PRODUCTION DEVELOPMENT IN SHORT RUN MANUFACTURING

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ABSTRACT

The aims of this thesis are analysing current solutions and identifying main problems with production processes in the Company, as well as searching for costless or low-cost solutions to those issues. To accomplish those goals various practices of analysing have been applied. Amongst those methods were: interviewing employees and management, own expertise of 3 years working in the case company, stopwatch study, analysing production processes following various example parts going through production path. This thesis consists of the study methods with examples and analysis as well as conclusions and propositions of improvements.

In the theoretical part of this thesis solutions for production improvement are being found in literature. Company's own ideas and already made improvements are being assessed, as well as discussed with management.

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CONTENTS

1 INTRODUCTION

1.1 Manufacturing

> "Manufacturing is the backbone of any industrialized nation. Manufacturing and technical staff in industry must know the various manufacturing processes, materials being processed, tools and equipment for manufacturing different components or products with optimal process plan using proper precautions and specified safety rules to avoid accidents. (Singh 2006, 1)"

1.2 Case company

The Company is a family owned company that specialises mostly in low volume production of metal plate or tubular products, the variation of products, as well as customers is very large. Main customers come from railway, automotive, construction equipment, furniture industries, but companies in need of prototype or even private customers requiring specific product are not being dismissed. Another quality of the Company is great flexibility and ability to produce urgent delivery items, because of low volume of products it usually does not cause large disturbance in production flow due to retooling. The company is also characterised by a great variation of products and diversity in production.

Most of Company's production consists of parts which start as sheet metal, tubes or metal profiles, which are cut to specific dimensions with saw, power shear, laser cut, or punched depending on a product. Further details are then bench drilled, punched, welded on or bent depending on a product and production volume. There is also CNC department with milling machines and lathes which mostly produces small parts of more complicated larger components, which are then welded to them. The next step is finishing and surface treatment which in case of powder coating is done in-house, otherwise subcontracted to companies specialising in coating. Company has a variety of devices and qualified workforce which allows it to offer very short-term deliveries, should the need arise. It is one of the Company's characteristic features, care for customer needs is very high. It is also complying with ISO 9001, 14001 certificates. It has been growing continuously during last years.

2 COMPANY LAYOUT

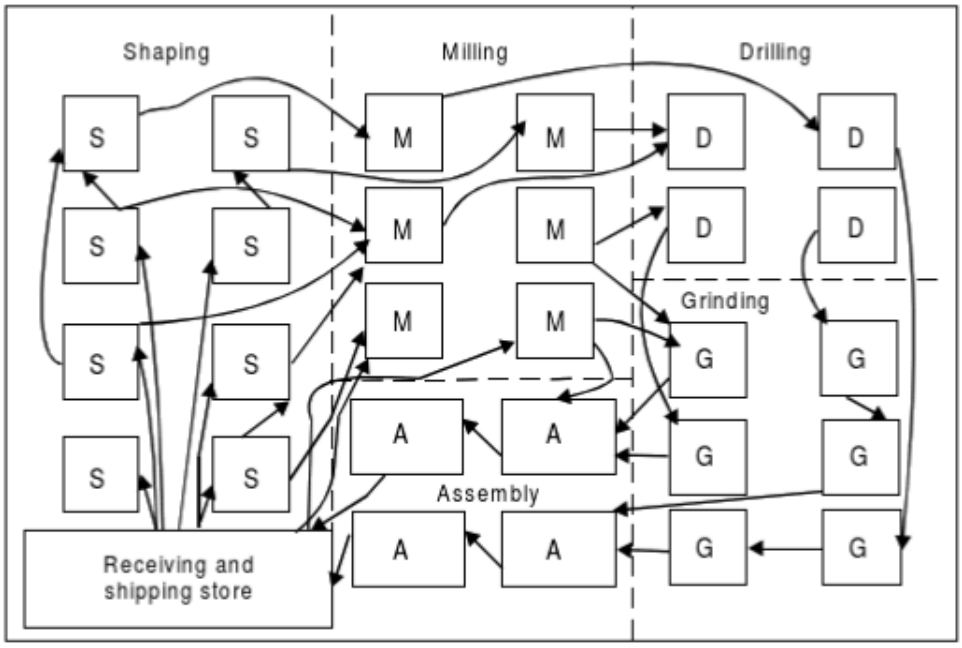
Plant layout is such a systematic and efficient functional arrangement of various departments, machines, tools, equipment and other supports services of an industrial organization that will facilitate the smooth processing of the proposed or undertaken product in the most effective, most efficient and most economical manner in the minimum possible time. (Singh 2006, 17)

Company utilizes a functional layout (Fig. 1) which is perfectly suited for this type of company, because of its flexibility, ease of adjustment for different orders and suitability for batch production, especially for small batches of different products. Other merits of that layout are better utilisation of the machines, comparatively to other layouts and smaller investment in the machines, which is one of crucial factors in companies of similar size.

Another benefit of functional layout is that employees are assigned with similar tasks and equipment on everyday basis and are specialized in their work, this improves quality and pace of work.

Downsides of that layout are layover times, slower production and need for manual product handling inside the company, but this last quantity is almost negligible because of small batches and generally low weight as well as using palettes with hand pallet trucks and carts or other handling devices. Apart from these and the other downsides it is the best suited layout for the Company because of large differentiation in production, small batches and need for constant retooling.

The Company is a business operating in two shifts, first starts at 6:00 and finishes at 14:30, second starts at 14:00 and ends at 22:00, half an hour buffer between shifts is meant for workers to discuss work related topics, such as what has been done, what needs doing etc., this time is also used for smooth takeover of work stands and on Thursdays for development meetings. This system of work ensures better utilization of machinery and shortens delivery times, as well as allows to utilize space better.



Graph of a functional layout company. (Singh 2006, 21)

A rough sketch of layout currently present in case company divided by function in Appendix 1.
According to this layout Company is divided to the following departments

2.1 **Laser cutting and punching**

For most of the orders this is the first step, blanks are being cut or punched from sheet metal according to the customer's drawings.
Machines used in this department:
Bystronic BySprint Fiber laser loaded with forklift and combination of laser and punching machine FinnPower LPE5 with suction cup arm loading.
First mentioned laser is used for most of small to medium batches because of ease of changing works and more flexibility as well as better finished edges.

The LPE5 is used for works which are larger in volume, because of the automatic loading and palettizing system. Specific works which require threading, chamfering and other similar activities can be made at far larger pace using this machine, as well as some simple shaped parts which do not require retooling of the punching tool revolver. Using punching instead of laser is also more economical because of no need of using laser gases. The downside of this machine is that it requires more retooling time and it takes longer to create new programs which makes it less suitable for small batches and new prototypes, which might change as well as work which has to be done quickly.

There is also sheet metal guillotine for very simple shaped low thickness products which do not require high precision, or for prototyping when customer does not have exact dimensions of the blank.

2.2 Threading/drilling/chamfering/finishing

This is a step of production, which depending on the type of work might be the first, second or even further along the journey through production process. Most of the work is drilling holes which might have been dispersed during bending, because of being close to the bending edge, amongst other tasks of this department are reaming pilot holes made by laser in materials of large thickness, because the holes tend to be imprecise in those cases, drilling tubes, threading small batches, deburring.

This department utilizes a few bench drilling machines, some equipped with threading devices, a few deburring devices of different kinds.

Some of the work in this department has been taken over by LPE5.

2.3 Bending

The bending is mostly done using two similar FinnPower hydraulic machines, using mostly air bending tools with some exceptions, apart from that there is also a hydraulic FinnPower using another tool standard and utilising mostly v-dies.
The last bending machine is a Safan electric press brake used for small/low thickness/requiring low force products, which come in large batches, because of its quicker action and lesser bending force.
The two newer FinnPower machines are mostly utilised for majority of the products, the older for parts requiring different tools. Bending is an important step of the production path, as most of the products undergo bending operations.

2.4 Tube/profile cutting/bending

This department is responsible for preparing tubes and profiles for further operations, there are 4 saws of different kind, sanding machine for finishing rough edges and a CNC bending machine. Company is producing tube/profile-based parts and whole outsourced devices some with tube/profile frame, some when tube is just a part of them. Tubes are being cut from 6m blanks to the desired length, then bent should the need arise, if not they are being drilled and/or have other parts welded to them.

2.5 CNC milling/turning

The CNC department is equipped with a manual turning machine, CNC lathe, a CNC milling machine. All of those machines are used mainly to

produce parts needed for subcontracted products, or for Company's own use e.g. making welding jigs.
Manually operated turning machine is used only for simple products which are done single time, are in small batch, or there is another reason it will take longer to make a program and do all the other operations to utilize CNC lathe.

2.6 **Welding**

It is the biggest department in terms of number of employees, most of subcontracted products are being welded, there are several of MIG/MAG welding machines, as well as couple of TIG, special machine for welding aluminium, also a welding robot for large batches and a spot welding machine.

2.7 **Powder coating**

Most of the ordered steel parts are powder coated in order to prevent rusting and/or to make them more appealing as a part of a machine/vehicle or other product. Powder coating department has two ovens, and one painting chamber, as well as a stand for preparing products for painting, a steam cleaner, sanding machine and a vibration grinder.

2.8 **Assembly/Shipping**

This department is connected, as not many products need assembly and those which do are usually welded, so they have to be assembled beforehand. Most of the work in this department is limited to packing ready made products, so that they do not get damaged during transportation and making sure all the products leave on time and to the right place. This is also the last step in quality control, last chance of stopping product before it gets to the customer. Most of the products are wrapped in protective materials, then collected on palettes for specific customers in accordance with their destination and the date of shipping.
Trucks come regularly, three times a week, to pick up readymade products.

3 THEORY

3.1 Basics

What is the purpose of developing production, if the Company is profitable and growing? The answer to that question is competitive advantage, which is nowadays an important topic amongst manufacturers.
The basic idea being given the same material and resources with developed production high quality products can be produced in shorter time. It is even more important in Finland, which is a country with comparatively large labour costs. This means that for the company to have advantage over its competitors manufacturing has to undergo certain criteria. Amongst which according to K. Aswathappa and K. Shridharabhat are:

- Shorter new-product-lead time,
- More inventory turns,
- Shorter manufacturing lead time,
- Higher quality,
- Greater flexibility,
- Better customer service,
- Reduced wastage.

Because of Company business model of subcontracting company some of the points are not as relevant as the others but they will be described more thoroughly in the further part of that thesis.

Shorter new-product-lead time is only partially dependant on Company, because new products are being received either in the form of technical drawings or in ready prototype and then sent out on evaluation, if it meets the customer's needs. This means that the quality of drawings and engineering work, as well as processing and testing is not dependant on Company's effort and cannot be improved. Otherwise Company has an assigned employee, which is responsible for prototyping which increases the efficiency of that process due to having experience in that field.

More inventory turns are also dependant on the orders coming from the companies that use Company as a subcontractor, search for new customers is continuing but it is not the case of that thesis, though should be easier with increased competitiveness.

Shorter manufacturing lead time is possible to achieve with greater production effectiveness as well as on careful production planning and in a practical approach it has been analysed by departments in a further part of this thesis in chapters 5-7.

Higher quality is incredibly important to a manufacturing organization for it to stay competitive and is something that the Company was putting high

emphasis on in the last years of its own development work, during those years they acquired ISO 9001 and 14001 certificates, but mistakes still happen and prevention ideas for this case are presented in the latter part of that thesis, specifically in chapters 6-7.

Flexibility is the upside of small to medium companies, because for more competitive in terms of cost large enterprises it is not economical to produce a very small amount of parts. It is criteria which causes the manufacturing companies to be chosen even though they may not be the cheapest, but they will provide the shortest delivery time or just in time delivery. It is a case where small and medium sized companies can have advantage over large companies is short term deliveries, when the cost is not as important, because prevention of losing even larger amounts of money is goal for example for automotive companies in which cost of seizing production is counted in thousands of Euros per hour are lacking vital parts, because transportation is late can rely on small company to send out a batch in short amount of time, this is one of the strengths of Company and there is not much room for improvement in that matter as those requests are never ignored.

Greater customer service is becoming increasingly important and can be a decisive factor in choosing a company, especially when other factors like quality and pricing are similar, resolving issues quickly and favourably to the customer may make the customer come back to the company for new orders or choose it in the first place.

Reducing wastage is a reducing cost as well as time and other resources solution, by reducing steps that do not add value to the product, a factor that was one of the main goals of this thesis and is further analysed in chapters 5-7. (Anil Kumar S.; Suresh N. 2007, 2-12)

3.2 **Work study**

"Work study is a means of enhancing the production efficiency (productivity) of the firm by elimination of waste and unnecessary operations. It is a technique to identify non-value adding operations by investigation of all the factors affecting the job. (Anil Kumar S.; Suresh N. 2007, 178)"

Method study is an analysis of current manufacturing techniques by separating them looking for waste as well as analysing systematic approach of all of the components combined. Elements analysed should involve:

- Operations involved and their sequence,
- Workforce,
- Materials, tools and machines,
- Layout and workstation design,

- Movement and material handling,
- Environment.

The efficiency increase is achieved through:

- Improved layout and design of workplace,
- Improved work procedures,
- Better utilisation of workforce machines and materials,
- Improvements of final product (not relevant in this case).

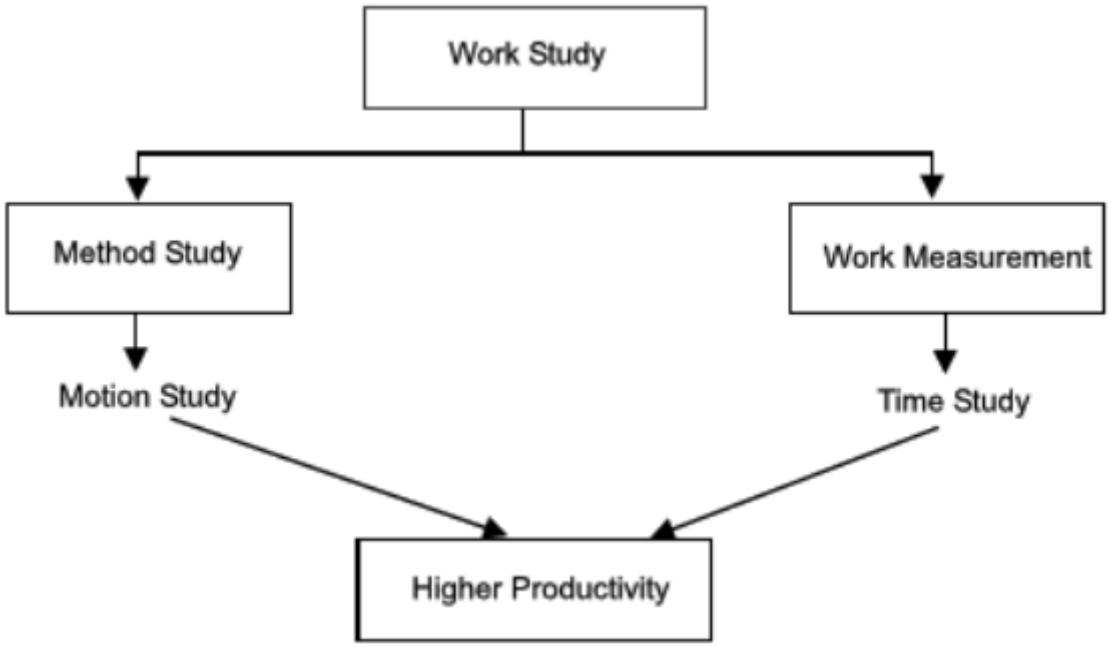
The objectives of Method study are:

- Analysing situation,
- Critical examination of the situation,
- Development of solution based on current situation. (Anil Kumar S.; Suresh N. 2007, 179-180)

Steps of Method study:

- Select,
- Record,
- Examine,
- Develop,
- Measure,
- Define,
- Install,
- Maintain.

In case of this thesis last two steps have not been realized. The results of Method study are in chapters 4-7. (Aswathappa, K.; Shridhara Bhat K. 2010, 175-176)



Framework of work study. (Anil Kumar S.; Suresh N. 2007, 178)

3.3 **Lean manufacturing**

Lean manufacturing is according to (Wilson, 2010) as well as many other sources a set of tools and techniques, which combined allow to reduce the seven wastes of manufacturing, making the company more flexible and more responsive.

Those previously mentioned tools are:

3.3.1 JIT

This stands for Just in Time, which is a technique that provides exactly the right amount at the right time and in the right place. It is one of the pillars of reducing waste through better management.

3.3.2 5S

The 5S system is a lean manufacturing tool that improves efficiency and reduces waste. The 5S stand for:

- Sort
- Set in Order
- Shine
- Standardize
- Sustain.

Which were further described by Matt Wastradowski:
"Sort (seiri, or tidiness) involves removing unnecessary tools and materials from a workspace. Only what is needed at a given station should be kept there; this frees up space for the rest of the process.

Set in Order (seiton, or orderliness) is carefully organizing the materials and tools that remain after the Sort step: "a place for everything, and everything in its place." Organized work spaces can be used more efficiently and effectively.

Shine (seiso, or cleanliness) calls for routine cleaning of the work area, tools, and equipment. A clean work area prevents clutter or dirt from hiding potential problems and improves the working life of equipment.

Standardize (seiketsu, or standardization) means documenting what's being done so those improvements can be shared across the facility and into the future. This makes the new approach part of normal business.

Sustain (shitsuke, or discipline) requires ongoing effort to maintain 5S in the facility. Keep track of progress with evaluations, communication, and ongoing training. Assign continuing responsibility. This way, the benefits of 5S aren't lost over time. (Wastradowski, 2018)"

3.3.3 Mura, muri, muda

Mura is a lack of uniformity, unevenness. The idea is to reduce waste by uniformly distributing work, reducing overtime and utilizing normal shifts in a more efficient way by reducing idle time.

Muri represents inability, unreasonableness of the task taken, this can be avoided by standardising the work and reducing the risks of irregularity of work by preventing happenings that could disturb the workflow.

Muda means wastefulness. The solution to avoid wastefulness is to reduce non-value adding activities around the product. Ohno identifies seven forms of wastes as:

- Transport,
- Inventory,
- Motion,
- Waiting,
- Overproduction,
- Over processing,
- Defects. (Ohno, 1988)

3.3.4 Kanban

Kanban is a method of continuous improvement. It is usually implied with creation of teams that ensure every operation is as efficient as it can be.

3.3.5 Poka-yoke

It is a mistake proofing of a process technique.
Example: Most of the cars nowadays will not start without depressing the clutch pedal or brake pedal to prevent unintended movement, this also causes the driver to remember about it and promotes such behaviour, so even when using an older vehicle without this system, depressing the clutch or brake pedal should occur as it is something that needed doing routinely, so the likelihood of forgetting about it is lower.

3.3.6 Pull system

In opposition to most production systems before lean which focused on forecasting production and producing to stock, this system focuses on greater production flexibility and manufacturing to order, so no product is being manufactured until demand arrives, this is possible to achieve through quick changes of produced goods and flexibility. This system brings many benefits such as no need of keeping stock.

3.3.7 5 Whys

Technique which is used and was developed in Toyota Motor Corporation by Sakichi Toyoda, later described by Taiichi Ohno "…by repeating why five times, the nature of the problem as well as its solution becomes clear. (Ohno, 1988)".

"The Five-Whys exercise is vastly improved when applied by a team and there are five basic steps to conducting it:

• Gather a team and develop the problem statement in agreement. After this is done, decide whether or not additional individuals are needed to resolve the problem.

• Ask the first "why" of the team: why is this or that problem taking place? There will probably be three or four sensible answers: record them all on a flip chart or whiteboard or use index cards taped to a wall.

• Ask four more successive "whys," repeating the process for every statement on the flip chart, whiteboard, or index cards. Post each answer near its "parent." Follow up on all plausible answers. You will have identified the root cause when asking "why" yields no further useful information. (If necessary, continue to ask questions beyond the arbitrary five layers to get to the root cause.)

• Among the dozen or so answers to the last asked "why" look for systemic causes of the problem. Discuss these and settle on the most likely systemic cause. Follow the team session with a debriefing and show the product to others to confirm that they see logic in the analysis.

• After settling on the most probable root cause of the problem and obtaining confirmation of the logic behind the analysis, develop appropriate corrective actions to remove the root cause from the system.

The actions can (as the case demands) be undertaken by others but planning and implementation will benefit from team inputs. (Serrat, 2009)"

Example:
Problem: The vehicle is not working?
Why? Because the engine refuses to start.
Why2? Because the battery is dead.
Why3? Because it was not charged.
Why4? Because the alternator was not working.
Why5? Because of the broken belt that drives it.
Why6? Because of poor maintenance it was not changed when it was necessary. This last why addresses the root of the problem.

3.3.8 Lean in the case company

Due to the relatively short time spend on development in the Company the whole concept of Lean manufacturing could not be implemented, but some ideas could be used, or were already implemented by Company's own actions, that could be useful in development and leave basis for future improvements.

The Company as previously mentioned produces hundreds of different parts and subassemblies, which is challenging for implementing some ideas like setting a takt time, reducing wasteful steps, optimizing the work, because some of the products are produced in the number of few in the long, even a few months, periods. During time spend in the company only a little fraction could be followed and examined. Moreover the differences in size, steps taken with the product, batch size and many other factors, make it very difficult, if not impossible to reduce the waste totally, for example rearranging the assembly station, for a small assembly, putting parts in boxes, close to hand, arranging the seat, from which employee could reach everything needed, which is waste reducing in a way of preventing unnecessary motion and transportation and eliminating waste of time makes the station useless for a completely different large assembly, requiring different parts, tools and larger amount of space. Another part of Lean, redesigning parts for simplifying production process, thus reducing cost is only dependant on the other company, since case Company is only a subcontractor, everything depends of the customer and would require requesting changes from customer.

On the other hand, some of the ideas have already been implemented or are a result of the Company's business model, for example meetings arranged when mistakes happen and gathering prevention ideas. Another example would be pull system, so significant in Lean, which is forced by the nature of subcontracting, nothing is being produced before customer's order.

3.4 **Stopwatch study**

The goal of the stopwatch study was to assess the accuracy of the existing system of calculating time needed for executing given task, which is then used in production planning, as well as other crucial stages of planning and managing the plant. The period of this study was two weeks, when products of wide variety were being followed going step by step through production path. During this time production of those items was timed while conducting this study. Other objective of this study was determining what stages of the production could be improved, how long the layover times are, finding out in production process, by following all the steps it was easier to determine all those factors. Considering that the workers were being observed and timed might have influenced their normal

behaviour, for example they might change their normal pace of work, would otherwise take a small break, 20% allowance was added to the times measured.

3.4.1 Some of the products chosen for the study:

Product 1 - product made from 1,5mm sheet metal with the method of laser cutting,
blank dimensions ~300x200mm, 6 bends - final dimensions ~110x150x130mm, 2 welds
~80mm each, MIG welded, welds finished and chamfered by hand, prepared and powder coated, transported in-house by hand due to the low weight and dimensions, in this batch there were 6 pieces of this product. Retooling, transporting in-house and all the other production-oriented activities are calculated in Table 1, this concerns all the mentioned products.

Product 2 - product made of 1mm stainless steel, laser cut, blank dimensions ~580x205mm, 8 bends – final dimensions ~340x70x100mm, 2 welds ~5mm each TIG welded, cleaned and powder coated, transported in-house by hand, this batch contained 15 pieces.

Product 3 - product made from 5mm sheet metal and a steel profile, subcontracted from company specializing in laser cutting profiles into desired shape. Only operations done in Company are laser cutting two sheet metal parts, welding them onto the profile and powder coating. 10 pieces in a batch.

Product 4 - made from 2,5mm sheet metal, 2 bends, blank dimensions ~640x110mm, dimensions after bending ~640x110x20mm, sanded and powder coated, 52 pieces in a batch.

Product 5 - made from 4mm ferrite, laser cut, 3 bends, blank dimensions ~340x230mm, dimensions after bending ~190x150x80mm, 2 welds ~80mm each MIG welded, sanded and powder coated, transported with a cart or on a palette because of its weight. Batch contained 50 pieces.

Product 6 - made from many parts laser cut from 3,4 and 5mm aluminium, final dimensions are ~1200x400x200mm as there was only one piece in this batch it will be considered as one part, for the purpose of this thesis there is no need of such detailed description, as it is irrelevant to the outcome of this study. Welded and powder coated, welds and surface cleaned by hand as the bulk was too large to fit into the sanding machine.

Product 7 - laser cut from 3mm aluminium, blank dimensions ~900x300mm, 4 bends, final dimensions ~900x130x80mm transported in-house by cart, no other operations performed, apart from packing.

All the values are given in minutes per one piece	Time estimated by the company using current system	Time measured with allowances added	Difference	Percentage of the difference
Product 1	27,5	22	5,5	-20%
Product 2	6	6	0	0%
Product 3	6,5	7	0,5	~7%
Product 4	4	4	0	0%
Product 5	4	4	0	0%
Product 6	165	160	5	~3%
Product 7	4	5	1	20%

Figure 3. Data on production times of selected products

Data collected was much larger this is just a fraction of it. Specific data of each process has been measured and conclusions have been drawn. This example shows similar correlations as the larger tested group, usually the differences, between “real time” and the estimations were not significant, on average about 7% difference between them, but the allowance level used was 20%, should the allowance be smaller, it could even be a smaller difference. Another conclusion is, that when trying to utilize different ways of calculating those values, the results have not been closer than that, this leads to the final conclusion, that the current system used by Company for calculating production times is accurate and does not need to be changed.

3.5 **Motion study**

In this study production processes and methods were analysed.
The purpose of motion study was following employees in their work environment, searching for waste and inefficiency in manufacturing processes. This study was conducted for a period of two weeks parallel to time study. Problems and waste generating activities are further described in paragraph 5.

4 PROBLEMS FOUND BY DEPARTMENTS

4.1 **Laser department**

This department seems to be running quite smoothly, this is thanks to very organized team of people working there, they have been constantly addressing problems found and looking for solutions by themselves.
There are however some issues still to be found with storing ready parts taken out from laser, they are put on palettes in the layover area next to the laser, then workers from other departments after receiving technical

documentation of order go to that area in search of parts needed, sometimes it takes a while, especially for the small parts in small batches. Another issue is lack of contact between departments, for example someone from the bending department is taking parts for bending not knowing that the same parts are just being cut for the next batch and a lot of time could have been saved because this next batch will not require retooling, reprogramming, getting familiar with the drawings. The next problem is that, the system that was devised to make the work more efficient, which is planning orders ahead and cutting parts in consideration of the material, all the parts of the same thickness and material type are being cut together, which is saving time and material, but as it was mentioned before, one of Company's niches is not refusing short term deliveries and those interrupt this scheme, another interruptions are caused if the worker of other department further along production process makes a mistake and part is damaged in an unrepairable way, repairing it is uneconomical, or would affect the final product's quality, then obviously another part has to be cut, distorting this plan. The last problem of this department is relatively low efficiency and usability of the FinnPower LP5 machine, this device offers wide range of advantages over the conventional laser, such as tapping, threading, chamfering, also cost savings because of no need for using gases when punching, also ensures the continuity of production, should the other laser require servicing, but it is quite time consuming when used for small batches and it can only operate on one shift, contrary to the rest of the company, because only one employee is qualified to use it.

4.2 **Threading/drilling/chamfering/finishing department**

This department's role in the company is quite small, there are some minor problems, minor negligence of the condition of the machines and sometime tools get lost, but no issues that would affect the whole production process, or that would cause major setbacks.

4.3 **Bending department**

One of the problems in this department is old and unreliable FinnPower press brake. It is used for producing some of the parts, the tooling in this machine is quite worn out, but investing in it does not make much sense, as the other newer FinnPower machines use different type of tooling. It is only used for a few products, that will require investment in special tooling for the other machines. Another issue is the lengthy process of learning needed for somebody already familiar with machinery. Programs are not so clear at the first glance, as well as some settings of the machines, there are corrections made by operator, instead of fixing the machines. This may indicate that the machine is deteriorating, and it may become unnoticed

until it breaks down, because of the operator masking the variability with his experience.

4.4 Tube/profile cutting/bending department

The layout is a main problem of this department, tubes for cutting have to be passed over another machine, the automatic cutter used for larger batches, has to be loaded manually. This layout has been caused by changing the laser to another one and the need for finding space for it.
Another problem is that the shelves with raw material had to be taken outside because of this change which makes moving the tubes indoors and cutting them very time-consuming and inefficient. The same as in all the departments lack of space is an issue. The rough sketch of this layout is in the Appendix 2.

4.5 CNC department

This department suffers from its role in the company, it was created because of parts of the larger products which are often done for a short-term delivery and need to be done quickly and no CNC company will take the order, order material, produce those parts and send them in short enough period of time. Most of the parts produced are a single element of a larger product. This department is therefore a must, not bringing much value to the company. Another issue is lack of qualified specialist to run this department, the skills of current workforce are enough for producing the parts that are currently made to stock, but under pressure if new orders would flood this department it might not be sufficient. Because of this department's need of existence and the fact that parts that need doing are in quite small amounts, the machines are running at relatively low speeds to extend tool life. It is of course saving money on a small scale, but it is an issue.

4.6 Welding department

The main problem is lack of qualified workers. The solution was supposed to be renting workforce from external company specializing in this. Some of the employees were qualified welders, but they used to weld ships, or pipelines and while they are very experienced, it did not necessarily help with welding small to medium parts. Another issue is time spent on training new workers, or time the other welders, or a foreman to help them figure out how to put everything in the welding jig, or what is the most important and what practices should be avoided in specific products. Also depending on one's experience they are differently handling the welding drawings, some are very familiar with this concept, some not,

mistakes are common. More tooling is needed such as clamps, jigs. There are not enough tools on every welding station (which is considered welding table, welding machine, tools, mask). It is not the company's denial that has led to the lack of tools, they are being bought constantly, workers from one shift are borrowing them, forgetting to put them back, some go missing. This causes some chaos, because welders need to go around borrowing tools, some must wait for somebody else to finish work, because of the lack of the tools needed.

4.7 **Powder coating department**

This is the bottleneck process in Company, vast majority of products is powder coated and the existing solution for coating is not sufficient enough. Only one oven which is connected with rails on which the products are hung, then coated and put to the oven and then cooled down, is operating on quite a low temperature, so that the products have to spend there more time than necessary. Increasing temperature causes unevenness in the heat distribution in the oven, which then causes some products quality of coating to be insufficient. Another problem is lack of an automated cleaning system, so all the products have to be cleaned by hand or using a steam cleaner, but then manually taken out and hung on the rails. The other oven is meant for larger products, but it operates with carts which are tailored for specific products and even making new ones wouldn't solve the problem completely, because then cleaning and having one coating chamber would be a problem. Another issue is recoating after products are coated in the wrong colour or the quality of the coating is insufficient, this is causing a major setback, as the preparing for recoating means that the whole coating has to be removed very carefully, this is a time consuming and expensive process.

4.8 **Assembly/shipping**

This department is suffering, as most of the other departments from scarcity of space, but apart from that it is generally running problem free.

4.9 **Overall**

Company also suffers from problems which are present in every department, some problems between departments, which need to be mentioned as well. The main problem considering all the departments is the lack of space, this causes major disruptions in all the departments. Another problem is missing/incomplete documentation. Negligence of employees is also an issue, but not as common. Small issues with quality are not mentioned by the employees, special tool was created for that

purpose of an inside complaint/reclamation, it is not commonly used. Another issue is circulation of employees, which is generating a lot of waste in time needed to train them, after which some of them quit the job.

5 PROPOSED SOLUTIONS FOR THE PROBLEMS FOUND

Company was already taking actions before starting development work. Meetings were organized weekly, so that the management has the opportunity to exchange information with employees and a few times in a year there are development days where ideas for improvement are being exchanged. Some of them have been implemented or are going to be implemented shortly. This development work was an extension of that actions, another point of view, showing a different approach and utilizing theoretical knowledge gained at the university. Some of the proposed solutions have already been implemented, some are being reconsidered by the management, others either wait for being realised in the future, or confirm managements own thoughts of a problems solution and are being discussed or in some cases of larger investments actions are beginning to take place. Most of the proposed solutions have been found using deduction, qualitative methods, own thoughts, ideas from other companies and techniques such as 5 whys. Due to such vast portfolio of the Company and limited timeline of the study it was impossible to introduce methods for reducing waste in specific products and measuring the effects they have, because of lack of same parts being produced again and managing the development of production methods for hundreds of parts separately would have been too great task to cover. Quantitative methods could not have been applied and in this case, they would have been impractical, so larger and less focused approach was taken.

5.1 Laser department

During the Company's own development process the solution for wasted time, because of searching parts was proposed and implemented with some effect. As it was mentioned before in the paragraph 4.1, the problem was that the workers of different departments given the documentation were searching for the parts needed and wasted time looking through multiple palettes to find given parts. The solution to reduce that time needed for searching was that parts would be divided in terms of what process needs to be performed next and put by laser staff on shelved carts, marked accordingly with the name of the department. Then this cart would be taken to the destined department which in theory would save time on searching. It was a partially successful, it had worked as predicted, but there is a different side to it, instead of producing to inventory and making searching through it easier, searching and inventory could be

eliminated at all. If the lean was to develop in this company the natural solution of this and other problems along the production process, would be not making parts to wait for further processing, but with the true pull system, making parts because the next department is finishing previous orders and is ready to take another job, this would lengthen the process at the laser department, meaning changes of different sheets of metal instead of cutting everything from one thickness and material type and then another, but it should reduce overall lead time of the product, also allowing the “hot jobs” to not disturb the flow. The other advantages of using this proven for example in KDC & Associates idea of splitting large batches into many “one sheet” parts are reducing work in progress, reducing overall production time, noticing problems with product only after producing a small number of parts not the whole large batch. Another employee should be trained to use FinnPower LP5 machine to improve flexibility of the company, especially under the conditions when the laser is not working.

5.2 **Threading/drilling/chamfering/finishing department**

As mentioned before in the paragraph 5.2 no major issues are present and low influence of this department to the whole production process makes it rather neglected, but there is a room for improvement in there as well. Definitely some investment would be useful, machines operating there are quite worn out, tools are lacking, it is not a priority now, but it might become an issue in the future, when efficiency of the whole company increases, it may fall behind.

5.3 **Bending department**

The obvious solution would be to remove the old machine and purchase new tooling necessary for the newer ones to produce the same parts using more reliable and faster machines, that will also have a positive effect on space which is scarce. This solution though is quite costly and since it is not affecting company in such a way that it would need such dramatic actions immediately and a goal of this thesis was to find costless to low budget solutions I would leave those decisions to management of Company, so that they could decide on taking actions of that matter, being aware of a problem and a possible solution. The solution would be to mistake proof the documentation for the products that are too complicated for a professional walking into the company to immediately know how it should be made and allowing to reduce costly and long training to the minimum.

5.4 **Tube/profile cutting/bending department**

The main problem of layout was solved as much as it could have been with such limitations of floor space availability, but the machines and saws were moved around, shelves have been added inside the building. Machines have been moved in such a way, that the automatic saw can be now loaded with the forklift, machine was modified in a way so that it can be loaded with a whole bundle of tubes or profiles, removing the time consuming process of loading the tubes one by one by hand, another saws are significantly closer to the shelves than before, this caused another gain in time, it is not ideal though, the whole arrangement is quite tightly packed and cramped, but it is significantly better than before. The changed layout is sketched in the Appendix 3.

5.5 **CNC department**

One of the solutions, if the conditions are favourable would be educating the staff, or employing experienced CNC operator, reducing tool life with increased efficiency and finding more work for this department but that solution would require a lot of effort and as I mentioned before happenings that will make it possible, for example current customers needing CNC parts. Another solution could be finding a CNC company that could produce and ship the products quickly enough and removing this department from company's portfolio altogether. There is one more solution that I can think of, but it seems unlikely, that would be renting this building (this department is placed in a different building than the rest of the company), with all the existing equipment to a start-up or a company, perhaps even someone that wanted to create a company like this but did not want to make investment. Within this contract could be an appendix that would guarantee Company supply of parts and the proximity would cause no need for shipping and the time needed for shipping would not be an issue.

5.6 **Welding department**

One of the solutions to the problem would be sourcing welders for the company instead of renting them, but this may be challenging since of scarcity of qualified, experienced welders on market and expensive, because of high demand of professionals, so they would have to receive high salaries to keep them in the company. Another solution could be improving the documentation, attaching pictures and photos with detailed description of all the products and how to put them in the welding jigs, apart from mistake proofing this will reduce the need of explaining and guiding from other welders or foreman. This solution has its roots in Poka-yoke, mistake proofing of the process, checking with detailed instructions

and photos would have made the thinking process quicker, without the need of wondering how it should be done, as well as making workers more independent and requiring less skill without increasing the probability of mistake. The latter solution has been discussed with the management, which seemed to be keen to try out this idea, but unfortunately because of lack of time was not put into action. Considering the problem with the missing tools, the solution could be to equip all the welding stations with all the tooling needed with a board, for hanging them, preferably, with the imprint of the tool on the board, so that when anything is missing it can be easily spotted. The negligence of the workers would not probably improve, because of that solution, so the measures should be taken, making each employee responsible for their workstation, checking daily what is missing, before starting work verifying, that every tool is on its place, as well as marking the checklist confirming that everything is in order. The proposed tooling solution has been working for many companies and is common in the industry, as shown on a picture below, taken from the Miller Welding and Machine Co. (Heston T., 2014.)

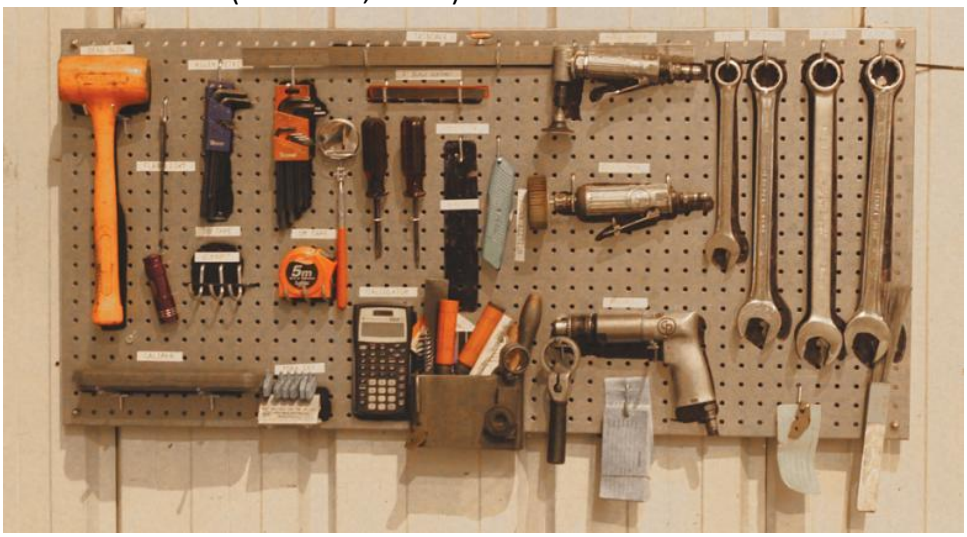


Figure 4. Tools set in order, after 5S rules being applied. (Heston T., 2014.)

Another upside of that solution apart from reducing waste in time needed for searching tools is better appeal to customers visiting site, as well as potential customers, this leaves good first impression, also employees have tangible proof that the change is happening. (Heston T., 2014.)

5.7 **Powder coating department**

As mentioned before, this is the bottleneck process, of the case company, but there is no other way of changing that situation without investment in that department, preferably to the whole system, that would clean move the products on the line to an oven and out of it without the need of removing it at any point, obviously those systems are available, but it is a costly investment and it requires plenty of space, which is now unavailable.

The solution for the issues with quality of coating may be investing in noncontact gauge, measuring the thickness of the coat before being baked in the oven, allowing to prevent expensive reworks, this solution has been proven to work in a company with similar diversity of products as case company Prince Precision Products. (Heston T., 2015)
There are though plans to expand and with the new building and availability of space, investment in such system is probably going to take place in the near future.

5.8 **Assembly/shipping**

As mentioned before no major problems have been found, the lack of space could be an issue in the future, because with the amount of space available and the existing workforce it is running closely to maximum capacity of this department.

5.9 **Overall**

The problem of space is being addressed, company has already purchased ground neighbouring with current plant and there are plans of another building to come. New layout was being discussed during the writing of this thesis, it was not yet concrete enough so that this topic could be discussed within this thesis. Also lowering the amount of work in progress would help gaining extra space. One of the problems with documentation was that sometimes more than one step of production was taking place at once. This caused problems with sharing the documentation, this has been addressed by the company beforehand, with special appendices reaching appropriate departments. Other documentation related problems are caused by employee's negligence, not mentioning to the foreman or management that something is missing and no actions are taken. Similar negligence is present when it comes to internal reclamations. People at the Company tend to have quite strong friendships with co-workers and tend to cover each other. It is important that they are friends and it may be good for company that the employees like each other, it creates more pleasant working experience. In some cases, though it would have been better, if they were questioning each other's work, when necessary. Another problem is that this is the whole page to fill and for some employees it may be too time consuming and they may be thinking that is unnecessary. It would be better, to simplify that document and provide measures to encourage in employee's behaviour leading to sharing more information with management. The last point could be taking poll with current and those quitting employees. Asking what the reasons of their dissatisfaction with the job or the company were and improving on those factors, if possible making the company more appealing to new coming employees and making them want to stay. Another idea taken from KDC &

Associates is as Kallage the principal of the company refers to it “Two-minute challenge”. The idea is to arrange the tools in such a way that a person not familiar with the shop, but knowing basics of fabrication, can walk into the production cell and find everything needed within two minutes, this is vastly important to keep flexibility and avoid time consuming questions about where something is or looking for tools. (Heston T., 2010)

6 PROPOSALS FOR FURTHER DEVELOPMENT

6.1 Shop floor improvements

The layout of the company can be changed in a little way, due to the lack of space and the type of activities, as well as the fact that this layout is the best solution for this type of company.

There are though little things that could be improved, one of those would be marking the shop floor with assigned spaces for ready products, parts that are waiting for the process to be performed. This idea was taken from the 5S method as it utilizes the concepts

Furthermore, wasted time searching for tools could be reduced by arranging the tooling in such a way that it can be found easily, marking the place for specific tool, this would also help realising when the tool is missing or broken and a new one is required. To reduce time spend searching for tools even more as well as gaining space, a space should be assigned for the unused/worn out/unnecessary tools and other parts and materials to be assessed, if they should be disposed. This is an idea that has been implemented in many workshops with good results a good example of that is Miller Welding and Machines, from which the photo in the Figure 5 came from.

Figure 5. Lines marking the work-in-progress areas and shined floor. (Heston T., 2014.)

Another idea, also used in many cases of post lean changes workshops is better utilization of pull system, as mentioned before Company already based on external pull, generated by the customers orders, but the inside the company parts have been sometimes stacking up for weeks waiting for another process to be performed on them, taking up such scarce space, with the need to rearrange everything in order to move pallets, causing the process of transportation which is waste generating, because it does not add value to the product, between stations much longer than it needs to be. An example of that actions working in the figures 6 and 7 taken from the Miller Welding and Machine Co. (Heston T., 2014.)

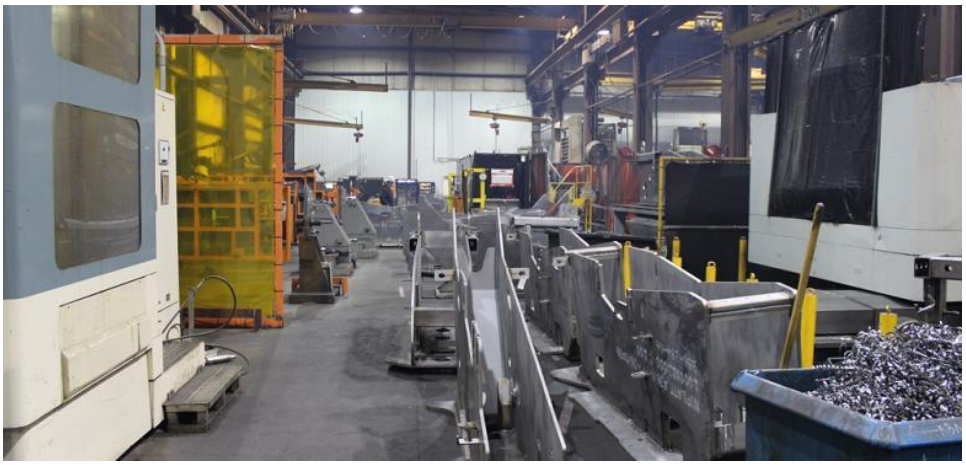


Figure 6. Before lean, parts waiting for the next process in queue – push system. (Heston T., 2014.)

Figure 7. The same spot after lean - pull system. (Heston T., 2014.)

6.2 **Employee development**

In order to increase efficiency and make production more flexible, workers should be able to switch between departments, helping when there is higher demand for work of some department, which is one of the parts of Lean manufacturing ideas. There are already workers that are multiskilled, but this idea should be developed even further, this has other positive effects, such as reducing boredom, increasing focus needed for performing actions differing from usual, chance for development for employees. Educating workers, teaching them new ways of work, increasing the skill

level, giving them a chance of personal development inside the company and taking care of their well-being, involving them in decision making and problem solving should increase efficiency, strengthen the bond with the company and convince them to not leave for another job. All of this is encouraged in Lean philosophy and has worked for multiple businesses around the world, the flexibility that the company has and benefits of developing skill in employees are undeniable and should be encouraged.

6.3 **Management improvements**

More encouraging workers is needed, as well as motivating them with different means. More emphasis on production planning should increase productivity, now mostly actions are taken when some department is flooded with work, but this could be foreseen with careful production planning. Better communication between management and workers could help improving problem solving and discovering workers needs and potential production issues in early stages. Mistake reporting should be encouraged, as well as inviting employees to discussion on how to avoid them in the future. It has already been happening, but not with needed extent.

6.4 **Quick response manufacturing**

The problem of balancing the production line while having such a mixed variety of different works may be a nightmare and can cause a lot of confusion between the foreman, management and employees, fortunately there is a system that is self-regulating and could be an idea for future improvement in the case company.

According to Ritchie it is possible with the system he devised, which is paired-cell overlapping loops of cards with authorization, shortly POLCA, it is based on Kanban, but the difference is that it does not focus on specific products, as it is in original, but overall capacity, this makes it suitable for businesses such as the case company.

The idea is to have cross-trained operators working together sending cards to other department, that they are ready to take more work, because they are about to finish, then the previous cell is producing for them, when they lag behind and the previous cell does not have any job, they come to help (Figure 8). (Heston T., 2016.)

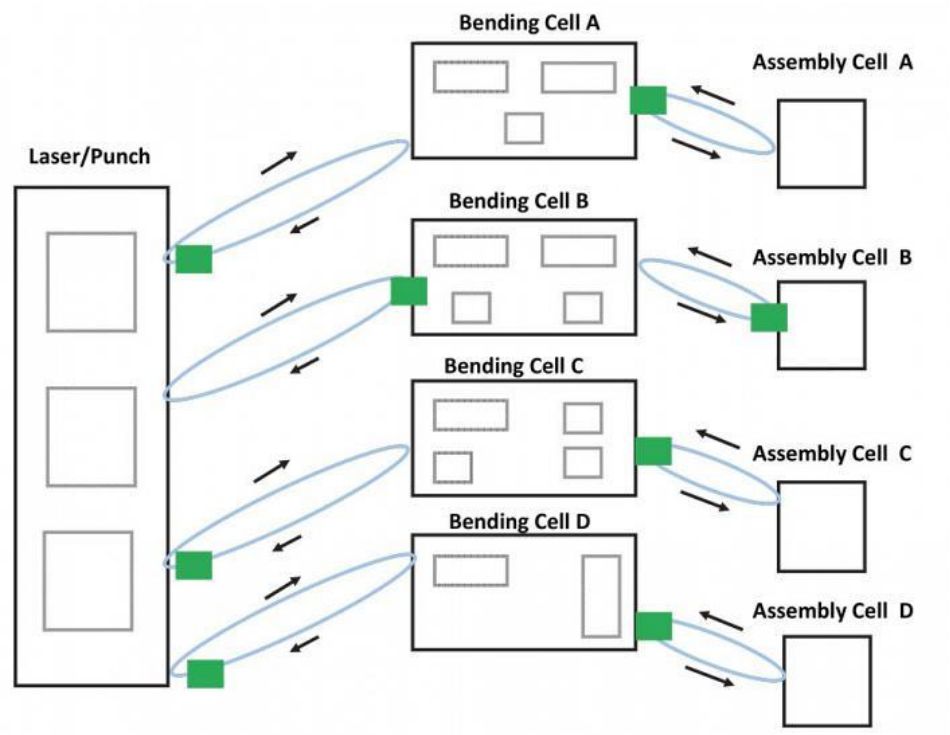


Figure 8. POLCA at work. (Heston T., 2016)

7 CONCLUSION

As a result of this project Company found out main problems and what could be done to improve its productivity or in some cases confirmed their own thoughts on what could and should be done. The company found out that the system that is used for work measurement is working in real life and complies with the calculations. Unfortunately, not all of the solutions have been implemented during my presence in Company and the time spent on research was not sufficient enough, so that their effect could be measured, but the company is doing their best in development and it is a continuous process, now with the new information, data and second opinion from someone outside the company surely the improvements will be substantial. The changes that were applied during my stay at Company had positive effect and gained workers as well as managements approval and the feedback was mainly positive.

Myself, I acquired beneficial experience in production engineering and development. Development work in Company allowed me to take a different approach at looking at a production, which seems to go smoothly but there are problems and issues to be found and everywhere is a room for improvements. I was able to utilize my knowledge from HAMK mostly in production engineering field. My skills in reporting have improved. I

gained practical knowledge from production engineering field and had a chance to develop an eye for looking at production process and seeing what could be improved.

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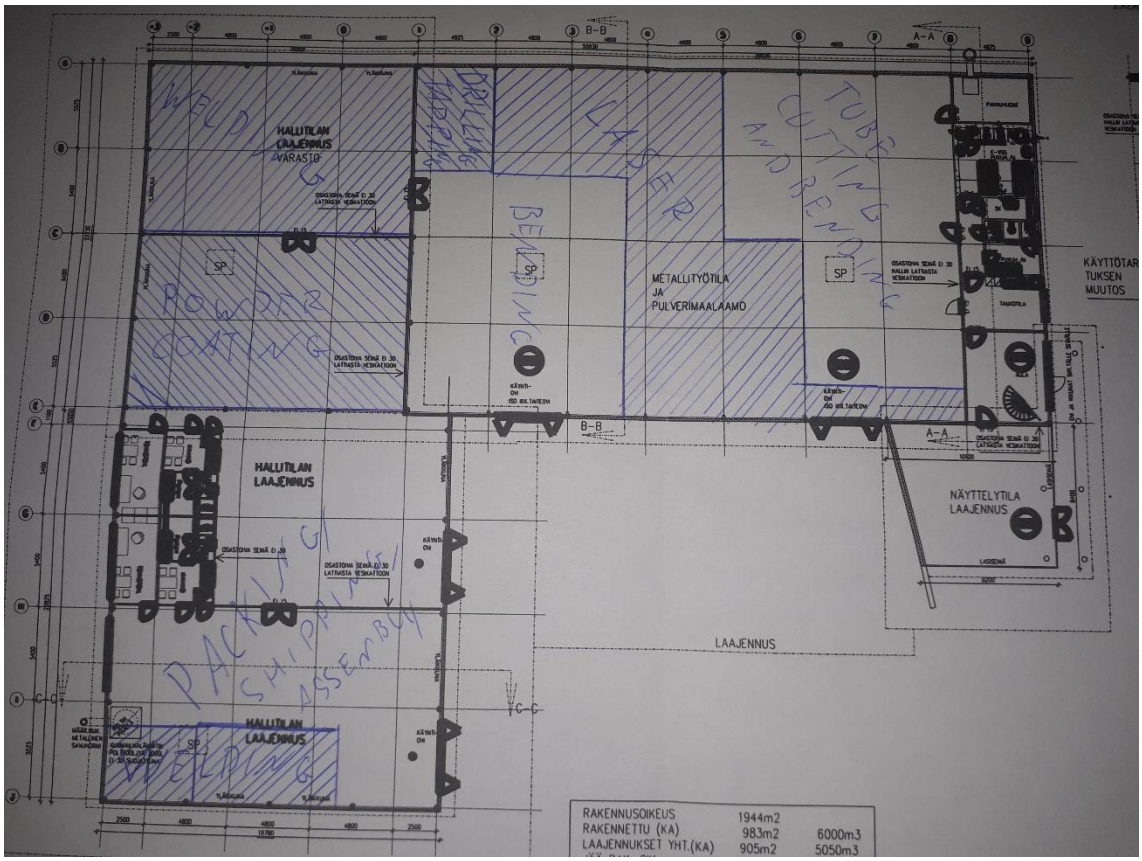
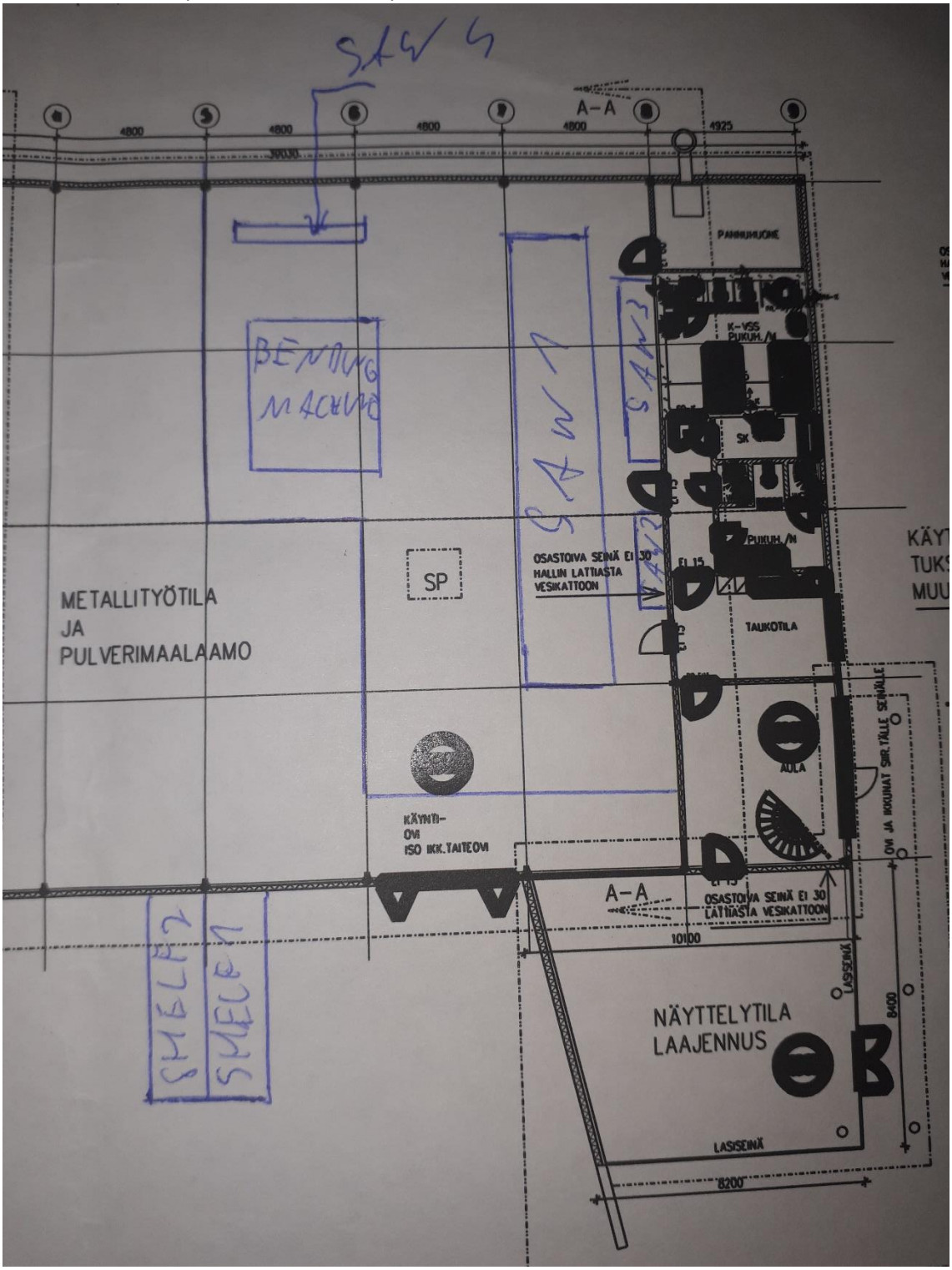
Appendix 1

SKETCH OF COMPANY LAYOUT



Appendix 2

SKETCH OF TUBE/PROFILE CUTTING/BENDING LAYOUT BEFORE DEVELOPMENT



Appendix 3

SKETCH OF TUBE/PROFILE CUTTING/BENDING LAYOUT AFTER DEVELOPMENT