Design of a new production plant
Preface

This report is written in connection to my graduation period at Ginaf Trucks Nederland B.V. in Veenendaal. From the 28th of January 2013 until the 10th of June 2013 I have been working fulltime on my assignments in the production department.

During the execution of the assignment and the writing of my report I was supported by both Ginaf and the University of Applied Sciences in Utrecht. This graduation assignment gave me the opportunity to put all the theoretical knowledge, learnt in four years, into practice. I have been given the opportunity to show my skills in a real organization by executing this assignment for the company. Through this assignment I have shown that I measure up to the prescribed skills of my study.

This graduation thesis became a success thanks to several persons. First of all I would like to say special thanks to Johan van Rijsbergen, tutor from the University of Applied Sciences, for helping me to pass my thesis. Secondly I would like to thank Erik Slot for giving me the opportunity to write my thesis based on an assignment at Ginaf Trucks Nederland B.V. He was my tutor from the company. I would also like to thank André Molengraaf, COO at Ginaf, for his support and for sharing his view on my findings.

Finally I would like to thank all the production employees for sharing information about the process. They were also very helpful during the time measurements in production.

Veenendaal, the Netherlands 06-08-2013
Ricardo Kroek
Executive Summary

This report is written for the design of a new production facility to produce the Ginaf HD5380T mining truck. Several requirements were studied to reach an output of five trucks per week. The study relates to:

- Purchasing, which parts should be purchased centrally at Ginaf Veenendaal and which products should be purchased locally;
- Production, what does the design of the production process look like and what is the standard time to produce the truck;
- Lay-out, what is the proposed lay-out for a new production facility.

When a new production facility is set up it is advised that the strategic products like the engine and the cabin are purchased centrally. This will result in lower costs for the products and therefore a lower cost price. For the non-strategic products e.g. the nuts and bolts should be looked for local suppliers. It is advised to keep a safety stock of one week for the strategic products. This applies to both the new production facility and Ginaf Veenendaal. The non-strategic parts already have a safety stock in Veenendaal. This should also be applied in the new production facility.

The assembly times in production are measured to determine a standard time for the production of the HD5380T. The standard time in production is 138 hours per truck. This standard time will count as a reference for the design of a new production facility. For the production facility in Veenendaal the calculated standard time is compared to the time it took the production employees to assemble the truck. They fill in time sheets at the end of the day. The average time used to build one truck is approximately 286 hours. The difference in assembly times are caused by the following:

- The production employees determine their own production pace, which results in longer production time. The goals set by management should be explained to the production employees and they should be monitored;
- Parts used to produce the truck are not at the assembly site and should be picked at the warehouse;
- Transfer times, the time it takes to transfer the parts from one department to another, are higher as initially assumed;
- Currently the culture is one where talking during the shifts is commonly accepted. When the employees are talking to each other they tend to stop working which causes a delay in production.

For the design of the proposed lay-out, a new production process is made. The production process is shown in figure 7 on page 20. This production process is based on the production in three shifts. The total production time for one truck will be 160 hours. The proposed layout is shown in figure 14 on page 26.
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IV
1. Introduction

Ginaf Trucks Nederland B.V. is a Dutch truck manufacturer specialized in heavy duty trucks. Late 2011 the company went bankrupt. At the start of 2012 Ginaf was bought by a Chinese investor, this investor is CHTC (Chinese High Tech Group Corporation). This corporation operates in several sectors. One of these is the mining sector. For this Ginaf received an order to produce heavy duty mining trucks. Before Ginaf went bankrupt, they were used to customize each truck according to the customer requirements. With the order for mining trucks they needed to change their way of working and produce one truck in batches. This truck is not customized and therefore standardization in production is a requirement to reach cheap and quick production.

The graduation assignment at Ginaf Trucks Nederland B.V. was to research and analyze the requirements to produce the mining truck HD5380T at any other location. The goal for the possible new production location is to reach an output of five trucks per week. In addition to this time measurements in production were executed to see what the real assembly times of the truck consist of. Based on this it is possible to design the production process for a possible new production facility. Also the production process at Veenendaal can be optimized to decrease the throughput time.

This research is executed by answering one key question by analyzing production and purchasing. For the analysis four sub-questions are made. By answering these questions the key question could be answered. The questions used for this research are:

Key question:
- What is required to produce the HD5380T at any other location with an output of five trucks per week?

Sub-questions:
- What are the requirements for production, when the same process steps as in Veenendaal are followed?
- What is the average assembly time to produce the HD5380T in Veenendaal?
- What is the best practical layout for production?
- What is the best layout for production in Veenendaal?

The sub-questions are answered by doing analysis made in the different departments supported by literature study. The literature study is done for the following subjects:
- The purchasing portfolio analysis by using the Kraljic Matrix (chapter 5.1.1);
- What did others achieve with time studies (chapter 6.1);
- Learning curve theory (chapter 6.2);
- Theory of constraints (chapter 7);
- Systematic layout planning (chapter 7).
2. **Approach**

The project was started after the project initiation document was approved by Ginaf Trucks Nederland B.V. and by school. The research is divided in three different analyses. These analyses are:

- Time measurements, these consist of:
  - Literature study;
    - What did others achieve with time and motion studies;
    - Learning curve theory.
  - The analysis;
    - Time measurements for the assembly department;
    - Time written in the database per chassis number;
    - Comparison of these with a conclusion.
- A purchasing portfolio analysis;
  - Carried out for a possible new factory;
    - Which products should be purchased locally and which products centrally.
- Layout planning;
  - Best layout for a possible new factory;
  - Improved layout for the factory in Veenendaal.

The time measurements started with reading about time and motion studies. How they should be executed and what to measure was learnt. The outcome was that only the assembly times should be measured and that the production process should be divided in small steps. Approximately 40 different steps are defined and measured. In each assembly department several steps were measured. The clock was used as a time reference. These time measurements are compared to the time it took the employees to build the truck. These times are found in the database of Ginaf. In between the time measurements, the literature study was executed. Several articles were found and two of the articles are summarized in this report. The outcome of their study functioned as a reference for this report. A theory for assembly times in a possible new factory is called the learning curve theory. This theory is included in the report. The effect of this theory should be taken into account when a new factory starts producing.

The purchasing portfolio analysis is executed to find out which products should be defined as ‘strategic products’. It started by mapping the important parts for the Ginaf mining truck. These were inserted in a table and behind it is written if the part is customized for the mining truck or if it is a standard product purchased at the supplier.

Finally for the layout planning the systematic layout planning method is used. Before the layout could be developed, the theory of constraints is used to define the production process. The systematic layout planning defines six steps to create a new layout. These are used to create a layout for a possible new factory. These steps are as followed:

1. Identifying different activities and creating a relationship chart;
2. Determining the required space;
3. Create an activity relationship diagram;
4. Drawing layouts based on space and relationship;
5. Evaluating alternatives;
6. Create a detailed layout planning.

The factory in Veenendaal is analyzed for a better layout to decrease the transfer time between the departments. This is shown in chapter 8.
3. General information GINAF

This project focuses on the production of mining trucks with a loading capacity of 80 tons. This truck is called the HD5380T (HD stands for heavy duty). The entire process from chassis to testing the truck is done in house.

The production of the trucks is divided in five different departments supported by three pre-assembly departments. Several parts of the truck are delivered to Ginaf as semi-finished products, but most of the truck is produced in house. The semi-products are assembled in the pre-assembly departments.

3.1 History

GINAF B.V. was founded in 1948 by the brothers van Ginkel in a town called Ederveen. Their core-business was renovating and redesigning military vehicles to use them for construction transport. In the beginning they used the names of the military vehicles for their own trucks, until law subscribed that they must have a brand name for the registration of their vehicles. This name became GINAF. In 1978 they moved to Veenendaal with their production, because the production facility in Ederveen became too small for them. Until 2011 they modified trucks to the heavy duty vehicles specialized for the customer. (Kroek, 2013)

In 2011 GINAF was declared bankrupt, they were bought by the Chinese CHTC (China High-Tech Group Corporation) and they received orders from Chinese customers almost immediately. Just recently they started the production of a mining truck for transport between the mines and the factory, who process the products from the mines. These trucks have a loading capacity of 80 Ton. These trucks are produced in series. Due to bankruptcy it was unable for most of the production personnel to return to Ginaf after the new start of the factory. In the production department for the HD5380T there are only a few people who have worked at GINAF for longer than one year. This means that new employees still need to be educated and become familiar with the production processes and the new trucks. There were some construction failures in their prototype but these were eliminated after the prototype was finished. (Kroek, 2013)

Recently GINAF bought a former bus factory in Maribor, Slovenia. This facility has got a better layout for manufacturing in series. Their current factory in Veenendaal has not got the proper layout for manufacturing trucks in series. The production facility in Veenendaal is more suitable for the production and development of prototypes. Therefore a systematic layout planning at the new plant in Slovenia is of interest to Ginaf. The production costs will probably decrease because of the possible shorter throughput times and the lower wages of the Slovenian personnel.
3.2 Production process

The production process at Ginaf is divided in five different departments supported by three pre-assembly departments. The production departments are as shown in table 1 below.

<table>
<thead>
<tr>
<th>Production</th>
<th>Pre-assembly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chassis assembly</td>
<td>Engine and gearbox</td>
</tr>
<tr>
<td>Assembly before painting</td>
<td>Axles</td>
</tr>
<tr>
<td>Paint shop</td>
<td>Cabin</td>
</tr>
<tr>
<td>Final assembly</td>
<td></td>
</tr>
<tr>
<td>Final phase and quality checks</td>
<td></td>
</tr>
</tbody>
</table>

At the chassis assembly the chassis is prepared for the next department where they will start with mounting the axles under the chassis. Therefore the chassis is finished to the part where the axles can be mounted under the chassis. At the assembly before painting department there are four different processes. The axles are assembled, the grease and air lines are assembled, the hydraulics are installed and the cylinders are mounted on the truck. After this the truck will be painted. When the paint is dry the engine and the wiring system are installed in the truck. When these are all installed the truck is driven to the final phase and quality check, the truck is checked for flaws and prepared for sales. The production process is shown in figure 1.

![Figure 1: Production process Ginaf, production and pre-assembly departments](image-url)

A more detailed production process is shown in Appendix 2.
3.3 Competition

GINAF has always been a brand for the niche market of trucks. They produce trucks for customized jobs and they are specialized in trucks used in rough terrains and for heavy duty jobs. Each axle modification from 4x2 to 10x8 is possible with a Ginaf truck. Recently they started producing for the mining industry. This is a truck which uses Ginaf’s knowledge on heavy duty trucks for rough terrains.

The competition for Ginaf’s regular market (read: no mining market) is fierce. The market they operate in is only small, and multiple organizations operate in this segment. All competitors have a share of the market. Their major competitor is Terberg trucks. They act in the exact same market as Ginaf does. Ginaf has a collaboration with DAF by using their engines and cabins on the trucks, Terberg has that same collaboration with Volvo trucks. As you can see in Table 2 the market share of Ginaf is almost 0.5% higher as the market share of Terberg, their direct competitor (Terberg Group, 2013). Another competitor for Ginaf is the Czech producer Tatra which uses DAF components as well as Ginaf. They even created a new truck together called the ‘Phoenix’. It is made for the heavy duty industry and popular because of their unconventional tubular chassis. (Tatra S.V., 2011)

<table>
<thead>
<tr>
<th>Brand</th>
<th>Amount</th>
<th>Market share</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAF</td>
<td>52 794</td>
<td>31.07%</td>
</tr>
<tr>
<td>Mercedes</td>
<td>25 456</td>
<td>14.98%</td>
</tr>
<tr>
<td>Volvo</td>
<td>24 253</td>
<td>14.27%</td>
</tr>
<tr>
<td>Scania</td>
<td>23 325</td>
<td>13.73%</td>
</tr>
<tr>
<td>MAN</td>
<td>16 750</td>
<td>9.86%</td>
</tr>
<tr>
<td>Iveco</td>
<td>6 939</td>
<td>4.08%</td>
</tr>
<tr>
<td>Renault</td>
<td>4 842</td>
<td>2.85%</td>
</tr>
<tr>
<td>Ginaf</td>
<td>2 259</td>
<td>1.33%</td>
</tr>
<tr>
<td>VDL Berkhof</td>
<td>1 565</td>
<td>0.92%</td>
</tr>
<tr>
<td>Terberg</td>
<td>1 000</td>
<td>0.59%</td>
</tr>
<tr>
<td>Other</td>
<td>10 725</td>
<td>6.31%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>169 908</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

The market share of Ginaf is the highest of the customized truck market for heavy duty vehicles. It is higher as Terberg Trucks and Tatra is not even in this list under its own name. The other truck brands only have regular heavy duty trucks used for standard heavy duty jobs. The customized market is a bit different from the regular heavy duty market. Companies like Ginaf and Terberg Trucks operate in a niche as mentioned before, brands like DAF, Mercedes, Volvo, Scania and MAN operate in the heavy duty market with standardized trucks.

For the mining trucks there is also a new form of competition. Some brands are specialized in heavy duty mining transport. The main competitors are: Komatsu, Caterpillar, Liebherr and Hitachi. They produce heavy duty vehicles for the mining industry with a payload up to approximately 90 Tons. Ginaf’s HD5380T has a maximum payload of 60 Tons. The unique selling points of the HD5380T are; the maintenance costs and the fuel consumption. These are both low. The maintenance costs are low because the spare parts are regular truck parts and not special parts for Komatsu of Caterpillar.
4. Brief situation analysis

Late 2011 Ginaf Trucks Nederland B.V. went bankrupt. The Chinese corporation CHTC was interested in Ginaf and bought the company. This company has been involved in the automotive industry for a longer period of time now. They wanted to increase their interests in this market. Early 2012, Ginaf was operational again. Because Ginaf was taken over by a Chinese company the opportunities in Asia were opened to Ginaf. This resulted in a large order for mining trucks, which were new to Ginaf. They started with building the HD5364T, which has a maximum payload of 45 tons. Soon they realized that the maximum payload of 45 tons, used in the mines in China, was not high enough. They switched to the production of the HD5380T instead, these have a maximum payload of 60 tons. The truck has the same maneuverability as the HD5364T but the payload is higher, and therefore the output of the miners will be higher.

To determine an accurate cost price of the HD5380T, Ginaf needs data about the time it takes to produce a truck. This is to determine the labour costs per truck. Therefore the time measurements in production are of importance to Ginaf. The assembly time and the time it takes to transport parts are measured. This data could be of influence for improvements in production or for a decision to produce in a new/different production facility. If decision makers decide to produce the HD5380T in a different production facility, the time measurements in Veenendaal will count as the norm for production.

Due to a management decision, the output is only two trucks per week. Compared to the start of February, when the output was three to four trucks per week, these are only a few trucks. Before this decision, the production stagnated due to a lack of critical parts in production. After interviewing several employees in production, it became clear that the lack of parts in production is not new to Ginaf, they are used to it. To increase the output and to decrease the throughput time it is useful to research the purchasing process.
5. What are the requirements for production, when the same process steps as in Veenendaal are followed?

In this chapter the requirements for production in a different production facility will be discussed. With the requirements, the parts used for production are meant. The same parts should be used on the truck but they could be ordered at different suppliers. Which parts should be ordered centrally and which locally is described by using the purchasing portfolio analysis. This applies to parts designed and made by Ginaf as well as the “bolts and nuts”, all other component like axles etc. will have to be supplied by the regular suppliers.

5.1 Purchasing portfolio analysis

5.1.1 The theory

Purchasing is a major expense for most manufacturing organizations. On average these organizations spend 50% of their total sales money on the purchase of raw materials, components and supplies. If you achieve to lower the costs on purchases this will directly increase the profit of an organization. (Arnold, Chapman, & Clive, 2008) Therefore the development of purchasing strategies is a good way to lower the costs and increase the profits.

The Kraljic-Matrix is a model used for the development of purchasing strategies. The goal is to minimize the supply vulnerability and to maximize the buying power of an organization. The matrix is divided in four different quadrants, these quadrants represent the products purchased at suppliers. This model determines the product’s impact on the profit and their vulnerability to the supplier. In figure 2 below the model is shown. After the four quadrants are filled with the purchased items, it is possible to determine the purchasing strategy for these items. Kraljic developed one strategy for each quadrant. The four strategies are:

- Strategic products: Form partnerships with your suppliers;
- Leverage products: Exploit your purchasing power;
- Bottleneck products: Assure the supply of these items;
- Routine products: Ensure efficient processing. (Acuity Consultants Ltd., 2012)

Figure 2: Kraljic matrix with strategies (KnowledgeBrief, 2009)
To make strategic decisions you should be aware of the supplier’s perspective on your company. What kind of a customer are you to them, what share of their sales do you represent. Gelderman and Câniëls wrote about mutual dependencies and relative power as a way to make strategic purchasing decisions. They created more strategies for each quadrant in the Kraljic matrix. “Firms always depend, to varying extend, on their trading partner.” (Câniëls & Gelderman, 2005) This mutual dependency causes firms to have power over one another. Therefore you should look at each supplier filled in in the Kraljic matrix individually and therefore there is not only one strategy for each quadrant. All the strategies for the matrix are shown below in table 3.

Table 3: Kraljic matrix with related strategies (Gelderman & Weele, 2003)

<table>
<thead>
<tr>
<th>Leverage</th>
<th>Strategic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploit purchasing power</td>
<td>Maintain strategic partnership</td>
</tr>
<tr>
<td>Develop a strategic partnership</td>
<td>Accept locked-in partnership</td>
</tr>
<tr>
<td></td>
<td>Terminate partnership, find new supplier</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Routine</th>
<th>Bottleneck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual ordering, pursue efficient processing</td>
<td>Accept dependence, reduce negative consequences</td>
</tr>
<tr>
<td>Pooling of requirements</td>
<td>Reduce dependence and risk, find other solutions</td>
</tr>
</tbody>
</table>

5.1.2 The analysis

The goal for this purchasing portfolio analysis is to determine which products should be purchased centrally at Ginaf and which products should be purchased locally when production is moved to a different location. The research for Ginaf’s purchasing portfolio analysis started by mapping the entire process of purchasing. This is to understand the process steps and to determine how products are purchased. A detailed overview of the purchasing process is shown in figure 23 in appendix 3. A condensed version of the purchasing process at Ginaf is shown in figure 3 below. The system Sofon, shown at the start of the process, is an application to configure the truck in. Each specification is determined in this program. These specifications are sent to the ERP system which creates an order list of the parts needed for the truck.

Figure 3: Simplified purchasing process Ginaf

To produce the HD 5380T at a different location as in Veenendaal it is essential to look at the purchased products. The strategic products, as the theory describes, should be purchased centrally and most other parts can be purchased locally. The strategic products purchased for the HD5380T are shown in table 4 on the next page. The strategic products, which are purchased, are written in the first column of the table. The second column describes whether it is a standard product or a customized product especially...
for Ginaf or in collaboration with Ginaf. Please note that Ginaf and Durabus work together by using the same suppliers where possible (like the gearbox supplier) to get better prices.

Table 4: Strategic products Ginaf

<table>
<thead>
<tr>
<th>Strategic product</th>
<th>Customized/Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabin, Engine, Exhaust</td>
<td>Standard</td>
</tr>
<tr>
<td>Transmission</td>
<td>Standard</td>
</tr>
<tr>
<td>Axles</td>
<td>Customized</td>
</tr>
<tr>
<td>Tires</td>
<td>Standard</td>
</tr>
<tr>
<td>Wiring, DTS system, Cylinders</td>
<td>Customized</td>
</tr>
<tr>
<td>Tipper</td>
<td>Customized</td>
</tr>
<tr>
<td>Chassis beams</td>
<td>Customized</td>
</tr>
</tbody>
</table>

To produce at a different location, the products described in table 4 should be purchased centrally by a purchasing agent at Ginaf. Possibly Ginaf is producing at different locations at the same time when sales go up. This will allow Ginaf to buy more strategic products at the same time, which will provide economies of scale for these products. The costs per truck will decrease because the products can be purchased for a lower price per piece.

There is one supplier with a low supplier’s reliability. This is the supplier of the tires. Ginaf has looked for a different supplier of the tires, but the prices were higher than the prices of their tires. They made the decision not to change the tires. It is necessary for Ginaf to examine which costs are higher; the costs for different tires or a standstill in production for one or more trucks.

The hydraulics, a special part in a Ginaf truck, needed for the assembly, are specified by the supplier of the DTS system and the wiring system. The hydraulics supplier is therefore no strategic supplier to Ginaf. If Ginaf decides to produce at a different location, the DTS and wiring supplier can deliver the specifications to a local supplier. It is then possible to write out a tender to different quality suppliers in the region and choose the supplier with the lowest price. This is also a possibility for all the other ‘not strategic products’.

A brief overview of other products which are purchased at suppliers, are written below. Note that these products are always in stock. These are used for both the HD5380T ad the trucks for the Dutch market.

- Nuts and bolts;
- Beams in between the chassis;
- Fittings;
- Paint;
- Battery;
- Air and grease lines.

The strategic products must always be available for production. If the strategic products are not available when they are needed, the entire process will be delayed. The delay will look as followed; the department where the part is needed has to wait for the part, the next department has to wait until the department has finished assembling the part, etc. Just-in-time deliveries are currently not feasible because the supplier needs assurance about their sales. The output at Ginaf is to small for suppliers to deliver just-in-time.
There are two ways to protect yourself against a possible shortage in strategic products:

1. Safety stock, carrying extra stock to protect against quantity uncertainty and delivery uncertainty;
2. Safety lead time, used to protect against timing uncertainty by planning order releases and order receipts earlier than required. This will also result in a higher stock.

Not every supplier has a high delivery reliability and therefore the safety lead time is not an option for Ginaf. Safety lead time is only possible if all your suppliers deliver according to their lead times. For this reason Ginaf must have a safety stock for the strategic products. This ensures that there will be no disturbances in the throughput time. The productivity and the output will both benefit from this decision. It is recommended to have a safety stock of one week. This week of safety stock is based on the assumption that the purchasing department at Ginaf orders the products according to the lead time of the suppliers and the production planning. It is assumed that one week of safety stock is enough time for the supplier to deliver the backorder.
6. What is the average assembly time to produce the HD5380T in Veenendaal?

6.1 Desk research; what did others achieve with time studies/measurements?

Time and motion studies are developed by Frederick Taylor in the late 19th century to increase the efficiency of a worker. This was part of scientific management, also developed by Frederick Taylor. He described a scientific method to improve productivity. The production was divided in different process steps and each employee was given a small task. This way the productivity of each employee would be higher and therefore the entire productivity would be increased. (NetMBA, 2010) To determine the best way of producing, time and motion studies were conducted. The goals of these time and motion studies are:

- Improvement, improving production by eliminating non-value added time;
- Scheduling/balancing production, determining interdependencies between processes;
- Calculating costs, making a cost price for the labor costs;
- Safety improvements, determining the easiest way to produce.

These improvements and calculations are established by measuring and controlling the process. Time measurements in production is a form of controlling and measuring the process. With the results of the time measurements, you can set means and standard deviations in production. (University of Washington, 2010)

When executing time measurements, you need to keep in mind that workers will work quicker or slower when they are being measured. This may cause performance increases or decreases that are not caused by the production process itself, but because the employee feels that he should adjust his production pace, because he is being measured. He will do what he thinks is best for himself and the process. This phenomenon is called the Hawthorne effect. “Reliable productivity levels are best determined with long-term follow-up studies, or by analyzing long-term production statistics.” (Acuna et al., 2012)

For this reports two time studies are examined. The first one is executed in a hospital by several doctors. The objective was to document how nurses spend their time and at which location they find themselves. The results of the time study is divided in two outcomes;

1. Nursing practices and non-nursing practices;
2. The location they find themselves at.

The non-nursing practices are specified in unit-related functions, waste and non-clinical activities. The conclusion is as followed. “The time and motion study identified three main targets for improving the efficiency of nursing care: documentation, medication administration, and care coordination. Changes in technology, work processes, and unit organization and design may allow for substantial improvements in the use of nurses' time and the safe delivery of care.” (Chow, Hendrich, Lu, & Skierczynski, Hospital time and motion study, 2008)

The second time and motion study examined is executed at Laricina Energy Ltd. by the University of Calgary. The result of this study was an increase of the productivity. They defined two goals for their time and motion study. These goals are:

1. Monitoring construction activities and site activities, this is done to measure the amount of time workers spend in producing tangible outputs, called tool time;
2. Look for improvements by identifying inefficiencies and opportunities.
The tool time measured was only 37%, early quits & breaks (14%) and wait time (15%) were the biggest bottlenecks for productivity. The advice to the company was divided in two different scenarios. The first scenario assumed that they only implemented one best practice, this would lead to a productivity increase of 17%. The second scenario assumed that they implemented a set of best practices, this would lead to a productivity increase of 20%.

**Criticism on time and motion studies**

Criticism towards the founder of time and motion studies, F.W. Taylor, was there from the beginning of his theory. They said that the time measurements and the quest for the best tools to use in production were destroying the soul of the work and they were dehumanizing factories. (SkyMark Corporation, 2013) Another downside of doing tie measurements in a production environment is that the majority of the measured employees do not like the fact that they are being measured. They try to adjust their speed to influence their performances.
6.2 Learning curve

The learning curve is a way to predict how productivity goes up when new employees get more experienced. As the experience is gained, the performance of the worker improves, the time taken per unit reduces and thus productivity goes up. This is due to the learning effect. The goal is to make better decisions regarding the cost price, especially those relating to direct labour cost.

The learning curve subsists when the employee is new and has no experience in the particular job. In this period the productivity increases with each repetition of the job. After a while, when the limits of learning are reached and productivity stabilizes, no further improvement is possible. (The Institute of Chartered Accountants of India, 2008). The effect of the productivity improvement is that the costs per unit are declining. T.P. Wright (1895 – 1970) was the first person who wrote about the learning curve when he studied the time required to build airplane parts. Wright noticed that as the quantity of an item doubled, the costs of that item decreased at a fixed rate. Causes for this are:

- Better tooling methods are developed and used;
- More productive equipment is designed and used to make the product;
- Designed bugs are detected and corrected;
- Designed engineering changes are prompted to achieve better design for reducing material and labour cost;
- Management’s strive for better planning and management;
- Rejections and rework tend to diminish over time. (The Institute of Chartered Accountants of India, 2008)

The learning curve does not only count for new employees but the learning curve is also a valid tool to monitor change in an organization. The downside to change is that many employees tend to have a negative attitude towards it. The theoretical regular learning curve is shown in figure 5 and the learning curve measured with employees who were against change is shown in figure 4.
6.3 Field research; Actual time measurements in Veenendaal

The time measurements written in this report are carried out for the production of the HD5380T. The first step in measuring the process was to divide the production process in smaller process steps. The different departments which were measured are as follows:

- Axles pre-assembly;
- Cabin pre-assembly;
- Engine and gearbox pre-assembly;
- Chassis assembly;
- Assembly before painting;
- Paint shop;
- Final assembly;
- Final phase and quality checks.

In Appendix 1 you find the template used for the time measurements in production. The departments, process steps, different throughput times and the average throughput times are calculated in the sheet. For internal use the filenames for the building instructions are given in the sheet.

The processes are divided in approximately forty different steps. Each step is measured at least three to four times to exclude the possibility that a measurement is not accurate by whatever reason. Most of the steps include different persons who executed the process steps, this is done to include experienced employees and inexperienced employees.\(^1\)

The assembly times measured in production are measured to determine a standard time to assemble the truck. The measured times are shown in table 5 below. Table 5 describes two different times, the measured time (100%), and the measured time corrected by adding 5% (105%). The 5% is added to correct possible flaws in the measurements. Last mentioned will be the standard time to work with in this report. Please note that the standard time is rounded off upwards. In Appendix 1 you find the Excel sheet used for the time measurement with the measured times.

Table 5: Time measurements HD5380T

<table>
<thead>
<tr>
<th>Department</th>
<th>Time measured (in hours)</th>
<th>Time measured +5% and rounded off upwards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axles pre-assembly</td>
<td>14,42</td>
<td>16</td>
</tr>
<tr>
<td>Cabin pre-assembly</td>
<td>6,97</td>
<td>8</td>
</tr>
<tr>
<td>Engines and gearboxes</td>
<td>2,92</td>
<td>4</td>
</tr>
<tr>
<td>Chassis assembly</td>
<td>18,92</td>
<td>20</td>
</tr>
<tr>
<td>Assembly before painting</td>
<td>39,07</td>
<td>42</td>
</tr>
<tr>
<td>Paint shop</td>
<td>11,79</td>
<td>13</td>
</tr>
<tr>
<td>Final assembly</td>
<td>20,96</td>
<td>22</td>
</tr>
<tr>
<td>Final phase</td>
<td>12,02</td>
<td>13</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>126,54</strong></td>
<td><strong>138</strong></td>
</tr>
</tbody>
</table>

\(^1\) Note: Not every process could be measured with different persons because some processes are executed by only one person.
These measurements only include the assembly time for the HD5380T. Excluded are:

- Time to transfer the chassis or parts from one department to another;
- Clean up times after the chassis went to the next department;
- Gathering parts from the warehouse;
- Work meetings during the shift;
- And talking to a colleague during the shift.

At Ginaf the workers fill in their own time sheets and explain what activities they did that day. There is a record of these time sheets in the database of Ginaf. This record can be sorted per chassis number. For this report three time sheets were gathered and the results are written in table 6. The first time, gathered from the database, is from one of the first trucks build, the second time is from a truck build in the middle of a batch and the third time is from a truck build at the end of the batch.\(^2\) In the table this time is compared to the standard time as calculated in table 5.

*Table 6: Time filled in by employees on time sheets*

<table>
<thead>
<tr>
<th>Truck build at</th>
<th>Time on time sheets in hours</th>
<th>Standard time in hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of a batch</td>
<td>303</td>
<td>138</td>
</tr>
<tr>
<td>Middle of a batch</td>
<td>269.75</td>
<td>138</td>
</tr>
<tr>
<td>End of a batch</td>
<td>286</td>
<td>138</td>
</tr>
</tbody>
</table>

As shown in table 6, there is a significant difference between the time written in the time sheets and the assembly time measured. There are several causes for the difference in time:

- The main cause is that the production is not being managed with a goal. The management determines a production goal which is communicated to the assembly employees. If the goal is to make two trucks per week, as it is now, they tend to take on a slower pace in production. They do this because they ‘only’ have to produce two trucks per week. Before, this was three to four trucks per week. Their pace should be monitored. A solution for this could be to measure the productivity on each chassis number by checking the times written on the time sheets each week. After one week it is possible to check these times with the average time worked on other chassis. This is a reflection of the normal pace. The goal should be that the normal pace is closer to the standard time measured for this report. This way the production can be managed and the pace can be determined by management. Communication between different management layers is important in this case. Based on sales, purchasing and production figures they can make a production and purchasing planning for a certain period of time.

- The second cause for the time difference in the table above is that there are a lot of parts missing at the assembly site. These must be picked by the foreman. It frequently occurs that the parts have not been ordered yet. This takes a lot of time. Therefore it is recommended to research the warehousing activities. Stock levels and the purchasing process should be looked at. A plan to keep a stock for strategic items is written in chapter 5 of this report. It is important to have the right parts in the right place at the right time. These conditions must be met in order to increase the productivity in production. If production has to wait on one item, the production has to stop and this results in a lower pace in production and a decline in productivity.

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\(^2\) Note: The truck build at the end of the batch takes longer to build as the truck in the middle of the batch, because a lot of new employees had to be trained.
Currently the ruling culture is one where talking during the shifts is commonly accepted. When the employees are talking to each other they tend to stop working which causes a delay in production. Talking during the shift in this case means not work related small talk. Usually this small talk takes only a few minutes, but when several people talk to one another several times a day, the throughput time will not be benefitted and the costs will be high.

During the time studies the transfer times, compared to the assembly times, seem to have a bigger impact on the process as initially assumed. The transfer times are way more labour intensive and seem to slow down the process. Between each process step, the parts produced must be transferred to the next department. For example the axles need to be brought to the assembly department piece by piece. This means that several employees are busy with the transportation of parts or the chassis. This results in a hold on the assembly. The transfer times are written in table 7. The duration of the transfer times is not as high as the transfer times in the table, but when two or more people help with the transfer these transfer times are added together. This is done because this is the result of transferring the parts or the chassis. They can not produce when they are busy with the transportation of goods.

Table 7: Transfer times

<table>
<thead>
<tr>
<th>Department →</th>
<th>Department</th>
<th>Time (in minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chassis assembly → Chassis storage</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Chassis storage → Assembly</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Axles → Assembly</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Assembly → Paint shop</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Paint shop → Final assembly</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Cabin → Final assembly</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Engine → Final assembly</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Final assembly → Final phase</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>230</td>
<td></td>
</tr>
</tbody>
</table>

As shown in the table above, it takes approximately three hours and fifty minutes to transfer the parts from one department to another. This is waste in the production time. The transfer times could be reduced by changing the sites of the assembly departments. In the next chapter you find a solution for this problem for the factory in Veenendaal. In this same chapter you will also find a design for a possible new factory at a different location.

Concluding it can be said that the standard assembly time to produce the HD5380T is 138 hours. The assembly times measured are way lower than the time it took the production employees to produce the HD5380T. This is caused by the following:

- The production employees determine their own production pace, which causes them to take it easy in production. the goals set by management should be explained to the production employees and they should be monitored, this will help them understand why the production is increased or decreased. This will eventually result in a higher productivity and lower labour costs per truck.
- Parts used to produce the truck are not at the assembly site and should be gathered at the warehouse. The parts should always be at the right place, at the right time in the right quantity;
• Transfer times, the time it takes to transfer the parts from one department to another are higher as initially assumed. These should be as short as possible. Transferring parts or the chassis is a waste in production time;
• Productivity in production should be monitored in order to keep the production pace at a steady level.

It is recommended to execute additional research for the warehousing activities and the purchasing process. The parts missing in production are not always in the warehouse. A safety stock for the strategic products is recommended.
7. **What is the best practical layout for production?**

The layout for a possible new production facility, can only be designed if the production process and its throughput times are known. These have to be calculated based on the data from the time measurements. The goal is to design a layout which allows an output of five trucks per week. This means one finished truck per working day. In Ginaf there are eight departments which determine the throughput time. Most of the processes will have a shorter throughput time if they are executed by more than one employee. The assembly at Ginaf consists of the eight departments written in table 8. The average assembly times are written behind the departments.

<table>
<thead>
<tr>
<th>Department</th>
<th>standard assembly time per piece/set</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axles pre-assembly</td>
<td>16 hours</td>
</tr>
<tr>
<td>Cabin pre-assembly</td>
<td>8 hours</td>
</tr>
<tr>
<td>Engine pre-assembly</td>
<td>4 hours</td>
</tr>
<tr>
<td>Chassis assembly</td>
<td>20 hours</td>
</tr>
<tr>
<td>Assembly before painting</td>
<td>42 hours</td>
</tr>
<tr>
<td>Paint shop</td>
<td>13 hours</td>
</tr>
<tr>
<td>Final assembly</td>
<td>22 hours</td>
</tr>
<tr>
<td>Final phase</td>
<td>13 hours</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>138 hours</strong></td>
</tr>
</tbody>
</table>

The table above shows that not every department can finish their processes in one day (8 hours). At least not with one employee at each department. There are two solutions for this problem:

1. Some departments need more than one employee to finish the processes in one day;
2. Working in shifts on several departments to finish the processes in one day (24 hours).

Both of the solutions can be used to reach the goal of producing five trucks per week. The first solution can not be applied to every department. Not every process can be finished in half the time if two people are working on the same process. Some departments need to divide their processes in different steps in order to finish the processes in one day. If necessary, the process steps will be executed in up to three shifts per day. To demonstrate the flow of the production process, a flowchart of the process and its assembly times are shown in figure 6 on the next page.
To create a flow in production, the assembly before painting department needs to work on three chassis at the same time to keep up with the pace of chassis build. This creates a high work in process inventory. To decrease this inventory in production the theory of constraint will be used. The theory of constraints is created by Dr. Eli Goldratt. It is based on the principle that a chain is as strong as its weakest link. “According to the theory, organizational performance is dictated by constraints. These are where bottlenecks occur that prevent an organization from maximizing its performance and reaching its goals.” (Mindtools Ltd., 2013) These bottlenecks can be solved by following five different steps. These steps are:

1. Identify the constraint;
2. Exploit the constraint;
3. subordinate everything else to the constraint;
4. Elevate the constraint;
5. Go back to step 1. (Goldratt Institute, 2009)

For this project it is only possible to elaborate on the first three steps of the theory. This is because it can not be tested and evaluated in practice.

The measured assembly times written in figure 5, make it possible to find the constraint in the process. As you might see, the assembly before painting department takes 42 hours to complete their processes. These processes are the most time-consuming. To be able to create five trucks per week the total assembly time needs to be divided in several processes. As you can see in figure 6 the assembly before painting department will be divided in three processes. The same will be done for two other departments, the final assembly department and the quality check department. To reach the goal it is advised to work in several shifts in multiple departments. The process steps are defined in figure 7 on the next page. This includes the solution for the first bottleneck, the process of 42 hours is divided in three separate process steps. This solution makes it able to create five trucks per week.
In this design for a new production process, the departments are divided in 13 different process steps. Each of these steps can be finished in one day according to the calculation of the standard times. The circles in the figure represent the transfer times from one site of the production to another. The triangles in the figure represent storage points in the process. In front of the bottleneck there should always be a storage point in order to keep the bottleneck producing at its maximum capacity. That is because the bottleneck determines the pace in the process. The first bottleneck is solved by dividing the department in three different process steps. The new bottleneck is at the assembly of the hydraulics and the cylinders. This process should be finished in 16 hours with two employees. This is possible according to the calculated standard time, but the deviation is high. It can take two employees up to 22 hours to complete this process (two employees can only work 16 hours in one shift). Unfortunately it has no use to work on the process with three employees at the same time, simply because the throughput will not benefit from the third employee. The standard times are measured with the processes as they are executed in Veenendaal. The hydraulics are installed by one employee in Veenendaal. When you install the hydraulics with two employees, one of them can prepare the connectors and the other employee can gather the pipes and install them with the prepared connectors. It has not been tested yet, but assumed is that the process’ standard time will drop to 13-14 hours. To reach this there should be standard working instructions which will be followed by every production employee. These standard working instructions should be written in such a way that everybody could be able to execute the process.
The processes at the axles pre-assembly department take approximately 16 hours, the same standard time as the assembly of the hydraulics and the cylinders, but the deviation is smaller. The highest measured assembly time is less than one hour higher as the standard time. If absolutely necessary, they can work overtime to finish the process. Therefore this is a critical process but not a bottleneck process. It could become a bottleneck if the hydraulics and cylinders bottleneck is solved by implementing the aforementioned option.

The new process layout will be as shown in figure 8. The entire first week is needed to produce the first truck. After the startup they will be able to produce five trucks per week. Note that these assembly times can only be reached if the logistics processes are balanced and every assembly part is available at the assembly sites.

The quality check department has a standard time of 13 hours if there are no malfunctions found in the ‘finished truck’. If they found a malfunction in the truck it is possible to add an additional shift to solve the malfunction. It takes between 1 and 8 hours to solve the malfunction.

Three additional considerations/advises:

1. Hire an all-round assembly mechanic to fill possible gaps and to help with the transfers to minimize the delay due to transfer times. Especially in the first few weeks such an employee is of interest to balance the process and to look for improvements or design errors;
2. Install an extra quality check after the bottleneck process, installing the hydraulics and the cylinders, to minimize the malfunctions at the quality check department. This also decreases the standard time at the quality check department. This way they have more time to cope with possible malfunctions in the regular shifts;
3. Prepare the connections for the hydraulics at the pre-assembly department. This will decrease the assembly time at the bottleneck process.
Calculated from figure 8 you need at least 20 assembly employees to reach the goal of five trucks per week. This can be extended with an extra employee for the third shift at the quality check. This could be necessary to solve possible malfunctions in the truck. Currently approximately 5 out of 10 trucks deal with a malfunction. It takes approximately 1 to 8 hours to solve a malfunction. It depends on the cause of the malfunction.

Now that the process steps are known, it is able to start with a design for a possibly new factory. To determine the best practical layout to produce the HD5380T, the systematic layout planning method is used. This theory is made by Richard Muther. (Richard Muther & Associates, 2005) The theory consists of six different steps. The steps are as followed:

1. Identifying different activities and creating a relationship chart;
2. Determining the required space;
3. Create an activity relationship diagram;
4. Drawing layouts based on space and relationship;
5. Evaluating alternatives;
6. Create a detailed layout planning.

The first step is to identify the different activities and create a relationship chart. In figure 9 you can find the relationship chart with the associated activities.

![Relationship chart](image)

**Figure 9: Relationship chart**

The letters and numbers you find in the chart, are explained in the tables on the right hand side of the figure. This way you can determine which activities should be close to each other or not close to each other at all. The reasons for it are described by the numbers.
To produce five trucks per week the space needed per department should be calculated by measuring the space per chassis and per produced part. There should be enough space around the chassis to move the parts and to bring parts with a forklift truck. Table 9 shows what the space should be between the chassis and the wall and the space between the chassis and a stand.

Table 9: Space needed for movement around chassis

<table>
<thead>
<tr>
<th>Space</th>
<th>Space needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between chassis and wall</td>
<td>2,2m</td>
</tr>
<tr>
<td>Between chassis and stand</td>
<td>1,5m</td>
</tr>
<tr>
<td>Rear axles (length)</td>
<td>2,55m</td>
</tr>
<tr>
<td>Front axles (length)</td>
<td>2,52m</td>
</tr>
<tr>
<td>Cabin</td>
<td>2,20m * 2,40m</td>
</tr>
<tr>
<td>Engine</td>
<td>1,14m * 1,66m</td>
</tr>
<tr>
<td>Transmission</td>
<td>1m * 1,30m</td>
</tr>
</tbody>
</table>

Production is only possibly if all the facilities are present. All the requirements for production are shown in the next table, table 10. Without these, Ginaf is unable to produce the HD5380T at a different location.

Table 10: Requirements

<table>
<thead>
<tr>
<th>Department</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axles pre-assembly</td>
<td>1 overhead crane</td>
</tr>
<tr>
<td>Cabin pre-assembly</td>
<td>1 overhead crane</td>
</tr>
<tr>
<td>Engine pre-assembly</td>
<td>1 overhead crane</td>
</tr>
<tr>
<td>Chassis assembly</td>
<td>1 overhead crane</td>
</tr>
<tr>
<td>Assembly before painting</td>
<td>1 overhead crane</td>
</tr>
<tr>
<td>Paint shop</td>
<td>Extraction of air</td>
</tr>
<tr>
<td>Final assembly</td>
<td>1 overhead cranes</td>
</tr>
<tr>
<td>Final phase</td>
<td>1 overhead crane, 2 working pits</td>
</tr>
</tbody>
</table>

The space needed for general storage is based on storage space used in Veenendaal and on a safety stock of four weeks. This guarantees the production to keep assembling for four weeks when parts are delivered wrong or when purchasers make a mistake.
The second step is to determine the required space for each department. Based on the previous and the size of the chassis (24,2 m$^2$), the required space is shown in table 11 below.

Table 11: Required space

<table>
<thead>
<tr>
<th>Department</th>
<th>Required space (m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axles pre-assembly</td>
<td>180</td>
</tr>
<tr>
<td>Cabin pre-assembly</td>
<td>80</td>
</tr>
<tr>
<td>Engine pre-assembly</td>
<td>75</td>
</tr>
<tr>
<td>Chassis assembly</td>
<td>243</td>
</tr>
<tr>
<td>Assembly before painting</td>
<td>152</td>
</tr>
<tr>
<td>Paintshop</td>
<td>152</td>
</tr>
<tr>
<td>Final assembly</td>
<td>152</td>
</tr>
<tr>
<td>Final phase</td>
<td>152</td>
</tr>
<tr>
<td>General storage</td>
<td>700</td>
</tr>
<tr>
<td>Office</td>
<td>490</td>
</tr>
</tbody>
</table>

The third step is to determine an activity relationship diagram based on the first two steps. In figure 10 you find the activity relationship diagram for the best practical production layout for Ginaf.

Figure 10: Activity relationship diagram
Based on the previous steps a ground plan can be made for the best practical layout for the production of the HD5380T. In figure 11, 12 and 13 you find several ground plans for a new factory. The transfer distances are decreased to a minimum and the building is build to produce in a well directed process flow. Based on the requirements described in table 8 each step takes approximately one day and each day a truck can be finished.

Above three lay-outs are drawn. These lay-outs are drawn based on the previous steps of the systematic lay-out planning. In order to pick the best lay-out for the production of the HD5380T it is necessary to think of some criteria to measure. The criteria analyzed for these models are:

- Process flow (10X);
- General lay-out (5X);
- Easy parts flow (5X);
- And supervision/communication (4X).

The criteria are given multipliers for their importance. They are shown behind the criteria. Each lay-out will be tested on these criteria. Each criteria is given a value from one to five. The lay-out with the highest value will be the best lay-out for production. On the next page you will find the outcome in table 12.
Table 12: Evaluation of the alternatives

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Lay-out 1</th>
<th>Lay-out 2</th>
<th>Lay-out 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process flow (10X)</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>General lay-out (5X)</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Easy flow of parts/material (5X)</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Supervision/Communication (4X)</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>115</strong></td>
<td><strong>87</strong></td>
<td><strong>95</strong></td>
</tr>
</tbody>
</table>

Lay-out 1 turns out to be the best lay-out according to these criteria. A detailed lay-out is shown in figure 14 Below. As you can see the supervision and the communication from the offices to the assembly site is better because they are close to each other. The communication lines are shortened and it is very likely that this will benefit the productivity.

Figure 14: Best practical lay-out for the production of the HD5380T

The conclusion for this chapter is that it is recommended to work in shifts when a new production facility is build. Figures 7 and 8 show the design of the production process and the amount of employees needed for each shift. Based on these figures the best practical layout is designed. Further, it is recommended to hire an all-round assembly mechanic in the first few weeks, to fill possible gaps in production. An extra quality check after the bottleneck process (installing the hydraulics and the cylinders) is advised. Finally there has to be additional research to check if it is possible to pre-assemble some of the hydraulics. If it is possible the bottleneck will be solved, the throughput time for the main production process will decrease.
8. What is the best layout for production in Veenendaal?

Currently the production facility in Veenendaal looks as shown in figures 15 and 16. In these figures you find the interdependencies between the different departments in the factory. The lines represent the way the chassis follows from department to department. In figure 1 on page 4 the interdependencies between the departments are shown schematically. The colours used for the lines are defined in the legends. The factory is split in two different ground plans. This is done to give an orderly overview. This is the reason that the scales from drawing A and drawing B are different. The second ground plan covers a smaller ground and therefore the scale is made smaller.

The transfer times are a waste of time in the production process. They should be decreased to a minimum to keep the productivity as high as possible. Currently the chassis produced at the chassis build are transferred to the chassis storage and when the assembly before painting has a free spot, the chassis is transferred to this department (blue line). This is both a time consuming and a dangerous job. The chassis is hoisted as high as possible and lifted over the trucks for the Dutch market. There is a chance that the chassis will fall. This means that the employees who are working on the trucks for the Dutch market should stop their work until the chassis is lifted over there trucks. If the chassis falls down, the trucks for the Dutch market are damaged and the new chassis is damaged. Fortunately this has not happened before but the impact is great if it happens. A plan to change this is discussed later in this chapter.
In the previous chapters you read about the transfer times between the different departments. As you can see in the ground plans, there is a distance between the pre-assembly and the assembly departments. These can’t be changed unfortunately. The pre-assembly departments are in the best place for this factory. The way from the chassis assembly to the assembly before painting on the other hand can be declined. This decreases the total time of a truck with one and a half hour. Also the risk of damaging other trucks or injuring employees will be decreased this way. If the assembly before painting department would be at the storage point, the entire process time would be decreased with one and a half hour per truck. The new ground plan will look as shown in figure 17 or figure 18 on the next page. There are two options for reducing the transfer times.
Figure 17: Plan A to minimize the transfer times

Figure 18: Plan B to minimize the transfer times
In the figures 17 and 18 you find two possible solutions for decreasing the transfer times. Assembly before painting is now directly next to the chassis assembly department. This makes the process less labour intensive and it even increases the safety. The correct measurements between the different chassis are included in these ground plans. Figure 18 seems the most logical choice because the logistics to the paint shop are easier this way. There is also the possibility to make a storage point per chassis behind the chassis. This makes production more organized.

The other ground plan of production is still the same as in figure 16. Therefore this figure has not been changed. All the other departments used for the production of the HD5380T remain unchanged.

The conclusion is that the lead time of the production of the truck can be reduced with one and a half hour by changing the site of the assembly before painting. The site for the trucks build for the Dutch market will become the site for the assembly before painting of the HD5380T. The Dutch market will be produced at the site where the assembly before painting is in the current situation. This also reduces the chance of damaging the trucks for the Dutch market and it increases the safety.
9. Conclusion

What is required to produce the HD5380T at any other location with an output of five trucks per week?

To answer this question several aspects within the organization have been reviewed. As a first step the purchased parts have been looked at. Strategic parts, as described in chapter 5, should be purchased centrally if production is moved to a different location. This will result in lower costs due to economy of scale. All other parts should be purchased locally. These are usually standard products which can be produced at different suppliers. The next table shows the strategic parts for the HD5380T.

Table 13: Strategic products

<table>
<thead>
<tr>
<th>Strategic product</th>
<th>Customized/Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabin, Engine, Exhaust</td>
<td>Standard</td>
</tr>
<tr>
<td>Transmission</td>
<td>Standard</td>
</tr>
<tr>
<td>Axles</td>
<td>Customized</td>
</tr>
<tr>
<td>Tires</td>
<td>Standard</td>
</tr>
<tr>
<td>Wiring, DTS system, Cilinders</td>
<td>Customized</td>
</tr>
<tr>
<td>Tipper</td>
<td>Customized</td>
</tr>
<tr>
<td>Chassis beams</td>
<td>Customized</td>
</tr>
</tbody>
</table>

The second requirement was the standard time to produce the truck. To determine this standard time, time measurements were carried out in production. The assembly times and the transfer times between the different departments were measured. The standard assembly time to assemble the HD5380T is 138 hours. The assembly times measured are way lower than the time actually used in production to produce the HD5380T. Table 14 shows the difference in the assembly time measured and the time written on the time sheets.

Table 14: Assembly times written on time sheets and the measured assembly time in hours

<table>
<thead>
<tr>
<th>Truck build at</th>
<th>Time on time sheets in hours</th>
<th>Standard time in hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of a batch</td>
<td>303</td>
<td>138</td>
</tr>
<tr>
<td>Middle of a batch</td>
<td>269,75</td>
<td>138</td>
</tr>
<tr>
<td>End of a batch</td>
<td>286</td>
<td>138</td>
</tr>
</tbody>
</table>

This is caused by the following:

- The production employees determine their own production pace, which results in longer production time. The goals set by management should be explained to the production employees and they should be monitored. This will help them understand why the production is increased or decreased. This will eventually result in a higher productivity and lower labor costs per truck.
- Parts used to produce the truck are not at the assembly site and should be picked at the warehouse. These parts should always be at the right place, at the right time in the right quantity. Production is often stopped because some critical parts are missing. These must be ordered at the suppliers and this usually takes a few days or even weeks before the parts can be assembled;
- Transfer times, the time it takes to transfer the parts from one department to another, are higher as initially assumed. These should be as short as possible. Transferring parts or the chassis is a waste in production time;
- Currently the culture is one where talking during the shifts is commonly accepted. When the employees are talking to each other they tend to stop working which causes a delay in production. Talking during the shift in this case means not work related small talk. Usually this small talk only takes a few minutes, but when several people talk to one another several times a day, the throughput time will benefit.

The last requirement studied for this report is the best practical layout for the production in a new production facility. This begins with determining the production process. Because the goal is five trucks per week, each working day one truck should be finished. The production process used for the layout of a possible new production facility is as shown in figure 19 below.

This process will be executed by twenty employees divided over three shifts per day. This means that each day a new HD5380T will be finished. As you can see the bottleneck in the production process is the assembly of the hydraulics and the cylinders. This has to be done in 16 hours with two people in one shift. In chapter 7 you will find a solution to solve this bottleneck but this has to be tested before this is implemented (preparation of the hydraulics at the pre-assembly department). In total 160 labor hours are spent for the production of the truck. The learning curve should be taken into account when the production is moved to a new production facility.
To design the best layout to produce five trucks per week, the systematic layout planning method is used. The production process above was the input for the production process. The preferred layout for the production of the HD5380T is shown in figure 20 below.

The requirements for producing the HD5380T at any other location with an output of five trucks per week are:

- Purchase the strategic products centrally at Ginaf Veenendaal and purchase the not strategic products locally;
- Produce the HD5380T in 160 labor hours, in order to be able to produce five trucks per week;
- Design a production facility based on the proposed lay-out as shown to reach the output of five trucks per week.
10. Recommendation

The recommendations resulting from this report are divided in short term, and long term recommendations. The short term recommendations are for the production facility in Veenendaal and the long term recommendations are for the possible new production facility.

Short term:

- It is recommended that the best layout for production in Veenendaal as shown in chapter 8 is followed. This will decrease the lead time of the process. This means that the assembly before painting department will change to the site of the trucks for the Dutch market and the other way around.

- Keep a safety stock for the strategic products. This will increase productivity and will prevent that the production has to wait for parts. The not strategic parts are already in stock. The production flow will benefit from the safety stock.

- A tool to monitor productivity should be implemented in order to keep track of the production times. This should be done to increase productivity. A solution to do this is by checking the progress in production in combination with the time sheets each week. The time sheets are filled in by the production employees themselves. This way production employees can be monitored and motivated to increase productivity. Communication about the production goals is important in this case.

- It is advised to execute additional research to check if the current supplier are the suppliers with the best prices and the best quality for the parts needed to assemble the HD5380T. A business case could be made to check which costs are higher; waiting for parts in production because of the poor delivery reliability or finding a more expensive supplier with a higher delivery reliability. The purchasing activities and processes should be included in this study.

Long term:

- If a new production facility will open, the standard times measured in production in Veenendaal should be used as a reference point and a norm for assembling the truck. The new design of the production process is advised to implement in the new production facility. This is the fastest and most efficient way to build the truck. The new designed layout, based on the new production process, is advised to use when building the new production facility.

- The purchasing process is advised to change when the new production facility is opened. The strategic parts, as mentioned in table 13 in the conclusion, should be purchased centrally at Ginaf Veenendaal. The not strategic parts should be purchased locally. By purchasing strategic parts centrally, Ginaf will benefit from economies of scale and therefore the prices per product will be decreased. It is advised for Ginaf to calculate the costs for transportation to the new production facility.
Bibliography


### Appendix 1: Time measurement template used for the time measurements in production

<table>
<thead>
<tr>
<th>Task name</th>
<th>Total time</th>
<th>Average time</th>
<th>Base time</th>
<th>Assembly instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axles pre-assembly</td>
<td>12:45:00</td>
<td>8:45:00</td>
<td>9:45:00</td>
<td>8:55:00</td>
</tr>
<tr>
<td>Air-spring bellows</td>
<td>1:10:00</td>
<td>1:10:00</td>
<td>1:10:00</td>
<td></td>
</tr>
<tr>
<td>Valve body</td>
<td>1:50:00</td>
<td>2:00:00</td>
<td>1:55:00</td>
<td></td>
</tr>
<tr>
<td>Axles pre-assembly</td>
<td>10:02:30</td>
<td>602,50</td>
<td>10,04</td>
<td></td>
</tr>
<tr>
<td>Engine and gearbox assembly</td>
<td>2:55:00</td>
<td>275,00</td>
<td>2,92</td>
<td></td>
</tr>
<tr>
<td>Standard chassis assembly</td>
<td>18:00:00</td>
<td>1135,00</td>
<td>18,92</td>
<td></td>
</tr>
<tr>
<td>Connecting air and grease lubrication</td>
<td>14:40:00</td>
<td>681,67</td>
<td>11,36</td>
<td></td>
</tr>
<tr>
<td>Connecting cylinders</td>
<td>10:30:00</td>
<td>12:46:15</td>
<td>766,25</td>
<td></td>
</tr>
<tr>
<td>Taping up</td>
<td>3:45:00</td>
<td>212,50</td>
<td>3,54</td>
<td></td>
</tr>
<tr>
<td>Degrease</td>
<td>0:30:00</td>
<td>30,00</td>
<td>0,50</td>
<td></td>
</tr>
<tr>
<td>Spraying</td>
<td>6:45:00</td>
<td>398,00</td>
<td>6,63</td>
<td></td>
</tr>
<tr>
<td>Unpack</td>
<td>0:45:00</td>
<td>45,00</td>
<td>0,75</td>
<td></td>
</tr>
<tr>
<td>Wheel alignment and steering adjustment</td>
<td>3:13:00</td>
<td>158,25</td>
<td>2,64</td>
<td></td>
</tr>
</tbody>
</table>

The numbers written with the red font are assumptions. These are made because there was not enough time to measure every process several times.
Appendix 2: Extended Production process (description and figure)

The production process at GINAF starts with the assembly of the chassis of the HD5380T. First the chassis beams are being checked, if the chassis beams are correct they can send the beams to the assembly department. If the beams are not correct extra holes are drilled in them in order to assemble the chassis. At the assembly department the chassis beams are mounted together and many loose parts are attached to the chassis. The spring leafs, the air tanks, the support for the fuel tank and many more parts are added to the chassis. The next step in the process is the assembly before the chassis is painted.

First the axles are brought in position in order to hoist the chassis above the axles, this way the axles are easy to assemble them to the chassis. After that four steps follow. The hydraulics system is installed, the grease lines and the airlines are being attached and the lines for the braking system are installed on the chassis. After the hydraulics are finished, the cylinders for the suspension can be mounted on the truck. Later the steering rods are assembled and paint wheels are mounted under the truck in order to move the truck to the paint shop. Simultaneously the painter sands the air tanks and tapes up the parts which shouldn’t be painted. Three layers of paint are sprayed on the chassis. The first layer is to protect the nuts and bolts against corrosion. The second layer is the grey paint which covers the entire chassis, the third and last layer is just to make sure that the color covered the entire chassis. After painting the truck it dries overnight and the next day the chassis is moved to the final assembly department. Simultaneously three parts can be added to truck, these are the engine, the wiring system and the fuel tank. After the engine is build in the radiator and the exhaust can be installed. When these are mounted on the engine, the cabin is installed on the truck. After this step the wiring system can be connected to the cabin and the cabin can be finished by adding the headlights and the bumper. The battery can be installed and the cylinders can be connected. If the wheels are already mounted on the truck, it can be bled and started up. The truck can now drive to the last department of GINAF, the quality check and final phase. In this department they start by filling up the air conditioner and installing different software on the board computer. This is software for the different DAF-components, for the DTS-system (Dynamic Truck and Trailer Suspension) and for the braking system. After this the brakes are tested with air pressure gauges. Next the hydraulics system is checked by checking if all the fittings are tight and if the system is closed. When this is done the system is tested by increasing the pressure to the maximum of around 250 bars. Then they start with the alignment of the wheels. The last two axles are aligned first and later the three front axles are aligned, these axles are steered axles. When these are aligned as well, the freewheel is being checked. When these tests are all positive they take the truck for a test drive. All the final flaws discovered with this test drive are solved after testing. In the end the truck is driven to the container factory for the assembly of the container. The production process is shown in a flowchart on the next page in figure 1.
Figure 22: Chassis assembly department

Figure 23: Assembly before painting department

Figure 24: Paintshop
Figure 25: Final assembly department

- Engine is build in
- Radiator is installed on the engine
- Exhaust is assembled on the engine
- Wiring system is installed on the chassis
- Fuel tank is installed
- Radiator is installed on the engine
- Exhaust is assembled on the engine
- Cabin is mounted on the truck
- Wiring system is connected to the cabin
- Engine is build in
- Radiator is installed on the engine
- Exhaust is assembled on the engine
- Wiring system is installed on the chassis
- Fuel tank is installed
- Cabin is mounted on the truck
- Wiring system is connected to the cabin

Painted chassis is driven to the final assembly department

- Truck is started and the air is being extracted
- Truck is filled with oil and diesel
- Wheels are mounted on the truck
- Battery is installed on the truck
- Cabin is being finished by adding headlights and bumper

Truck is driven to the quality control

- The air conditioner is being filled
- Truck is driven in
- Final phase and quality check
- The air conditioner is being filled
- Truck is driven in
- Final phase and quality check

Figure 26: Quality check department

- Truck is started and the air is being extracted
- Truck is filled with oil and diesel
- Wheels are mounted on the truck
- Battery is installed on the truck
- Cabin is being finished by adding headlights and bumper

Truck is driven to the quality control

- Truck is started and the air is being extracted
- Truck is filled with oil and diesel
- Wheels are mounted on the truck
- Battery is installed on the truck
- Cabin is being finished by adding headlights and bumper

Truck is driven to the container producer

- Truck is driven in
- The air conditioner is being filled
- DAF software is being installed on the truck’s system
- DTS software is installed on the truck’s system
- The braking system software is installed on the truck’s system
- Brakes are being tested
- Test drive with the truck
- Freewheel check
- Wheels are being aligned
- Hydraulics system is tested
- The hydraulics system is checked if the system is closed

After the test drive the final flaws are solved

- Truck is driven to the container producer
- END

Final phase and quality check
Figure 27: Production process of the pre-assembly departments
Appendix 3: Purchasing process

Sales order enters Ginaf

Truck is configured in Sofon

Invoice is sent to the customer

Customer agrees with invoice?

YES

New customer order

NO

Change the invoice?

YES

New/changed invoice is sent

NO

No new order

Sales and purchasing process

Suggestion ok?

YES

EB2 produces a purchasing suggestion

EB2 checks what is in stock and what should be ordered

Customer order with configuration sent to EB2

NO

Order is sent to the suppliers

Sales order can be produced

NO

Adjust the suggestion and calculate what you need to order

Follow the suggestion in EB2

Sales and purchasing process

Figure 28: Purchasing Process
Appendix 4: Extended literature study on time studies

The time and motion study can be done in several ways. The old-fashioned ways are executed by using a stopwatch or by simply using the clock as your reference for time. There are also new ways for the time and motion studies. Some of these are used for a time and motion study in a hospital, the efficiency of nurses was measured. The new techniques used to measure time and motion are:

- PDA, with the use of a personal digital assistant, activities could be categorized immediately;
- RFID, stands for radio frequency identification. With this technique the researchers could measure every move and see all the locations the nurses went to;
- Bracelet, with the bracelet the parameters were automatically recorded. This way the researchers could process the data later.

Their research was on a voluntary basis. This means that the nurses who participated for this study chose to do so. There were only two restrictions to participate, the nurses must be licensed and they must provide direct nursing care to the patients.

The nurses were divided in four study protocols made by the researchers. These protocols were as follows:

- Protocol A: Baseline data for electronic health record implementation;
- Protocol B: How nurses spend their time;
- Protocol C: Nurse location and movement;
- Protocol D: Nurse physiologic responses.

For protocol A and B the nurses were divided randomly by the researchers. For protocol C all the nurses were monitored. The first protocol was set to collect data about the nurses’ activities during the day. These activities were collected by PDAs given to the nurses to record all documentation-related activities. This way the researchers could use this information to categorize the activities done by nurses who participated in protocol B. This protocol was divided in four different categories. The categories are:

- Waste;
- Unit-related functions;
- Nursing practice;
- Nonclinical.

Each of these nurses was given a PDA which was programmed to vibrate 25 times per shift. Each time the PDA vibrated the nurses must fill in their location and their activity. This way the researchers could sort this data in one of the four categories.

For protocol C all the nurses participated. They were given an RFID tag to monitor their location and movement during the shifts. This way the researchers could categorize their activities again.

The result of the study is that 19,2% of the time the nurses are not nursing patients. This is divided in nonclinical activities (12,6%), such as documentation and administration, and waste (6,6%). In total this accounts for 104,2 minutes each day. These results are meant to be input for further research. (Chow, Hendrich, Lu, & Skierczynski, Hospital time and motion study, 2008)

Another time and motion study executed by the University of Calgary has improved the construction productivity at Laricina Energy Ltd. This study was initiated by Laricina Energy Ltd. themselves. In this study they focused on the increase of productivity by measuring time and motion. They used another modern technology for time and motion studies. For this research remotely controlled video cameras
were used. These video cameras have exclusive access for third party researchers, researchers from the University of Calgary. (Brindle, 2012) To start the research they required a definition of productivity to work with. The definition they came up with was: “Productivity is a ratio of production output to what is required to produce it (inputs).” In this research they focused and measured five specific issues affecting productivity. These five are:

- Technical issues;
- Management issues;
- Human/labor issues;
- External issues/factors;
- Market conditions.

After this they created different objectives. Their first objective was to monitor the construction activities and site operations. This is done to measure the amount of time workers spend in producing tangible outputs, this is called tool time. This directly contributes to productivity. The next objective was to look for improvements by identifying inefficiencies and opportunities. In the end they made a consultancy report and quantified the impacts.

For their aggregated resources the tool time was approximately 50% in previous studies. Therefore they measured a different business unit this time, the oil sands were measured. The tool time measured was only 37%, early quits & breaks (14%) and wait time (15%) were the biggest bottlenecks for productivity.

The results of the research were presented to the company as an advice. The advice to the company was divided in two different scenarios. The first scenario assumed that they only implemented one best practice, this would lead to a productivity increase of 17%. The second scenario assumed that they implemented a set of best practices, this would lead to a productivity increase of 20%.

In contrast to the first study, this study comes up with results to improve the productivity. The first study was only there to collect data about how nurses spend their time at work. The result was clear but there were no improvement plans, the results are input for a new study.
Appendix 5: Different lay-outs

Figure 29: Lay-out 1

Figure 30: Lay-out 2
Figure 31: Lay-out 3
Appendix 6: Reflection report

This report is created to successfully complete my study. I am satisfied with the result of my graduation project at Ginaf Trucks Nederland B.V. To reflect on my performance I have chosen four critical actions/incidents. These relate to four competences, which are:

- Producing;
- Organizing;
- Mobilizing theoretical knowledge;
- And interaction.

The first critical moment is about the time measurements executed during this project. These measurements took more time as initially assumed. This was actually the most time-consuming activity during my graduation project. I have worked together with another intern to finish this part of my report. We had the idea that it was better to do these measurements together to correct each others flaws in measuring. After a few measurements it would have been more efficient to do one measurement each to increase the amount of measurement. Some measurements were carried out only once. Therefore I had to do assumptions for the rest of the measurements to calculate an average time. The results of the measurements are still very useful but not as accurate as I initially assumed. When all the processes were measured four times it would be more accurate. But the accuracy is good enough for the conclusion in my report.

My next critical moment is that I deviated from my original assignment when I received feedback from different employees. I even changed my research questions as a result of the new insights. I have learnt that I can not satisfy every employee by executing extra work which deviates from my assignment. After a month or so I realized that there was not enough time to do all these extras. Next time I will hold on to my original assignment. This leads to my third critical moment.

When I changed my research question as a result of feedback from different employees I found out that I could not make a conclusion based on these research questions. Therefore I had to change them again. This time this was done together with a manager at Ginaf. The new and final research question looked like the initial research question. Based on the progressive insights I made the new question. The answer to these questions result in one final conclusion.

My final critical moment was near the end of my graduation internship. For the design of a new production facility I started with the design of the lay-out. It should have been started with the redesign of the production process. Therefore I had to rewrite the entire chapter about the design of the lay-out. This took a lot of time. Next time, when I have to make another design for a new production facility, I start with redesigning the production process. This way you have more proof that the designed lay-out will actually work.