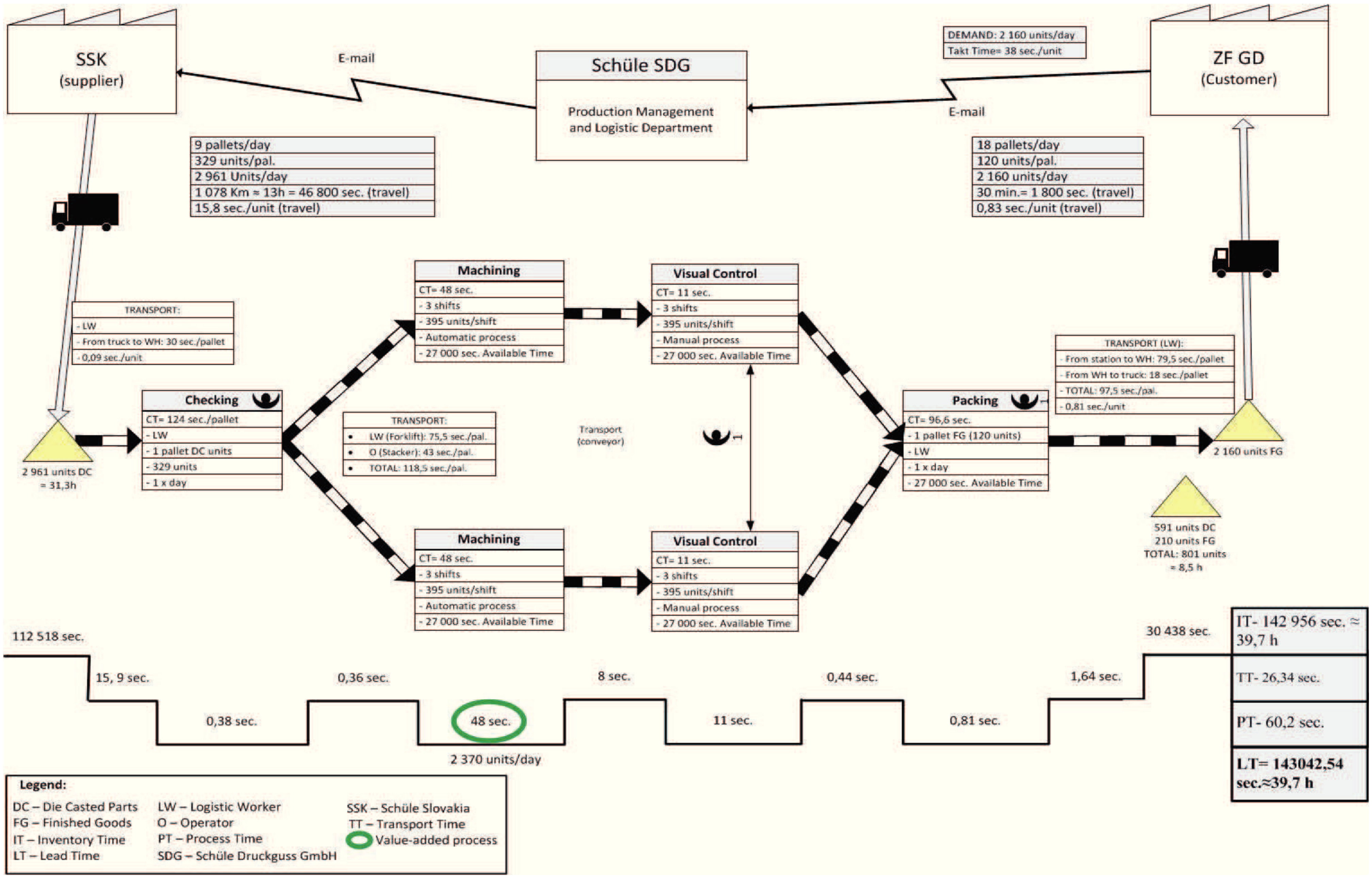

Figure 61 - Value Stream Mapping of the Gearbox PL7 in *Schüle* Germany.

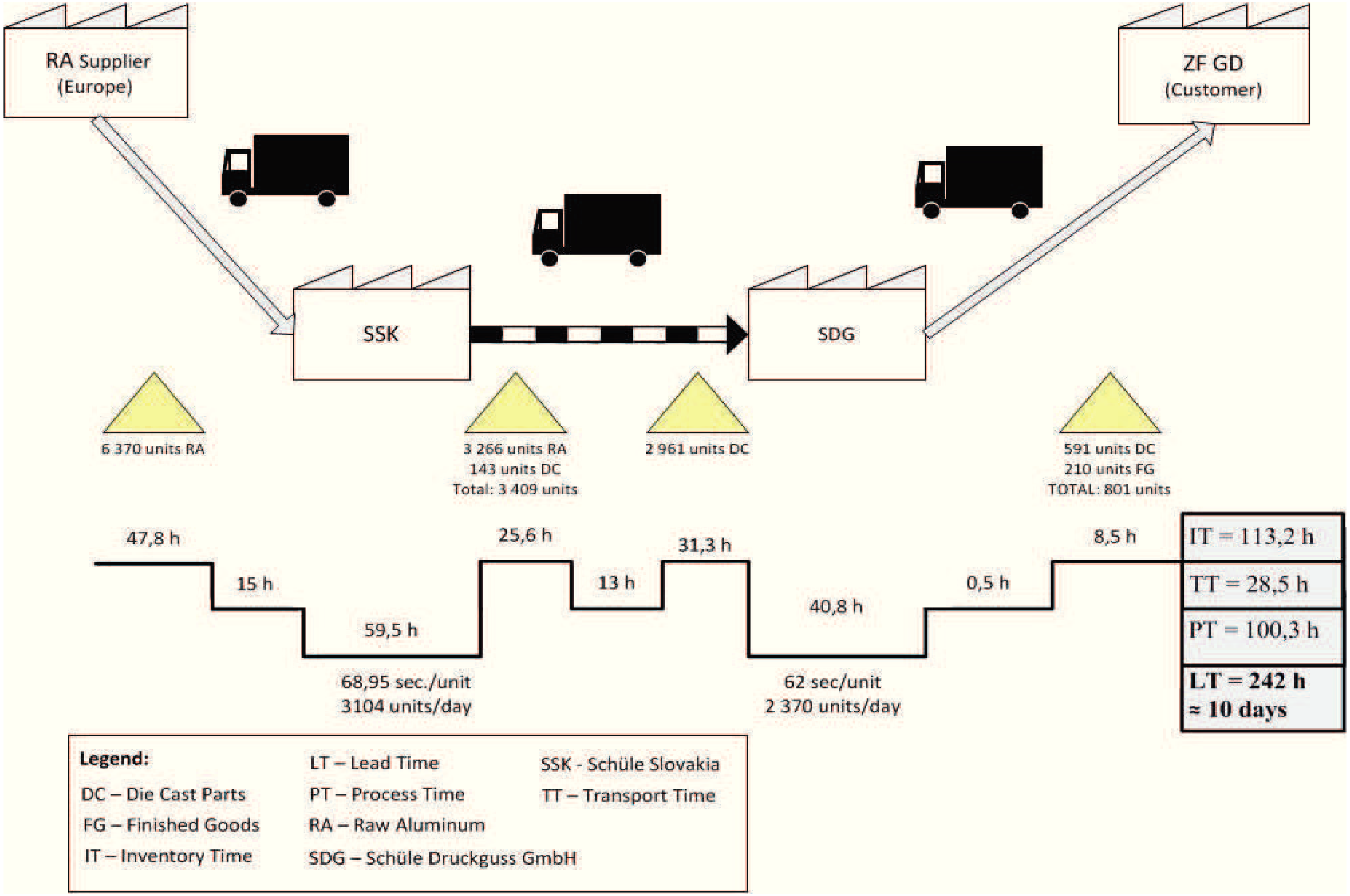

Figure 62 – External Value Stream Mapping of the Gearbox PL7.

4.4.3. Improvements and impacts estimation of the results

If the Gearbox Cover PL7 is moved to SSK, without make any change on the procedure, it will be possible to reach the production as described in figure 63 (VSM for the future situation). Based on that, it is possible to observe that the lead time of the process is 132,4 seconds per unit, without inventory and external transportation. The *takt* time is 38 seconds per unit, according with the available work time in SSK. It includes nine processes and five operators: 1 Foundry Worker, 3 operators and 1 Logistic Worker.

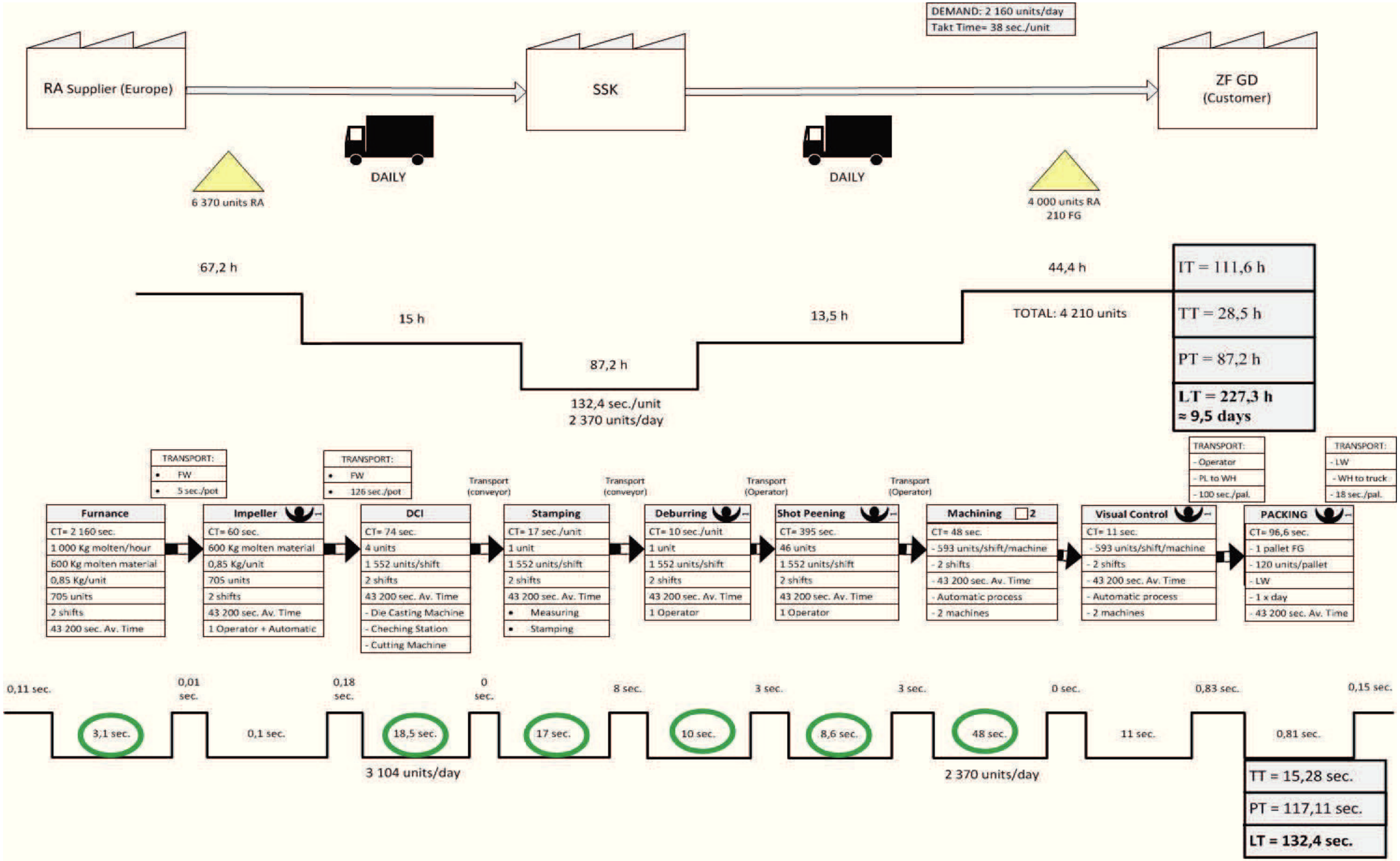

Figure 63 – Value Stream Mapping with the symbiosis of processes, without making any improvement.

Through a deep analysis of the VSM, it is recognized that there is the possibility to include the stamping, debarring and shot peening processes into the Die Casting Island (DCI). The result of this symbiosis is shown on figure 64.

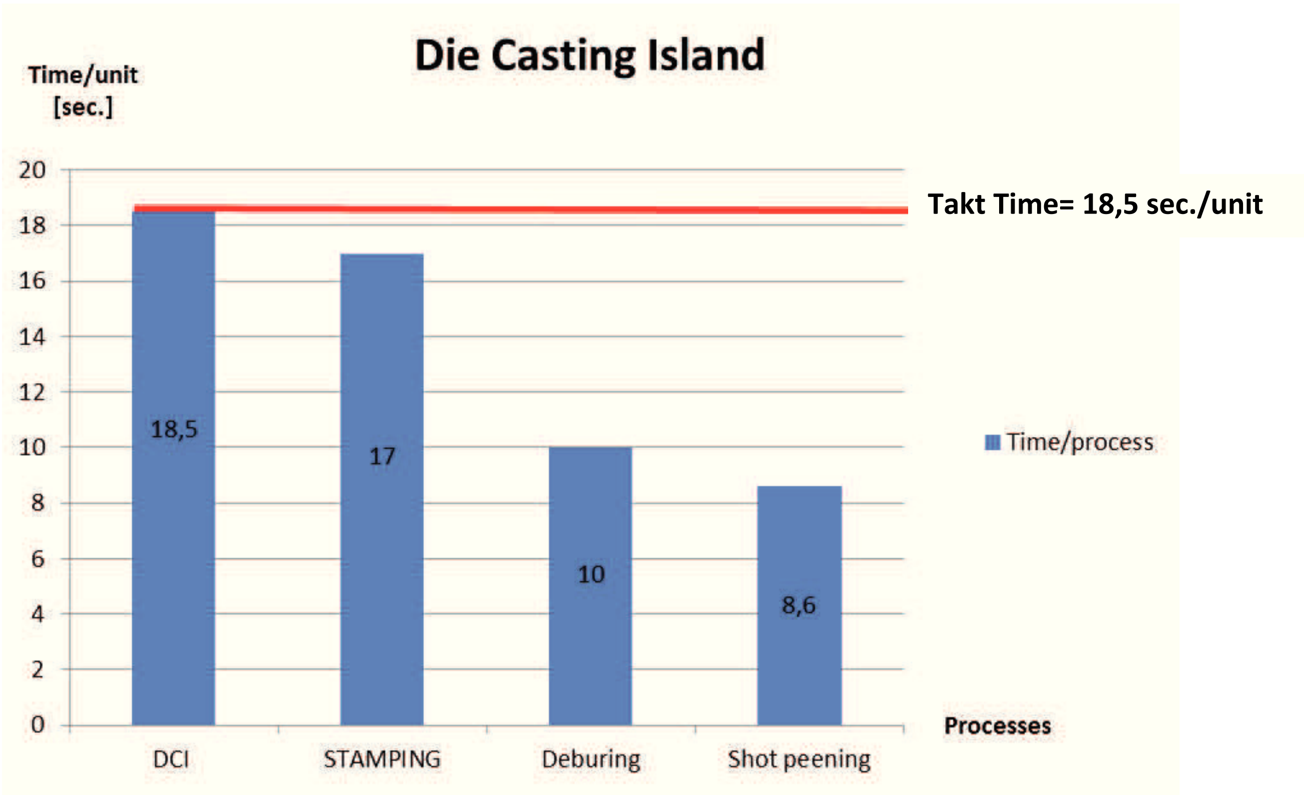

Figure 64 - *Takt* Time of the processes included inside of the Die-Casting Island.

Therefore, the *takt* time of the DCI will be maintained, once that 18,5 seconds is the higher cycle time among the processes in study. Afterwards, a new procedure is suggested, which can be visualized on figure 65.

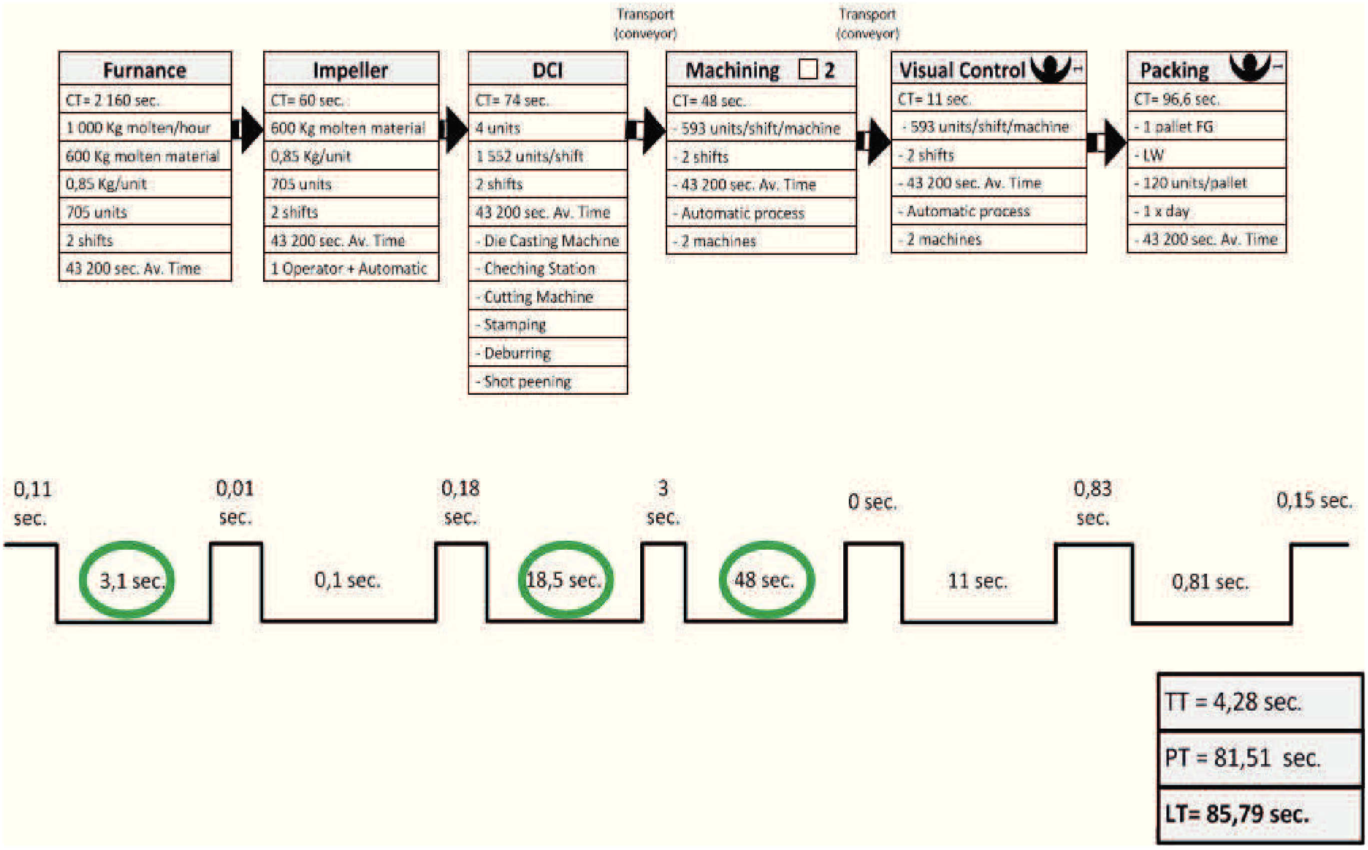

Figure 65 - Procedure for all manufacturing process of Gearbox PL7 with the improved situation.

Once that the debarring and shot peening processes will be automatized, the two workers involved on these procedures are not necessary and can do another tasks. The results for the time saved on the operator’s tasks, including the abovementioned processes inclusion on the automatic processes, are resumed on Table 15.

Table 15 - Percentage of operator’s tasks on the processes that will be automatized.

Process	Time [sec./unit]	Time saved/shift [%]
Debarring	10	36%
Shot peening	3	11%

Considering the improvement achieved and the procedure analyzed for the situation in SDG, mentioned previously, it is necessary two workers instead of three, to work in five PLs. These two workers still have 57% of free time that can be used for other tasks. Table 16 represents the time saved with this improvement.

Table 16 - Result of the time saved with the new improvement.

	Time Without improvement [sec./unit]	Time With improvement [sec./unit]	Time saved [%]
Process Time	117,11	81,51	30%
Transport Time	15,28	4,28	70%
Lead Time	**132,4**	**85,8**	**35%**

According with the proposed solution, it can be noticed that 35% of time is saved on the lead time per unit, the level of human resources needed decreases, the transport between *Schüle Druckguss* companies will be eliminated and the level for safety storage decreases.

5. Conclusion

Within the industry of die casting aluminium, it was developed projects based on some problematic issues faced by the company *Schüle Druckguss*. In order to achieve the best practices toward to improvement, it was used Lean tools and techniques to support on this upgrading. It started by observing and assesses to the production performance and the environment that surrounds, in order to identify bottlenecks or critical areas that could be changed for better.

According with a primary general study, the focus was on the workload inherent to the workers in *Schenk* Hall, as well as material flow and workplace organization. Aiming to optimize the workload, it was studied the tasks in which the operator spent mostly of the time, using the Pareto analysis and the result shows that the visual checking process must be reformulated. Therefore, it was studied the possibility of automation of this process and it would save 34% of the time on the product "Housing CP14" and 32% of the time for the product "GM Delta". In the same way it would require two operators instead of three, to work on six production lines, referring to these two products. Considering that the organization is raising its production, the mostly appliance of this project is on optimization of resources by using it properly and taking in consideration the respect for people.

Referring to the workplace in *Schenk* Hall, it was verified that there was no defined place for tools and boxes, and it was problematic to transport boxes between production line and warehouse, while material was on the way. Thus, it was created a colored marking system on the floor, aiming to create a way for transport and for place boxes and tools. This project was applied and the results were profitable with an organized workplace and consequently, workers more motivated to do their jobs. Therefore, the transport of boxes between production line and warehouse, done by the operator with a pallet jack, was shared with the logistic worker. Assuming that the logistic worker can drive an electric forklift, it would take less 43% of the time that corresponds to 46 minutes per day transporting the material.

Focusing on the high inventory of raw material for the product "Topf", it was determined the cost for the space on the warehouse to store it. Thus, the Economic Order Quantity (EOQ) was calculated, as a reference that considers features inherent to the amount necessary per year, and the outcome was 34% less inventory or less 1.106€ invested per year.

Referring to the finish goods of the same product, it was considered a new layout for store the parts inside the box that enables to place 42 parts instead of 40 per box. The supplier of the inlays would not need to make any investment on tools to concretize it, once these layout already belongs to the products available, just need to be adapted and its price should be the same. Therefore, the inventory of parts would decrease and the costs for transports would be reduced in 7.800€ per year.

Regarding the daily transportation between the daughter company in Slovakia and Germany, the activities inherent to the truck were measured and main sources of waste detected. Towards to eliminate time wasted by the logistic worker on the hall on unloading and loading again the wrong boxes, it was created a system to identify the material. It was implemented a system for the boxes, distinguishing the halls by colors, where the material belongs to, and label the box with the name of the material inside. Furthermore the route program of this truck was changed, saving 4 minutes per day, as well as the organization of the truck itself that was accordingly defined with the order of the truck' stops. Summarizing, the appliance of improvements saved 15% of the time per day, which is 22 minutes, within the new route for the truck and the elimination of its wasteful activities.

Referring to the product “Gearbox Cover PL7” that is die-casted in Slovakia, and machined in Germany, its production will be done entirely in Slovakia. Therefore, it was studied the workload of the operators on this product and predict the total Lead time with the support of the Value Stream Mapping (VSM). There were decided to automatize two processes and, consequently, the Lead time, without considering inventory, was reduced in 35%. The inventory time is responsible for most of the waste and is a target to be also reduced in the future, in order to short the Lead time.

Seeking for getting more profits, the organizations can find in Lean production a low cost enhancement of activities, by optimizing the existing resources. Even though people resist to changes, the persistence of getting methodologies for do better a task prevails and along the time the profits are visible.

Highlighting the standards is crucial on the way to achieve benefits, otherwise if the improvements made are not followed, it will be vainly the efforts to get more profits. Therefore the improvements suggested with this project should be applied and standardized in order to lead to a success organization.

5.1. Future perspectives

Regarding that in Lean philosophy there is always space for improvement, there are proposals of projects that can be concretized in the future. Even if the projects presented refer to cases of study using few products, the methodology can be applied to other projects in order to get standards.

Referring to the main hall of the company, there were determined on chapter 4.3, "Logistic of transports", causes that lead to a poor logistic organization, and one of these causes is an overlapping of trucks coming at the same time. It could be created a schedule for the trucks by making a study of all the trucks that came on the company and organize in a way that could make the work easier for the logistic worker and also for the drivers of the trucks, (i.e., so they would not wait so much time). Another suggestion should be applying an electronic *Kanban* for register the material that goes in and out of the warehouse once that the logistic worker is driving the boxes with the electric forklift. Certainly the boxes full or empty with material should be labeled with a code that gives this information to the system. Thus, the paperwork could be eliminated, as well as the task of insert all the information on the system and the material would not need to be checked every time before to be loaded.

Considering that the previous improvement is applied, and the boxes full of raw material are registered on the electronic *Kanban*, hereafter the logistic worker drives it directly to the correspondent warehouse. Thus, the external place used now to sort the boxes, which are checked previously before to be moved to different warehouses, could be free to make other activities, even more, for inserting other production lines.

In the future, through the new plant of the external warehouse on main hall, it also could be applied a net that would cover all the ceiling in order to eliminate the undesirable presence of birds, responsible for dirtying the material standing there.

Referring to the material, which comes from the Die Casting Island of the product "Topf", and is reused again on the furnace, it is driven by a worker every 15 minutes. Thus, the suggestion would be to invest on automatic transports for this and optimization of the mold, referring to the excess of material that comes out every time.

Hereby, there are always situations that can be improved, saving resources and time, in order to lead to a Lean organization.

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Annexes

I - Layout of the Production Lines in Schenk Hall

II - Layout of the Production Lines in Schenk Hall

III - Steps for control the product Housing CP 14

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V - Analysis of the product GM Delta

VI - Workload for the MGL and SMGL

VI - Analysis of the product GM Delta

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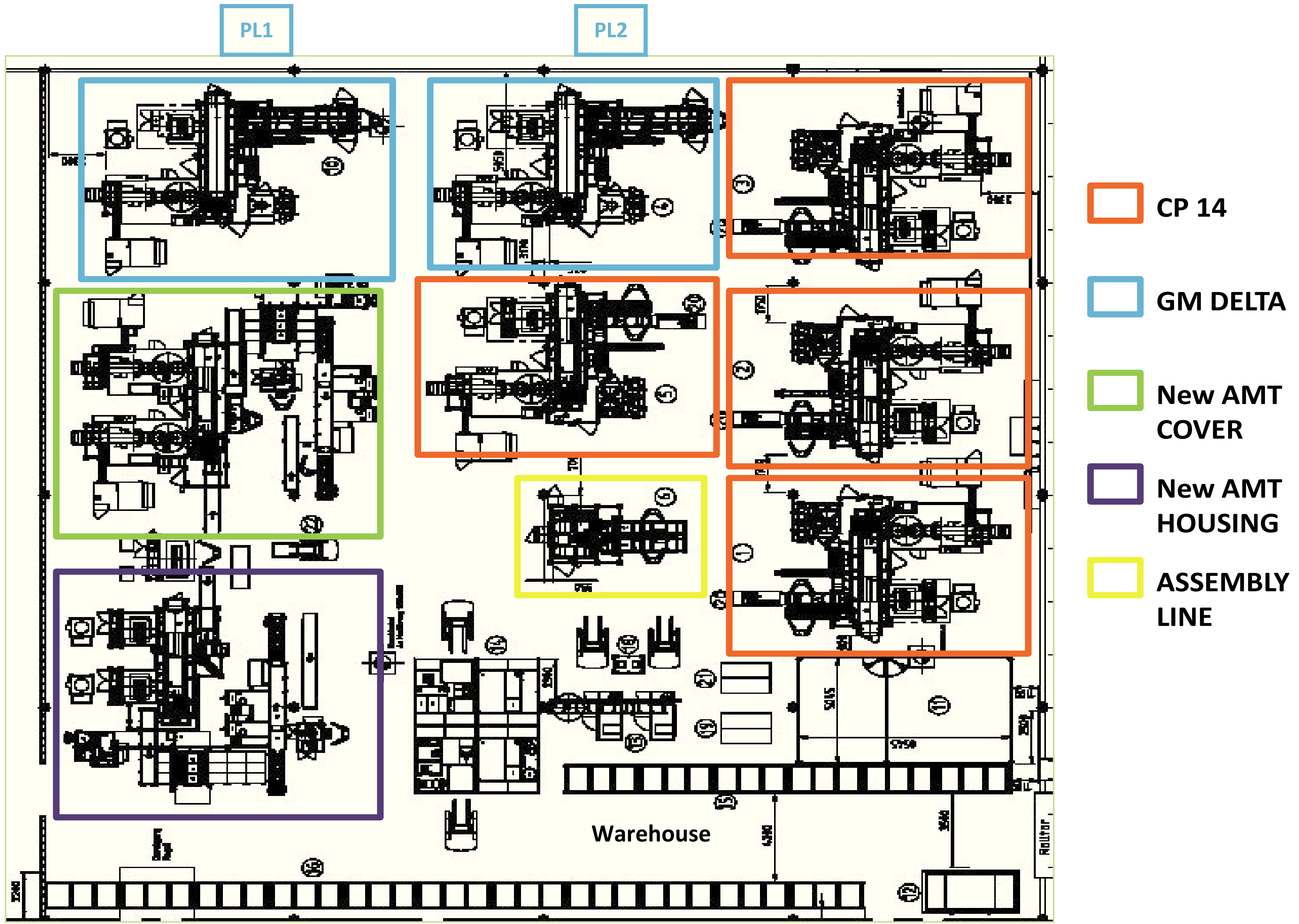
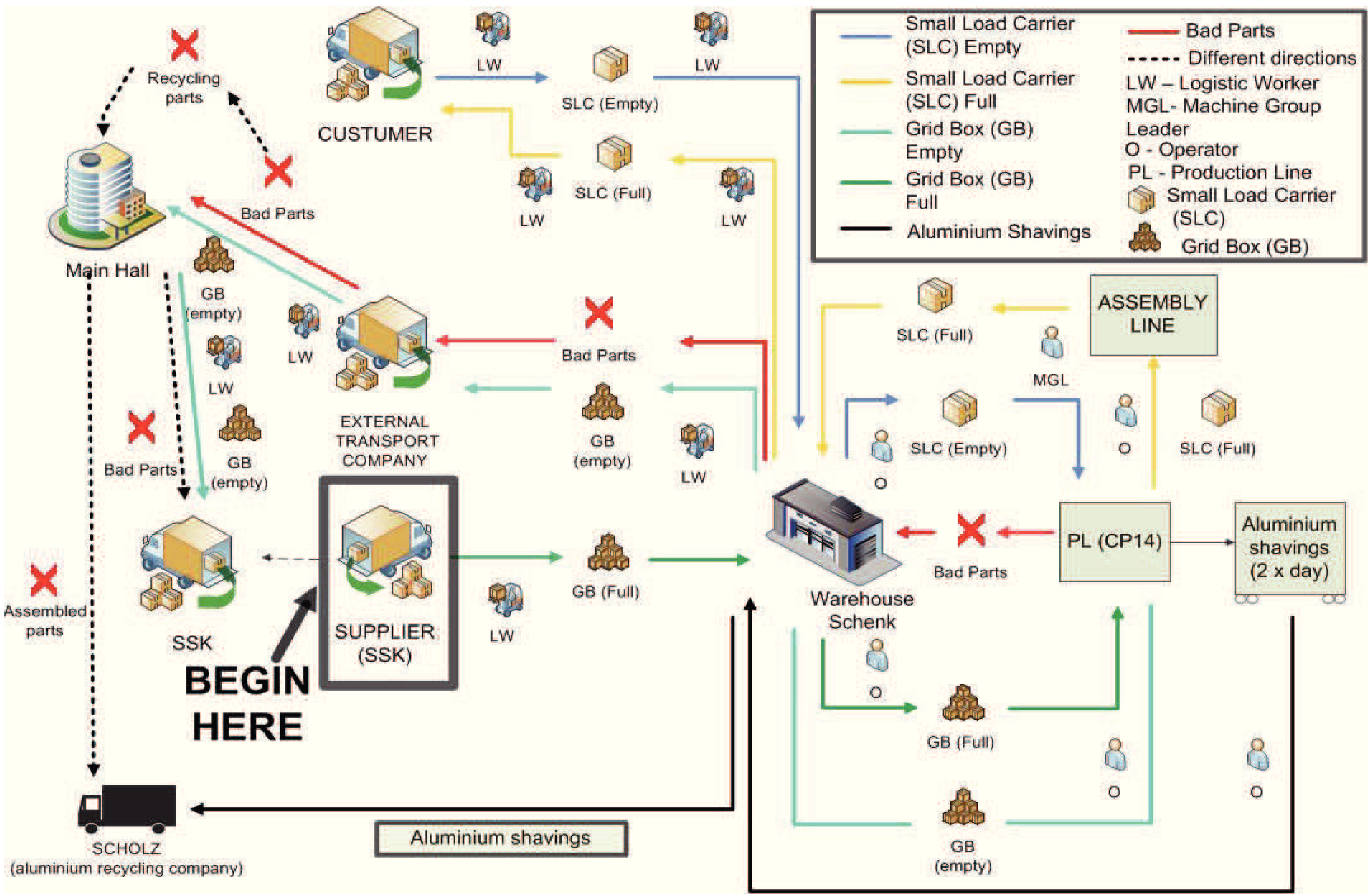
Annex I
Layout of the Production Lines in Schenk Hall


PL1
PL2
Warehouse
CP 14
GM DELTA
New AMT COVER
New AMT HOUSING
ASSEMBLY LINE

Annex II

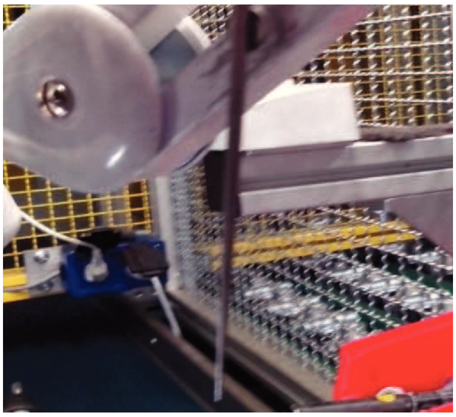
Layout of the Production Lines in Schenk Hall


Small Load Carrier (SLC) Empty
Small Load Carrier (SLC) Full
Grid Box (GB) Empty
Grid Box (GB) Full
Aluminium Shavings
Bad Parts
Different directions
LW – Logistic Worker
MGL- Machine Group Leader
O - Operator
PL - Production Line
Small Load Carrier (SLC)
Grid Box (GB)
Recycling parts
Bad Parts
Main Hall
CUSTUMER
LW
SLC (Empty)
LW
SLC (Full)
LW
LW
GB (empty)
LW
LW
EXTERNAL TRANSPORT COMPANY
Bad Parts
GB (empty)
LW
Bad Parts
GB (empty)
Assembled parts
SSK
SUPPLIER (SSK)
BEGIN HERE
LW
GB (Full)
ASSEMBLY LINE
SLC (Full)
MGL
SLC (Empty)
O
O
SLC (Full)
Warehouse Schenk
Bad Parts
PL (CP14)
Aluminium shavings (2 x day)
O
GB (Full)
O
O
GB (empty)
SCHOLZ (aluminium recycling company)
Aluminium shavings

Annex III
Steps for control the product Housing CP 14

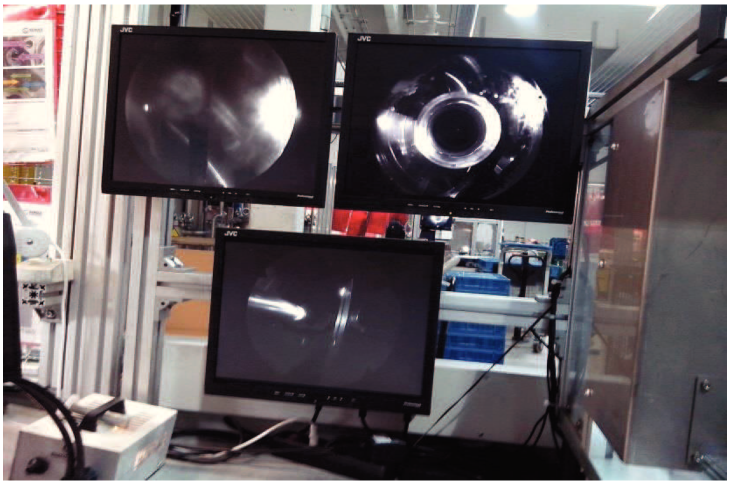
1. h a

2. Clean with a spiral automatic machine.



3. Make a visual control and take off the aluminium sharps with a tool.

4. Cleaning with a vacuum machine and check with a flashlight.



5. Make an endoscopy test in three different points of the part.

Annex IV

Measurement for control the product Housing CP 14

Measurement of time for controlling the part, done by two operators, including all steps.

		Time/ part [sec.]				
	Measurement	Step 1	Step 2	Step 3/4	Step 5	
Operator 1	1	3,5	2,5	20,1	4	
	2	3,5	2,5	24,7	8	
	3	3,5	2,5	20,7	7	
	4	3,6	3,8	19,0	5,3	
	5	3,6	3,8	22,0	12	
	6	3,6	3,8	21,0	7,9	
	7	3,6	5,0	24,0	9	
	8	3,3	5,0	25,0	7,6	
	9	3,3	5,0	26,0	8,9	
	10	3,3	3,5	25,0	6,4	
Operator 2	1	1,8	2,0	17,0	8,0	
	2	1,8	2,0	15,0	4,0	
	3	1,8	2,0	15,0	7,0	
	4	1,8	2,0	15,0	6,2	
	5	1,6	2,3	17,7	7,5	
	6	1,6	2,3	17,8	8,9	
	7	2,4	2,5	19,0	8,7	
	8	2,4	5,2	17,0	9,2	
	9	2,4	4,0	17,5	11,4	
	10	2,4	3,5	17,5	10,0	**Total**
	Average:	**2,7**	**3,3**	**19,8**	**7,9**	**33,7**

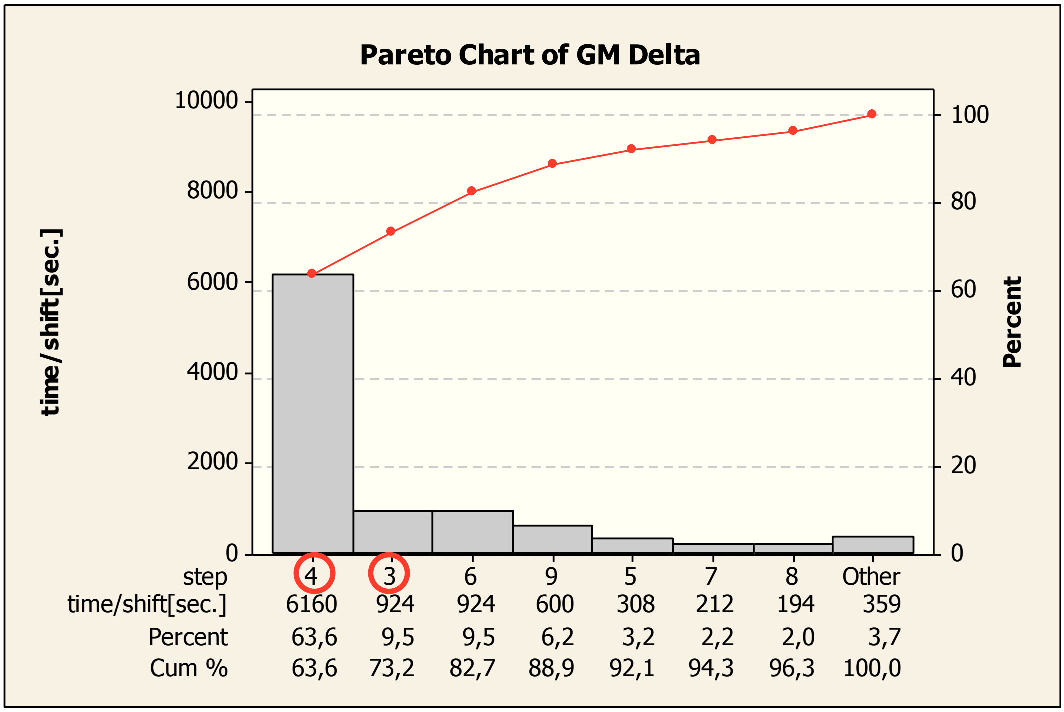
Annex V

Analysis of the product GM Delta

Workload for one operator on one PL of the product GM Delta.

1 Operator; 1 PL of GM Delta				
Step	Tasks	Time/step [sec.]	Time/shift [sec.]	Calculation
1	Transport GB empty from PL to WH	74,5	83	308 units/275 units=1,12 shifts/GB
2	Transport GB full from WH to PL	85,5	96	308 units/275 units=1,12 shifts/GB
3	Load on the conveyor	3	924	308 units/shift
4	Visual control/ Clean	20	6160	308 units/shift
5	Mark the part	1	308	308 units/shift
6	Load the Small Load Carrier	3	924	308 units/shift
7	Transport SLC full from PL to WH	81,5	212	308 units/120 units/SLC=2,6
8	Transport SLC empty from WH to PL	74,5	194	308 units/120 units/SLC=2,6
9	Examination	300	600	2 x shift
10	Bring the aluminium shavings to the big container	180	180	1 x shift
	Total:	**9681 sec./shift/ PL**		

Pareto analysis of the tasks for the operator on the product GM Delta



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Comparison between a manual and automatized control of the product GM Delta.

	Time/ Step [sec.]	Time/ Step/ Shift [sec.]	% Task/ Shift	Workload/ Shift [sec.]	% Workload/ 2 machines shift	Operators for 2 machines
Manual control	20	6160	23%	9681	72%	1
Automatized control	10	3080	11%	6601	49%	1
Total time saved	10	3080	11%	3080	22%	

Annex VI

Workload for the MGL and SMGL

MGL/ SMGL (total workload)			
Step	Task	Time/ Step [sec.]	Time/ shift [sec.]
1	Transport 1,8 SLC of CP 14 from assembly line to the warehouse	80	144
2	Load and unload the material in the assembly line(24 boxes;1,8 SLC)	10	432
4	100 % examination in the laboratory (3 units/shift)	1200	3600
5	Routine test of 1 unit/shift of each PL (7 units)	7	14
6	Maintenance of all machines (30% of the time)	8 100	8100
	TOTAL:	**12290 sec./shift**	

Worker	Workload/ shift [sec.]	Percentage of Workload/ shift
MGL	6145	22,8%
SMGL	6145	22,8%

Annex VII

Analysis of the workload for Logistic Worker

Shift 1				Shift 2	
Step	Task	Time/ shift[sec.]	Calculation	Time/ shift[sec.]	Calculation
1	Unload GB from SSK truck	320[1]	20sec/GB 13 GB		
2	Load empty GB	348[1]	16 sec./ GB 18 GB		
3	Unload empty SLC from the truck	684[1]	16 sec./ SLC 39 SLC		
4	Load SLC full on the truck	480[1]	30sec./ SLC 14 SLC		
5	Visual inspection of GM Delta	2232	3 parts x 6 GB		
6	Visual inspection of NEW AMT	1488	6 parts x 2 GB		
7	Visual inspection of Housing CP14	5208	7 parts x 6 GB		
8	Introduce information on the computer and label the GB	390	5 sec./step; 18 GB+300sec.		
9	Introduce information on the computer of SLC	300	300 sec.		
10	Sort GB on the shelves	260	20 sec./GB 13 GB		
11	Sort SLC on the shelves	780	20 sec./SLC 39 SLC		
12	Packing all SLC pallets and tagging	1067	22 SLC/2 shifts;97 sec.	1067	22 SLC/2 shifts;97 sec.
15	Prepare the container with aluminium shavings	40	1200 sec./week	40	1200 sec./week
16	Bring small container empty of aluminium shavings back in the station	840	120 sec./step	840	120 sec./step

[1] It was added 60 sec. Because the LW needs also to go to the forklift, communicate with the driver and others.

			7 machines		7 machines
17	Change garbage containers	300	600sec. 1xday	300	600sec. 1xday
TOTAL:		14 737 sec./shift		2 247 sec./shift	

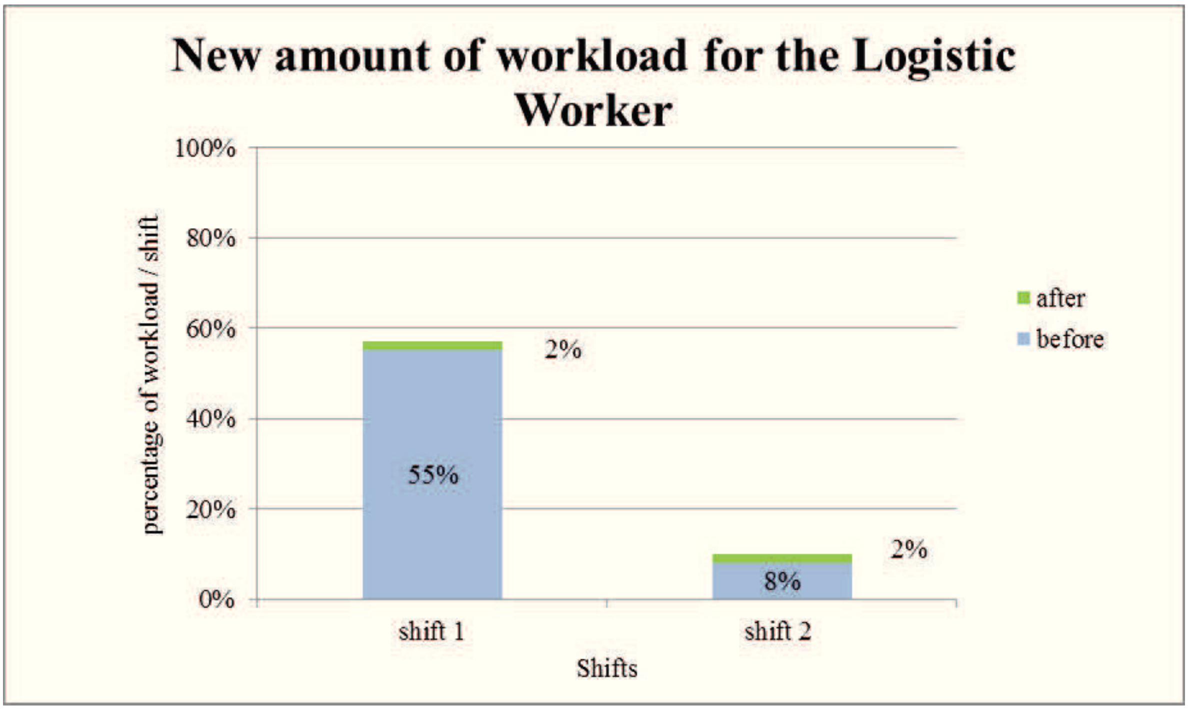
Logistic Worker		
Shift	Workload/ shift [sec.]	Percentage of Worload/ shift
1st	14 737	54,6%
2nd	2 247	8,3%

Annex VIII

Transport of material

Pallets' transport done by the operator					
	Actual		**Future**		Nr. boxes transported/ day
Housing CP 14	Time/step [sec]	Time/day [sec.]	Time/step [sec]	Time/day [sec.]	Boxes/ machine
Transport GB empty from PL to WH	72	72	28	28	1 GB/day
Transport GB full from WH to PL	84,6	85	32,0	32	1 GB/day
Transport SLC full to assembly line	9,0	18	32,0	64	2 SLC/day
Transport SLC empty from WH to PL	72	144	28	56	2 SLC/day
TOTAL for 3 PL:	**16 min./day**		**9 min. /day**		**12 boxes**
GM Delta PL1					
Transport GB empty from PL to WH	68	272			4 GB/day
Transport GB full from WH to PL	78	312			4 GB/day
Transport SLC full from PL to WH	74	592			8 SLC/day
Transport SLC empty from WH to PL	68	544			8 SLC/day
TOTAL for 1 PL:	**28,7 min./day**		**0 min./day**		**24 boxes**
GM Delta PL2					
Transport GB empty from PL to WH	81	324	41	164	4 GB /day
Transport GB full from WH to PL	93	372	47	188	4 GB/day
Transport SLC full from PL to WH	89	712	45	360	8 SLC/day
Transport SLC empty from WH to PL	81	648	40,5	324	8 SLC/day
TOTAL for 1 PL:	**34,3 min./day**		**17,3 min./day**		**24 boxes**
NEW AMT Cover + Housing					
Transport GB empty from PL to WH	66	132			2 GB/day
Transport GB full from WH to PL	74	148			2 GB/day
Transport SLC full from PL to WH	70	280			4 SLC/day
Transport SLC empty from WH to PL	66	264			4 SLC/day
TOTAL for 2 PL:	**27,5 min./ day**		**0 min./day**		**24 boxes**

Pallets' transport done by the Logistic Worker			
Housing CP 14	Time/step [sec]	Time/day [sec.]	Nr. boxes transported/ day
Transport GB empty from PL to WH	40	40	1 GB/day
Transport GB full from WH to PL	45	45	1 GB/day
Transport SLC full to assembly line	45	90	2 SLC/day
Transport SLC empty from WH to PL	40	80	2 SLC/day
TOTAL for 3 PL:	**6,4 min./day**		**12 Boxes; 6 transports**
GM Delta PL1			
Transport GB empty from PL to WH	55	220	4 GB/day
Transport GB full from WH to PL	60	240	4 GB/day
Transport SLC full from PL to WH	60	480	8 SLC/day
Transport SLC empty from WH to PL	55	440	8 SLC/day
TOTAL for 1 PL:	**11,5 min./day**		**24 Boxes; 12 transports**
GM Delta PL2			
Transport GB empty from PL to WH	40	160	4 GB /day
Transport GB full from WH to PL	45	180	4 GB/day
Transport SLC full from PL to WH	45	360	8 SLC/day
Transport SLC empty from WH to PL	40	320	8 SLC/day
TOTAL for 1 PL:	**8,5 min./day**		**24 Boxes; 12 transports**
NEW AMT Cover + Housing			
Transport GB empty from PL to WH	40	80	2 GB/day
Transport GB full from WH to PL	45	90	2 GB/day
Transport SLC full from PL to WH	45	180	4 SLC/day
Transport SLC empty from WH to PL	40	160	4 SLC/day
TOTAL for 2PL:	**8,5 min./day**		**24 Boxes; 12 transports**



New amount of workload for the Logistic Worker
100%
80%
60%
40%
20%
0%
percentage of workload / shift
55%
2%
8%
2%
shift 1
shift 2
Shifts
after
before

Annex IX

Informative Document for pallets' transport

Pallets Transport in *Schenk* Hall (Test run)

Pallets: Grid Boxes and Small Load Carriers

Transport way

Tool boxes and pallets transported by Logistic Worker.

Instructions:

- Do not place material on the transport way (limited with yellow marks);
- The pallets should be placed within the limits defined by the blue marks;
- The Logistic Worker transports the grid boxes, with raw parts from the warehouse to the production line and places it within the red marks (New AMT production lines)
- The Logistic Worker transports the grid boxes, with raw parts, and the empty small load carriers, from the warehouse to the production line and place it within the red marks (New AMT);
- The operator brings the Grid Box full and Small load carrier empty, from the red marks place to the area with blue marks, near the production line(New AMT);
- The operator moves the empty Grid Box and full Small load carrier, to the red marks area, to be transported by the logistic worker;
- The Logistic Worker transports the empty grid boxes and the full small load carriers, with finish goods, from the production line to the warehouse. (New AMT)
- When the logistic worker cannot make the transport between warehouse and production lines, Machine Group Leader or Sub Machine Group Leader have to do it.
- In case of impossibility of Machine Group Leader or Sub Machine Group Leader to make the transport, the operator will do it as before.

Notes and suggestions of the workers: