IMPLEMENTATION PLANNING IN MANUFACTURING COMPANY

GENICZECHOM

ENGINEERING PRODUCTION

INTERNSHIP PRODUCTION MANAGEMENT

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Abstract

The production lead time for the manufacturing company Geniczech should be reduced to meet customer demands. The lead time is reduced by observing the current working process and mainly by implementing changes in the ERP software package HELIOS Green. HELIOS Green has built in MRP and capacity planning software. Analysing the working the main errors that are discovered are: incorrect implementation of the interoperation time between operations , use of unlimited capacity planning option; incorrect use of the operation time for surface treatment operations that are outsourced and remaining of operations that are in reality already performed. The underlying problems of the errors were found. The interoperation times are changed such that they are correct for all workstations. Limited capacity planning is examined and implemented and works quite well. Remaining problems are splitting up operations and unknown priority rules for operations that compete for the same time slot. Operation times for outsourced operations should be set to zero for all orders and only be used for actual operation time. Almost all closed production orders are removed from the planning process resulting in 80 % shorter execution time in the planning process. Protocol has been introduced to prevent corruption of the capacities in the future. Many functions such as use of setup, inter-/operation time, forward/backwards planning HELIOS Green should be discarded due to incorrect functionality.

The Planning table module which is considered to be purchased gives a clear overview of the daily production plan. It is recommended to postpone the decision to purchase the module until the planning process works well.

It is recommended that beside further improving the planning, also the actual production procedures are improved. From observing the actual production and interoperation time it is clear

that the production floor is overloaded. The production should (more) closely follow the limited capacity planning. Practise must determine if the limited capacity planning works well for Geniczech. The limited capacity planning is able to reduce the lead time and limit the WIP which will improve Geniczech's position with the customer to deliver the manufactured products faster.

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I Acknowledgements

As part of Production Management track of the Master Program Mechanical Engineering at Twente University I have carried out an internship of 13 weeks at the company Geniczech in the Czech Republic. I have been on location during the entire period of the internship and have had the opportunity to get to know, learn from and support many of the departments within the production company. For this I am grateful to Mr Robert Havlik who has supported and guided me and provided with me with lots of information during my internship.

Furthermore I like to thank all my other colleagues for helping me out with the language and use of the computer systems. I also like to thank Dr. Ir. Sipke Hoekstra for being my supervisor from the University of Twente.

II About Geniczech

Geniczech-M, spol. s r.o is a privately owned company located in Zlín, Czech Republic which was founded in 1993 by the current owner Ing. Pavel Novosad. Geniczech currently has over a 100 employees. The core business is manufacturing and assembly of steel, stainless steel and aluminum parts according to the technical documentation provided by the customers. Furthermore it designs fixtures for machine tools according to customer requirements and it provides education in the field of engineering to students and machine operators.

1 PROBLEM DEFINITION

Geniczech's core business is to produce (stainless)steel and aluminum parts for its customers. The customer wants the ordered parts as soon as possible. Usually within two weeks. Geniczech is currently not able to meet these demands and uses a standard total order time of six weeks (Time from receiving order to delivery at the customer location). In order to improve the total order time there are several options. One of the options is to reduce the waiting time or interoperation time between machining operations. In order to accomplish this there are also multiple options. Geniczech uses the ERP software package HELIOS Green which has several options with regards to the material resource planning (MRP) and capacity planning (CP). Geniczech is also considering purchasing the Planning Table module for HELIOS Green consisting of a graphical planning table (Gantt charts) which should improve the planning process. This leads to the main questions that will be investigated:

> *How to use HELIOS Green to plan the production in such a way as to make optimal use of all resources and reduce the lead time?*

This leads to multiple sub questions that need to be answered:

- *How does the order process work within Geniczech?*
- *How is the production process executed at Geniczech?*
- *How does the MRP and CP planning work in HELIOS Green?*
- *How does the planning table module work and will it improve the planning process*
- *What further improvements can be made?*

This will be investigated during the internship.

1.1 Approach

There are many ways to answer the questions defined in the problem definition. Here a short description is given of the approach taken to investigate the questions.

The route of a customer order trough Geniczech and the ERP software HELIOS Green (HG) will be the red line in the report. The start will be the business department where request for quotations (RFQs) and orders are inserted in HELIOS Green. Furthermore the business department handles all accompanying tasks. The second part is within the technical department. There the process planning for multiple parts will be executed as well as make price calculations for those parts in order to send customers the quotations. Time will be spent on the production floor to see how the daily operations are executed. Special attention will go to the quality department where the specifications of the products will be checked.

This will create a clear picture of the real production and how it is handled by HELIOS Green. The MRP process within HELIOS Green will be checked and improved where necessary. When the MRP process performs adequately the use of the capacity planning process will be investigated. As part of the capacity planning a new module: the planning table, will be valued on how well it works and what it can contribute to the capacity planning process.

Finally the planning and the reality are compared; the results are presented and further recommendations will be given.

2 CUSTOMER ORDER PROCESS

In many cases the production process begins with a request for quotation. A customer sends a (set of) technical drawing(s) of some parts they want a price offer for one or multiple different quantities delivered on a given date. In other cases the customer will directly send an order with price and delivery date.

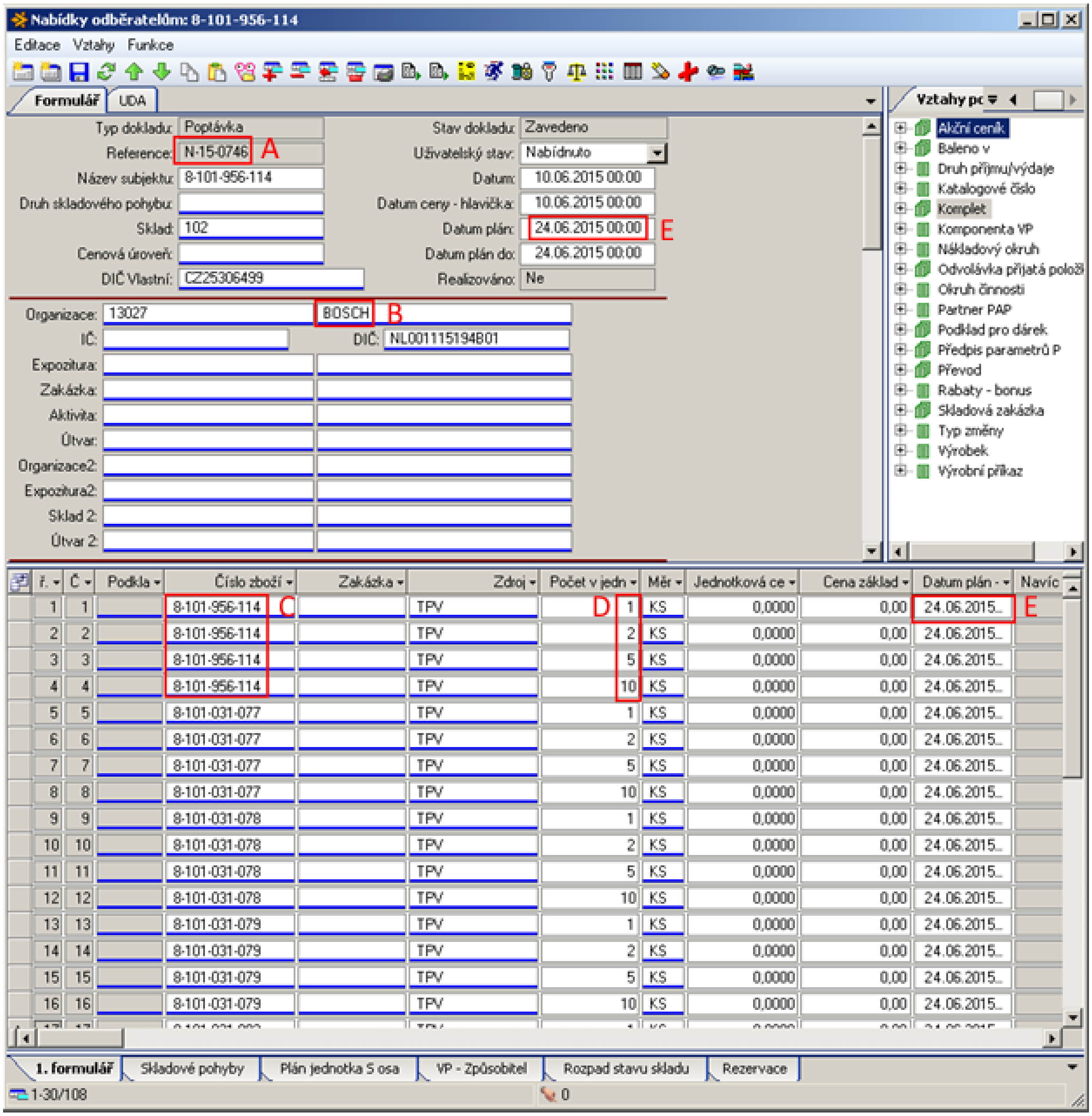
When a request for quotation (RFQ) comes in the order is registered in HELIOS Green by the business department as a new order (i.e. N-yy-<next order number>-<part number> The following information is inserted:

- Part/drawing number(s)
- Number of parts requested (could be multiple quantities)
- Delivery date for each part
- Customer
- (Notes about the order)

If the part is new, a new “part card” is created for that part in HELIOS Green. This will be used to assign all kinds of attributes to the part including the production technolog(y)(ies) and base material(s).

After a new order is inserted in the system, all drawings are printed out and, by hand, provided with the new order number and the requested amount(s). This document is than passed on to the Technology department for price determination.

For control purposes all new orders are also penned on a paper list and progress is followed as extra check and to make sure that all RFQ’s are processed. This is where the business department’s responsibility ends. Experience is gained by putting RFQ’s in the system for Dutch customers Hembrug, VDL and Bosch Weert.



1: Customer order screen HELIOS Green

Figure 1 shows a new order with order number (A), company (B), part numbers (C) with the quantities (D) and delivery dates (E).

Next to inserting the order information in the system the business department is responsible to keep the customer informed during the production process and answer all questions a customer may have. All relevant information about a specific order can be found in HELIOS Green.

2.1 Technology setup for production

The production department has two responsibilities. Setting up the production technology and determining the production cost for a given order. These two are closely related as the production procedure is the main cost driver for the customer order. In the following sections the price determination and setting up the production technology are discussed.

Before any of the two is executed a check is performed to determine if an offer for the production of the customer order is given at all. Production of a part will be offered if:

- The technology to produce the part is either available in-house or can be outsourced
- The base material can be procured or will be delivered by the customer
- All specifications of the part to be produced are clearly defined.

When all these criteria are met a quotation will be made and sent to the customer.

2.1.1 Determining production cost

When all the criteria from the precious section are met the price for all parts per quantity will be determined. Firstly it is checked if the product has been offered before. If so the offered price and the actual cost to produce the part are used to determine the offered price. When there is a new part the basic technology is setup.

2.1.1.1 Pricing of a new part

If the part is new, a quick calculation is made using the following formula for the price of a single part:

$$P_{part} = (C_m * W_m + \sum_{i=1}^{n} C_{o,i} * T_{o,i} + C_s * S_p) * F_p \qquad (1)$$

With:

$P_{part} = price\ of\ part$

$C_m = Material\ cost\ per\ kg$

$W_m = (Estimated)\ weight\ of\ part$

$C_{o,i} = Cost\ of\ operation\ i\ (workplace\ price\ per\ hour)$

$T_{o,i} = Time\ for\ operation\ i\ (in\ hours)$

$C_s = Cost\ for\ specific\ dimension\ surface\ treatment$

$S_p = Specific\ dimension\ of\ part\ (m^2\ or\ m^3)$

$F_p = Price\ factor\ to\ include\ profit\ and\ dimenisons$

The material cost and the surface and heat treatment costs are determined using Excel sheet. In the Excel sheets the basic dimensions and a general shape are inserted (rod, tube, ring, beam) to determine the volume and surface. These parameters are then used to determine the cost for all commonly offered treatments and material types (aluminium, (stain)steel). The prices for all needed operations can be summed.

The cost of an operation is basically divided in three general categories, low (handwork), middle conventional machining, and high (CNC machining). The time needed for each operation is mainly based on the expert's opinion of the employees. (Determination of the needed production time will be discussed in section 3.2.3 "Determination operation time") .

Finally the price factor is determined to get the final price. Normally the price factor is around 1.3 as to enclose the overhead costs and the profit margin. In general the size of the product also plays a role since customers are not willing to pay a high price for relatively small parts even though the production cost point in that direction.

When the cost for a single part is known, the cost per part for larger quantities can be determined. In general this is determined using a Reduction factors for which an example is shown in table 1.

Quantity	Reduction factor
1	1
2	0.96
4	0.91
8	0.85
16	0.77

1: Discount rate per quantity

For larger quantities the manufacturing procedure may change to include CNC machining instead of traditional machining which can decrease the production cost per part but will lead to an initial investment in order to write the program.

2.1.1.2 Pricing of a recurrent part

If the previous production of the part resulted in a profit than the same price will be offered. If the previous production of the part resulted in a net loss the reason for it is investigated. There can be two possibilities. The actual production cost where higher due to a structural or non-structural error. An example of a non-structural error is that a new inexperienced machine operator produced the part. This leads to an increase in production time and therefore to an increase in cost. If the part is produced by a regular, more experienced, employees the current production technology will likely lead to a net profit. For non-structural errors it is not necessary to increase the price or change the production technology. An example of a structural error is for example a part where multiple holes are drilled with a high tolerance. The part is produced by an experienced operator but the production took longer than planned. There are two ways to try to resolve this error. Use the more accurate production time for the drilling of the holes and increase the price. This may result in not receiving the order, because customers do not like it when the price for a part is increased. The second option is to try to look at technology procedure. It may be cost effective to change the technology procedure. In this example the drilling of the holes plus the previous milling operation can be performed by a CNC milling machine. This will lead to a reduction in cost per produced part but the initial investment to write the program will be higher. Because the part is now a recurrent part, and the change of future production orders is increased this option is chosen and the offered price remains the same after the quick price calculation was performed only with a different technology procedure.

All prices of the parts and quantities that will be offered are written down on the technical drawings. This is passed on to the business department that will put it in HELIOS green and will send the quotation to the customer.

3 PROCESS PLANNING

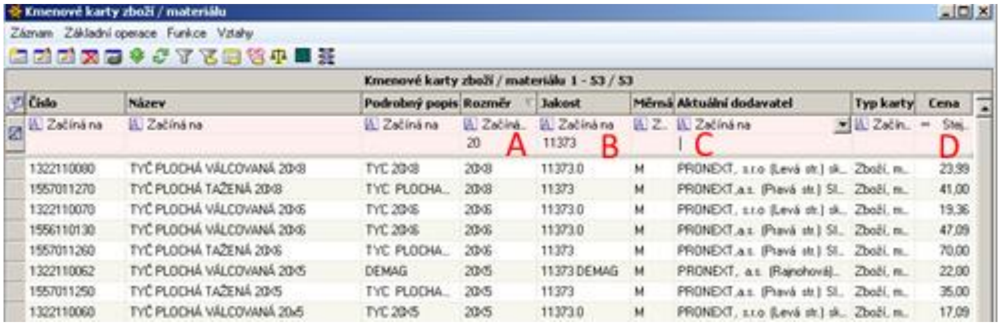
When a customer order is given to Geniczech the process planning (within Geniczech often called technology setup or production technology) is executed in detail for all parts in the order. The starting point of this process is the technical drawings provided by the customer. The current process plan can be split up into two scenarios similar to the price determination.

If the part is produced in the past and production of the part was profitable the same technology and therefore base material, in general, is used again.

If the part is new or the old production technology is not sufficient anymore the technology is setup in the following way:

3.1 Selection of the base material

For each part the chemical composition and/or one of the equivalent norms (ISO, EN, DIN, ČSN) is given as well as the dimensions, with tolerances, of the part. The chemical composition is, when necessary, converted to a Czech norm (ČSN). The dimensions for the base material depend on the available material and the process plan. Extra material may be needed for clamping the workpiece during production and/or removing it so the surface quality and/or tolerances of the workpiece are met. Using these inputs a base material is selected from the database containg a list of all base materials available to Geniczech by it‘s suppliers.



Kmenové karty zboží / materiálu

Záznam Základní operace Funkce Vztahy

Kmenové karty zboží / materiálu 1 - 53 / 53

Číslo	Název	Podrobný popis	Rozměr	Jakost	Měrná	Aktuální dodavatel	Typ karty	Cena
Začíná na	Začíná na	Začíná na	Začíná... 20 A	Začíná na 11373 B	Z...	Začíná na C	Začín...	Stej... D
1322110080	TYČ PLOCHÁ VÁLCOVANÁ 20X8	TYC 20X8	20X8	11373.0	M	PRONEXT, s.r.o (Levá str.) sk...	Zboží, m...	23,99
1557011270	TYČ PLOCHÁ TAŽENÁ 20X8	TYC PLOCHA...	20X8	11373	M	PRONEXT,a.s. (Pravá str.) Sl...	Zboží, m...	41,00
1322110070	TYČ PLOCHÁ VÁLCOVANÁ 20X6	TYC 20X6	20X6	11373.0	M	PRONEXT, s.r.o (Levá str.) sk...	Zboží, m...	19,36
1556110130	TYČ PLOCHÁ VÁLCOVANÁ 20X6	TYC 20X6	20X6	11373.0	M	PRONEXT,a.s. (Pravá str.) Sl...	Zboží, m...	47,09
1557011260	TYČ PLOCHÁ TAŽENÁ 20X6	TYC PLOCHA...	20X6	11373	M	PRONEXT,a.s. (Pravá str.) Sl...	Zboží, m...	70,00
1322110062	TYČ PLOCHÁ VÁLCOVANÁ 20X5	DEMAG	20X5	11373 DEMAG	M	PRONEXT, a.s. (Rajnohová)...	Zboží, m...	22,00
1557011250	TYČ PLOCHÁ TAŽENÁ 20X5	TYC PLOCHA...	20X5	11373	M	PRONEXT,a.s. (Pravá str.) Sl...	Zboží, m...	35,00
1322110060	TYČ PLOCHÁ VÁLCOVANÁ 20x5	TYC 20X5	20X5	11373.0	M	PRONEXT, s.r.o (Levá str.) sk...	Zboží, m...	17,09

2: Base materials of s235 (ČSN:11373) with a dimension of 20 mm

Figure 2 shows part of a list with available material within HELIOS Green. Material can be found by searching the database for dimensions (A), material norm (B), supplier (C) and Cost (D). (If there is no suitable material available in the database and the part was offered than the material is either supplied by the customer or the material department found a supplier).

3.2 Process plan

The process plan begins by determining the production operations needed to produce the part. After determining the production operations the workplaces on which to perform the operations must be chosen. Many operations may be performed on multiple machines. The best suitable machine is selected. That is the machine that will get the desired result (shape, dimension, surface quality) and is not overqualified. That is, a small part will not be machined a on a machine more suited for large part and a simple machining operation will not be performed on a (CNC) machine more suited for more complex operations. When the production operation and workplace are defined the production time will be determined in section 3.2.3 In section 3.2.4 an example of part of the technology procedure is highlighted.

3.2.1 Determination of production steps

The shape of the base material determines the first production step. Normally production starts with a milling or turning operation to machine the work piece to the correct or general outer dimensions. After the general shape is machined there are in many possible steps, the most common are:

- Drilling/tapping of holes
- Machining (mill, turn) work piece to specific (base) dimensions (on different machine).
- Grinding a surface to a desired quality and/or tolerance

After a combination of these common production steps there is often a heat/and or surface treatment performed by a third party.

Besides the common production steps there are some other operations that are (almost) always inserted in the technology procedure:

- Preparation of the material. The first operation is always preparation of the material. The base material may be delivered by the supplier in a standard length. In this case the material must be sawed to specification. Otherwise the number of work pieces has to be checked. Around 90% of the material is delivered precut.
- Handwork: After most operations some additional handwork may be performed to remove sharp edges and residual material. It is a waste of time to let the machine operator perform this action so it is added as a separate operation to be performed on a different workplace.
- CNC operation: Before any CNC operation there are two other operations inserted:
    - Programming: For all new CNC operations a CNC program must be written. This is done by the programming department. The programmer receives the technical

drawing and (re)models the part(s) in SpaceClaim from these drawings. The part is then imported in CAMworks together with the (predesigned) clamps. All the machining operation are added. Tools are selected from a list of available machine specific tools. After Completion of the machining process the code is converted to the machine specific (CNC) code and uploaded to the server as to make it available to the machine (operator) to access it.

  - Tool preparation: For all CNC operations cutting tools are used. These cutting tools have some deviation in position (centricity) relative to the fixture and dimension (diameter). These deviations are measured and written on the tools sheet by the tool preparation department. The tool sheet is printed by the programmer by manually copying the tool list from CAMworks to a MS Word Template and adding the machine name, production number, order number and part number.

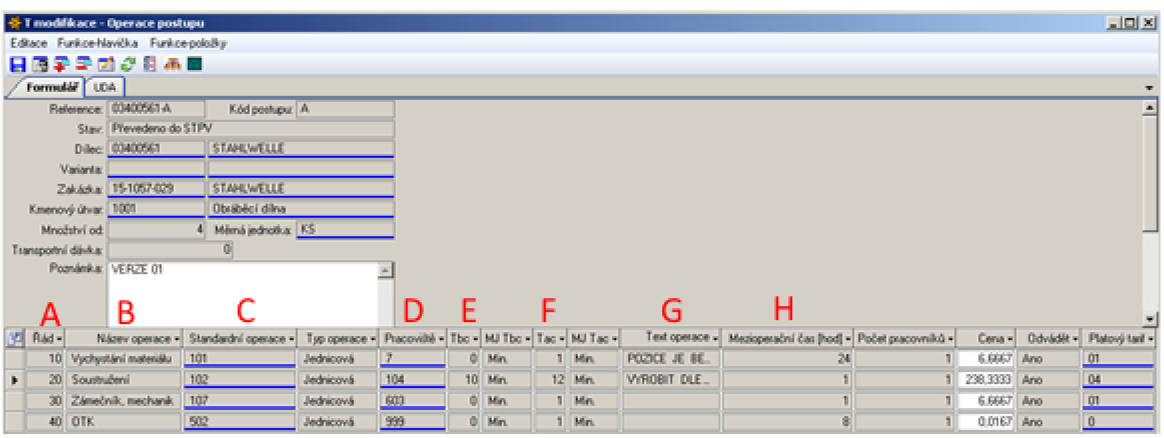
- Final Quality inspection (OTK): The last production step is always OTK. During this production step the final check is performed as to determine if all operations are executed satisfactory.

3.2.2 Machine determination

Determining which machines to use and how long each operation takes are the main challenges. Experience making process plans for multiple parts lead to the conclusion that it is convenient to use some simple rules, or best practises.

- Small production quantities should be produced on conventional machines is the geometry allows for this because it is not cost effective to write the programming for CNC machining.

It is difficult to determine which machine is best qualified for which operation. Geniczech has more than 10 CNC milling machines such as the Haas VF-2, VF-5, VF-6, MCFV 100, 1050, DMU 60, 80, 100. Many of them are suitable for similar sized products and on paper can get similar tolerances. In practise it turns out that this is not entirely the case. Some of the CNC machines have less powerful power trains which make them more suitable for machining softer aluminum parts, and/or smaller parts where the forces on the tools and therefore on the machine are smaller. Other machines do have enough power to mill larger, (stainless) steel products but due to age and wear are not capable of getting the high tolerances one might want. Due to these changing and experienced based determinations it is clear that it is difficult to execute the technology process and really difficult to standardize and automate the technology process.



3: Technology procedure of a part in HELIOS green

Figure 3 shows how the process plan is inserted in HELIOS green. The important parameters are: the operation index number (A); operation description (B); (standard) operation number (C);

workstation number (D); Setup time (E) and production time (F); room for instructions (G) and the inter operation time (H).

3.2.3 Determination operation time

When the best suitable machine is chosen the operation time is determined. The operation time is defined as:

$$Operation\ time = TBC + TAC * N \qquad (2)$$

TBC = the setup time is the time needed to collect and setup all the tools and clamps needed to complete a given operation.

TAC = the machining time. The time it takes to perform all the actual machining operations for the given operation.

N = # parts.

HELIOS Green currently works only with whole batches. The operation time in the planning that is used is the one defined in (2).

Some remarks and insight in determining the production time:

- Split up each machine operation in a number of common operations such as number of clamps, number of holes to be drilled, number of surface to be milled, number of tool changes.
- Use a standard time for each operation. For example, one minute to pre drill each hole, one minute to drill/tap each hole.
- At a factor to the sum of all standard times dependent on the shape and size of the product:

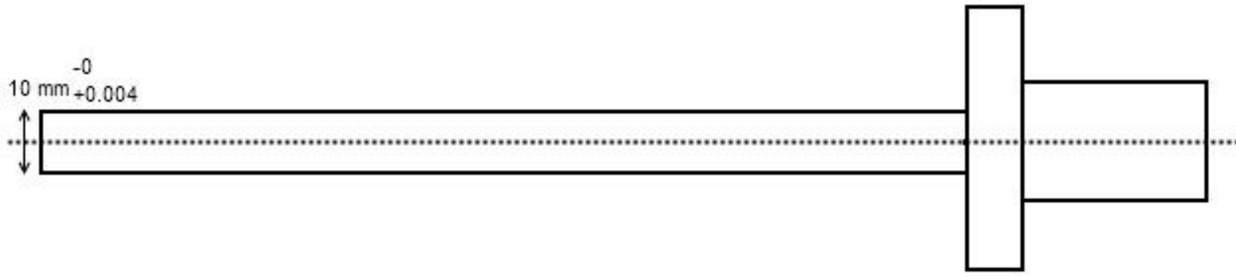
- Larger products take longer to setup than smaller products so the operation time for larger products should be increased.
- Products with small tolerances/ high surface quality have to be setup more precisely than products with larger tolerances. Include additional production time for production operations that have to meet these tight specifications.

Experience determining the production times for the small products says it is difficult. While making the production plan it is easy to lose track of the size and worth of the product for which the plan is developed, resulting in higher prices than the customer is willing to pay.

3.2.4 Example process plan

An important step in setting up the production technology is to take into account the need for additional material and production steps needed for the production itself. An example that needs consideration on both aspects:

A long shaft (figure 4) needed a tight tolerance ($\frac{-0}{+0.004}mm$) on a part of the axial direction. In order to meet the given tolerance the part must be grinded. In order to grind a part up to specification there must be still material left to grind. The previous turning operation must take this in to account and leave some additional material! Grinding is a time consuming operation so you want to remove the minimum amount of material. In general there is note added to the turning operation to leave 0.1 mm of material for the grinding operation. The part must be grinded up to the end of the shaft. This means that the clamp must be placed on the head of the shaft. The clamp on the grinding machine for outer surfaces is shaped like a cone. To ensure that the clamp has enough grip to keep the work piece in place, the work piece must be provided with holes on either side of the head of the shaft. This additional operation must be added to the turning operation as to not waste any time. This is also done to provide a note with the turning operation.



4: Schematic view of work piece to be grinded

3.2.5 Process planning within HELIOS Green.

When all production steps, workplaces and operation times are known these are inserted in HELIOS Green. Special attention goes to the outsourcing operations. All operations that will be outsourced are assigned to the workplace 0-K. Notes regarding the operations may be added to increase the probability that the supplier / machine operator meets the required quality demands. After the process plan is completed a production order is created. After the production order is created a production sheet can be printed within HELIOS Green. The production sheet is combined with the technical drawings to complete the production order and give the production department all necessary information to manage the production. The final step of the Technology department is to deliver the production sheet to the material department in the production hall.

When the process plan is finished the necessary base material is ordered. After this the production order is released and production can start.

4 PRODUCTION

The main activity for Geniczech is the production of parts by machining metal work pieces to required specification. Before production can start the process plan is made as described in chapter 3. The production planning ends with the creation of the production sheet.

4.1 The production Sheet

After the technology process is completed a production order is created. After the production order is created a production sheet can be printed within HELIOS Green. The production sheet consists of the following information:

- General information (part, production and order number, quantity)
- The base material(s) with barcode(s)
- All production steps with for each production step:
    - Operation number
    - Workplace
    - Operation barcode
    - Empty box for quality control
    - End date of operation (according to the MRP process)
- Shipping date with barcode

The production sheet is the red line through the production process. It is used to steer the production process and keep track of the progress in HELIOS Green. The barcodes are scanned every time a production step is started or ended. In this way the production times and progress is logged and inventory is kept. A sample of a production sheet for an assembly consisting of three parts can be found in APPENDIX D – PRODUCTION SHEET SAMPLE

4.2 Processing a production order.

In this section the production steps of a production order are discussed.

When the production order arrives at the material department the base material is found measured and when approved the barcode is scanned. (The inventory for the base material is than reduced within HELIOS Green).

The first production step is vychystani materialu (selection of material). If the base material is not delivered precut per work piece the material is sawed up to specification. When the material for all work pieces is cut (or was already cut) the base material is combined with the production sheet and stored in a different part of the material department. When this is done the first production step is scanned (beginning of operation is not scanned). In HELIOS Green it is shown that the first production step is completed.

The order is transported by the assistant production manager (APM) when the next production step can (almost) be executed. For an in-house production step the operation is scanned before and after the operation as to log the actual operation time. When a production step is completed the work pieces will be transported to the quality department where it will be checked (see Chapter 5). When the part is checked the empty box on the production sheet is marked and the work pieces will be transported to the next workstation. This process is repeated until all production steps are executed.

The final production step is OTK (final inspection) as mentioned in process planning. Here only a quick check is performed if the quantity is correct and all production steps are marked as checked and approved. When the barcode is scanned the production order is automatically closed.

Finally the production order will be transported to shipping and there it will be packaged. When the work pieces are packaged the accompanying barcode is scanned so that the order is released for actual shipping.

4.3 Outsourcing operations

Not all production steps are performed in-house. As mentioned earlier there are two reasons for outsourcing. The operation is not offered in-house or there is not enough capacity to perform the operation. When an operation is outsourced the cooperation department searches for a suitable supplier and creates a so called k-order. All standard outsourced operations are assigned to workplace 0-K. After the previous production step is completed and checked the work pieces are transported to the cooperation department where the work pieces are packaged and transported to the suppliers.

4.4 Types of orders

There are several types of production orders that are briefly discussed in this section.

<u>P-orders</u>

Some parts can only be manufactured with a special clamp to fix the part with a specified angle for example. If this is the case these clamps are designed, technical drawings are made and the technology process for this part is executed as for a normal part by the technology department. Than the P-order is delivered to the material department and the normal production procedure is followed. P-orders are also used for the production of parts needed by Geniczech self, for example production of spare parts for the manufacturing machines.

<u>S-orders</u>

S-orders are production to stock orders. A small fraction of the parts that are produced for the customers are delivered from stock. In order to keep the right inventory level S-orders are used to produce a new batch to stock.

R-orders

An R-order is a “Reklamace” order. These are orders that are used for the production of rejected parts. In the new way of working R-orders are not used anymore and a normal order is issued for the production of rejected parts when necessary.

5 QUALITY CONTROL

The Quality department is responsible for the quality of all work pieces that are produced at the production facilities at Geniczech as well as all operations that are outsourced and all material that is delivered to Geniczech. The quality department is located centrally in the manufacturing hall. This is a very good location because the quality department is the most visited location during production. A week was spent in the quality department to develop a good understanding of the measurement process; to measure many parts to see where the problems occur and to timing the time it takes to perform the measurements.

5.1 Quality procedure

The normal quality procedure at Geniczech is that after every production step the performed operation(s) is (are) checked. One production step can range from milling a single side of a work piece to the complete finishing of a work piece by a 5-axis CNC machine.

When work pieces come to the quality department they are sorted by workplace of the preceding operation. Measurement of the dimensions can be straightforward to rather complex depending on the given work piece. To speed up the measuring process there are many specific purpose tools ranging from basic tools for checking specific fittings and for measuring the diameter of inner tube grooves up to the WENZEL X055 3D measuring device.

The most used tools are the digital caliper and the linear digital altimeter Mitutoyo LH600. These are used to measure the in-plane distance between two features of the work piece.

In general quality control takes little time because it is done after each step and many of the production steps including minor operations such as drilling of a (couple of) hole(s) or grinding of one or two surfaces.

If a production order consists of multiple work pieces a selection of work pieces is usually measured. Especially when the production step is executed by a CNC machine, there is little reason to assume significant deviation between the work pieces produced. Some customers insist that all work pieces are measured and some customers demand a measurement report.
A measurement report usually consists of a list with critical dimensions for which the actual measured dimension must be written down.
For the measurement of the dimensions of complex geometries and out of plane relations the WENZEL is used. There are two ways to use the WENZEL. The first way is to manually operate the measuring head and touching the point for which the, 3D, location is wanted. This is usual the best way. In case there is a complex work pieces that is concurrently produced or in a sizeable batch it can be beneficial to create an automated measuring scheme. In order to make such a scheme, the 3d model of the work piece is uploaded in to the software package and all the desired measurements are inserted. In order to execute the measurement scheme only the origin position has to be set-up.
Geniczech currently realizes a 99% overall up-to specification rate for all products delivered to its customers due to the in production detection of many faulty work pieces.

5.2 Rejected parts by Geniczech

If a work piece is rejected there are two possible options for the continuing. If the defect can be recovered the work piece(s) are sent to the appropriate workstation to execute the repair. For example if a hole is to narrow. If the defect work piece(s) cannot be, economically, repaired a new production order is issued for the amount of defect work pieces and production starts from the beginning.

5.3 Rejected parts by customer

When a part is rejected by the customer the situation is somewhat more difficult.

In many cases the customer wants newly produced parts up to specification and a reimbursement of the sustained damages. Some customers request an 8D-report as to show the root cause of the error and to make sure it does not happen again. There are some difficulties with reimbursing customer rejected parts. namely:

- It is not sure if the part is actually faulty. In order to check if the part is faulty the part needs to be sent to Geniczech for inspection in many cases this costs a lot of money so it could be more economically to just reimburse the customer and take the loss.
- If the part is faulty it might not a part produced by Geniczech. Many customers have multiple suppliers some even for the same part. A similar part may be faulty produced by a competitor. Geniczech does not mark its products so in many cases it is impossible to tell if a product is produced at Geniczech or not.
- If a part is faulty it could due to mishandling of the product by the customer. Especially in the case of surface damage it is easy to imagine a customer dropping a product and trying to reimburse the damage at Geniczech.

In general the way to deal with these situations is to look at the value of customer. An older more profitable client should be given a more lenient treatment than a first time client with less value and less reliability.

6 CURRENT PLANNING PROCESS

The main focus of the internship is planning of the production at Geniczech. First the current way of production planning is discussed.

The current planning process can be divided in two parts: the MRP process and the capacity planning process. The planning processes are executed in HELIOS Green.

6.1 MRP Planning

Currently twice a day, at 11:30 and at 00:00 the MRP process is started in HELIOS Green. The MRP process executes the following:

It plans all not completed production steps of “released” orders backwards in time in accordance with

- The shipping date (from the customer order)
- The workplaces and production times (from the process planning)
- The availability of each workstation (from the calendar date, and shift definitions)
- The interoperation time (attribute of each workstation)

The end dates determined by the MRP process of each production step are presented on the production sheet.

Currently it is known that these dates are incorrect and are therefore not used in the actual planning of the production because the production manager has no confidence in the planned times for the operations. (see chapter 7 for details on the errors causing the faulty dates and proposed solutions)

6.2 Capacity planning process

The results of the MRP process are also used to fill up the capacities of all workplaces in HELIOS Green. The planned capacities are the MRP process results. The capacity planning is also not used at the moment due to the fact that it is known that the planned production times are incorrect.

6.3 Actual production planning

Production planning is used to determine which operation is to be produced when. The production planning at Geniczech is executed only for the CNC operations. It is assumed that for all traditional machining operations and other operations (programming, selection of material, tools selection, handwork etc.) production planning is not necessary due to enough time and capacity. The Production planning is currently done manually by the production planner using Excel sheets. In HELIOS Green the list for all open production orders for a given workplace is opened and copied to Excel. For each order the status is saved for:

- Material preparation
- Programming
- Completion of previous operation
- Shipping date

If the first three operations are performed it means that the order is ready to be produced on the given workplace. These orders are sorted according to the **shipping date**. The order with the earliest shipping date is to be produced first, then the next earliest order and so on. This list is printed out and used to instruct the machine operators which order to produce next. The order lists are updated on a daily basis. Unperformed operations are in general not taken into account yet but the problem is acknowledged.

A	B	C	D	E	DMU 80						F	G	H	I	16-7-2015		
213,28	VP	Zakázka	Zahájení	Ukončení	Dílec	Ř.	Zbýv	Tbc	Tac	Kap.Nh		Mat.	Před.op.	Úprava			
VYROBIT	083475	15-0790-001	24-6-2015	2-7-2015	75140231	70	2	60	120	5,00	pgm	m	n	zin;	LENGERICH		
VYROBIT	084957	15-1072-001	23-6-2015	7-7-2015	8-104-233-009/1	40	4	120	180	14,00	pgm	m	n	T-ELOX	B-W	pův.dmu100	
VYROBIT	085123	15-1113-001	22-6-2015	7-7-2015	065.017.004-ZM2	40	69	120	85	99,75	pgm	m	n		SERVICE		
PŘED.OPER.	084255	15-0941-091	3-7-2015	7-7-2015	K3513.54-10-13D015	60	2	110	50	3,50	pgm	m	mech;		SOMA		
PŘED.OPER.	084256	15-0941-092	3-7-2015	7-7-2015	K3513.54-10-13D015	60	1	110	50	2,67	pgm	m	mech;		SOMA		
VYROBIT	084257	15-0941-093	3-7-2015	7-7-2015	K3513.54-10-13D015	60	1	110	50	0,00	pgm	m	n		SOMA	na dmu60	
VYROBIT	081131	15-0569-010	22-6-2015	8-7-2015	8-104-631-844	50	1	90	150	4,00	pgm	m	n	T-ELOX	B-W		
NAPROG.	080744	15-0460-004	24-6-2015	8-7-2015	8-104-631-634	40	2	90	240	9,50	???	m	n	nikl;	B-W		
NAPROG.	083275	15-0860-001	3-7-2015	9-7-2015	30179990	130	2	120	178	7,93	???	m	n		LENGERICH		
PŘED.OPER.	085098	15-1091-006	1-7-2015	10-7-2015	8-101-032-858	50	1	150	120	4,50	pgm	m	mech;	čELOX	BOSCH		
NAPROG.	083189	15-0832-001	1-7-2015	10-7-2015	88757.32	70	2	90	165	7,00	???	m	n	čer;	KLINK		
VYROBIT	084874	15-1017-001	8-7-2015	14-7-2015	M4720.09-18-27B081	40	8	120	255	0,00	pgm	m	n		SOMA	na DMU100	
VYROBIT	084875	15-1017-002	8-7-2015	14-7-2015	M4720.09-18-27B081	40	8	120	255	36,00	pgm	m	n		SOMA		
VYROBIT	084876	15-1017-003	8-7-2015	14-7-2015	M4720.09-18-27B081	40	8	120	255	36,00	pgm	m	n		SOMA		
VYROBIT	084774	15-1042-005	14-7-2015	15-7-2015	8-104-233-748	40	1	90	47	0,00	pgm	m	n		B-W	na dmu60	
VYROBIT	083303	15-0812-001	22-6-2015	23-7-2015	75411084	70	4	120	160	12,67	pgm	m	n	nát;	LENGERICH		
PŘED.OPER.	084080	15-0993-001	23-6-2015	24-7-2015	143.04.866	100	6	240	280	32,00	pgm	m	mech,..	cem,kal;	HEMBRUG		
VYCH.MAT.	084077	15-0994-001	2-7-2015	24-7-2015	143.04.837A	80	5	300	340	33,33	pgm		fréz,..	cem,kal;	HEMBRUG		
VYCH.MAT.	085810	15-0994-001	8-7-2015	24-7-2015	143.04.837A	80	1	300	340	10,67	pgm		fréz,..	cem,kal;	HEMBRUG		
PŘED.OPER.	084024	15-0930-001	9-7-2015	24-7-2015	143.03.405	60	4	80	30	3,33	pgm	m	vf5;		HEMBRUG		
PŘED.OPER.	084024	15-0930-001	10-7-2015	24-7-2015	143.03.405	80	4	60	30	3,00	pgm	m	dmu80,mech;	čer;	HEMBRUG		
PŘED.OPER.	084080	15-0993-001	23-7-2015	24-7-2015	143.04.866	170	6	45	26	3,30		m	dmu80,..	cem,kal;	HEMBRUG		
PŘED.OPER.	085358	15-1088-001	23-7-2015	24-7-2015	WM.X79288	60	1	60	16	1,27		m	mech,sou;		GOSS USA		
ČERVENEC	18	PRAC. DNŮ=	22,0	J	VÝKONNOST(%)	100	L			329,42	K	2	SMĚNY		1-7-2015	31-7-2015	59 h CHYBÍ

2: Production plannind DMU 80 (cnc milling)

Table 2 shows the planning sheet for the DMU 80. The first column (A) gives the status of the production order. When the process plan (F), Material (G) and previous operation (H) are completed. the production step on the DMU 80 can be performed and (A) turns green. On the bottom part the total needed production time can be determined (J). In the example the total production time for 16-7-2015 is 22 hours (the capacity for the DMU 80 is 15 hours per day). In this case there is under capacity. All general information is also present: the production number (B); the order number (C), the HELIOS Green generated production date(D) and the shipping date (E).

Capacity planning

The capacity planning is used in two ways. First it is used to determine which part of the production should be outsourced in order to meet the shipping deadlines. At the other side it is used to determine which orders to accept from a customer in a given time window.

For this purpose there are also Excel files used. For determining the available capacity for new customer orders basically all production times are summed up for a planned workplace in order to determine when the workplace is available.

In order to determine the part of production to be outsourced, the production times for a given workplace are summed up for a given time period (based on shipping date) Figure 3 shows the workload per machine (A) summed over a one week period (B) If there is under capacity part of the orders in that period are outsourced to other manufacturing companies. In figure 3 it is shown that 10 hours of work (C) of the orders on the HAAS VF2 must be outsourced in week 26. When it is known how many production hours must be outsourced the planner using his experience and knowledge of the production capabilities at Geniczech determines which products are best suitable to be outsourced. In general the preference is to outsource the simpler to produce work pieces because the production cost of those parts are lower and it is therefore more profitable.

A VYTÍŽENÍ CNC STROJŮ PODLE VÝKONNOSTI PRACOVIŠŤ (MÍNUS 7 DNÍ)

ZPRACOVÁNO: 22-6-2015	TÝDEN	Nh	VÝKONNOST (%)	SCHÁZEJÍCÍ KAPACITA (h)	VOLNÁ KAPACITA (h)	ČERVEN / ČERVENEC
MCFV 1050	26	40	80		20	26.týden
	27	57	80		3	27.týden B
	28	40	80		1	28.týden
	29	128	80	38		29.týden
	30	0	80		30	30.týden
				38	54	
HAAS VF2	26	57	63	10 C		26.týden
	27	26	63		21	27.týden
	28	53	63	15		28.týden B
	29	58	63	11		29.týden
	30	6	63		18	30 týden
				36	39	
HAAS VF5	26	48	73		7	26.týden
	27	16	73		39	27. týden
	28	0	73		44	28.týden
	29	17	73		38	29. týden
	30	0	73		27	30.týden
					155	
HAAS VF6	26	112	84	18		26.týden
	27	63	84		32	27.týden
	28	105	84	29		28.týden
	29	26	84		37	29. týden
	30	5	84		27	30 týden
				47	96	
HAAS ES5	26	6	56		15	26 týden
	27	18	56		3	27.týden
	28	12	56		5	28.týden
	29	53	56	11		29.týden
	30	9	56		12	30. týden
				11	35	
DMU 60	26	15	76		42	26 týden
	27	29	76		28	27.týden
	28	3	76		43	28.týden
	29	7	76		50	29 týden
	30	0	76		28	30.týden
					191	
DMU 80	26	163	100	51		26.týden
	27	142	100	30		27.týden
	28	110	100	20		28.týden
	29	95	100		18	29.týden
	30	0	100		37	30.týden
				101	55	
DMU 100	26	69	96	69		mimo provoz
	27	61	96		11	27.týden
	28	17	96		41	28 týden
	29	80	96	8		29.týden
	30	36	96	0	0	30.týden
				77	52	
PORT. CENTR	26	94	80	4		26.týden
	27	192	80	102		27.týden
	28	0	80		72	28.týden
	29	111	80	21		29.týden
	30	0	80		30	30.týden
				127	102	

3: Capacity planning

Planning of a business case

Planning of production orders according to the shipping date is not the only possible way to plan a customer order. HELIOS Green also has the option to plan a business case. When a regular order is created; the process planning is performed and the production order is released for production there is the possibility to plan a business case. Planning of a business case is a simulation option where an existing order can be planned forward in time to see what the earliest possible shipping date is when the start date is inserted. The simulation uses the capacities determined by the MRP process. It is known that the times given by the simulation are not accurate but it still gives a rough indication of the required production time which can be used to make a more informed decision as to what shipping date to offer a customer.

Geniczech uses a total order time of six weeks for a regular order and manages to reach the final shipping date in around 90% of the cases.

7 EVALUATION FUNCTIONALITY HELIOS GREEN

Currently there is a planning process executed twice a day, at 11:30 and 00:00 that determines the time at which a given operation must be executed and when the material must be supplied. The main problem is that the dates are observed not to be correct and the first task is to find out why. When an error is found a solution is provided where one was found.

The second task is improvement of the planning. There are several currently unused functionality that will be investigated and evaluated.

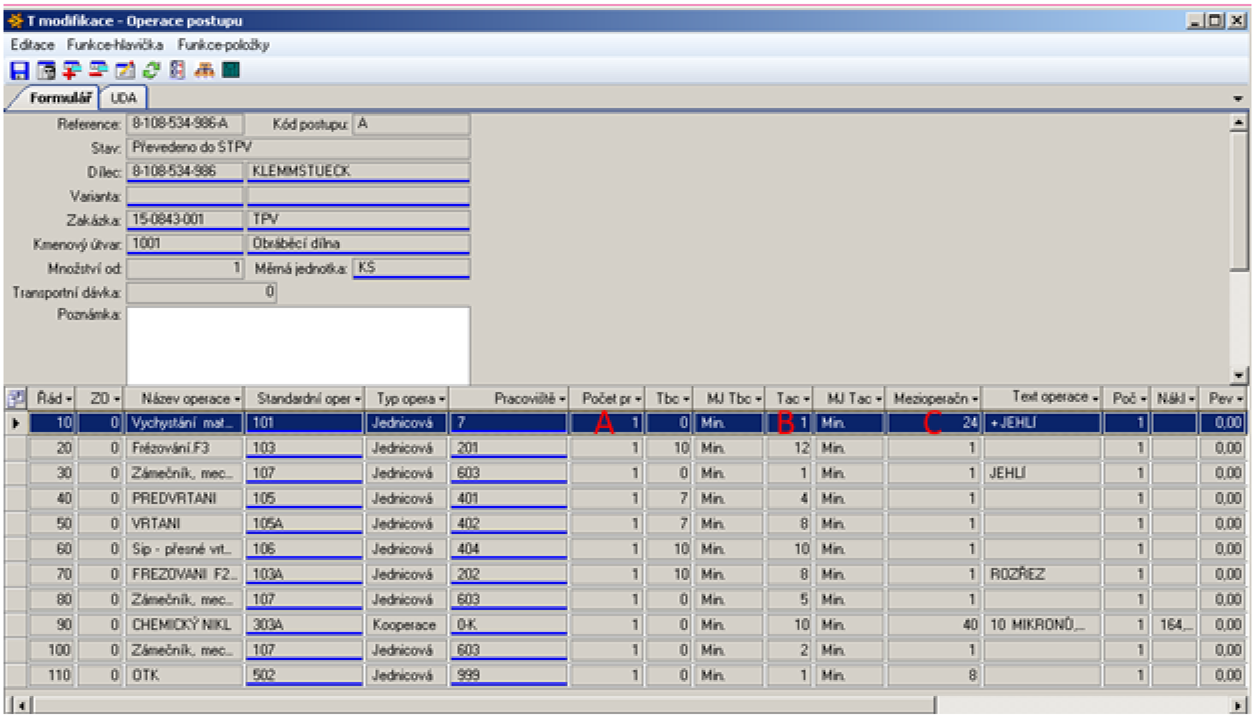
7.1 Errors in the current planned production times with HELIOS Green

In order to find out why the production times are not correct it is important to understand the working of HELIOS Green. Unfortunately the system is only available in the Czech language and no English manual or update is available as to add an extra challenge.

The main input for the planning process is the process planning. In the process plan all production steps are defined together with the corresponding workplaces (pracoviště) and operation times (setup time, production time). Every operation type and workplace has a list of attributes; one of them is the interoperation time. The interoperation time is the required time between two following operations where no production occurs.

7.1.1 Errors in MRP process

The production times for order 15-0843-001 are checked in the process planning, shown in figure 5. The important attributes are the setup time (A), the production time (B) and interoperation time (C)



Řád	ZO	Název operace	Standardní oper	Typ opera	Pracoviště	Počet pr	Tbc	MJ Tbc	Tac	MJ Tac	Mezioperačn	Text operace	Poč	Nákl	Pev
10	0	Vychystání mat...	101	Jednicová	7	1	0	Min.	1	Min.	24	+ JEHLI	1		0,00
20	0	Frézování F3	103	Jednicová	201	1	10	Min.	12	Min.	1		1		0,00
30	0	Zámečník, mec...	107	Jednicová	603	1	0	Min.	1	Min.	1	JEHLI	1		0,00
40	0	PREDVRTANI	105	Jednicová	401	1	7	Min.	4	Min.	1		1		0,00
50	0	VRTANI	105A	Jednicová	402	1	7	Min.	8	Min.	1		1		0,00
60	0	Sip - přesné vrt...	106	Jednicová	404	1	10	Min.	10	Min.	1		1		0,00
70	0	FREZOVANI F2...	103A	Jednicová	202	1	10	Min.	8	Min.	1	ROZŘEZ	1		0,00
80	0	Zámečník, mec...	107	Jednicová	603	1	0	Min.	5	Min.	1		1		0,00
90	0	CHEMICKÝ NIKL	303A	Kooperace	0-K	1	0	Min.	10	Min.	40	10 MIKRONŮ...	1	164...	0,00
100	0	Zámečník, mec...	107	Jednicová	603	1	0	Min.	2	Min.	1		1		0,00
110	0	OTK	502	Jednicová	999	1	0	Min.	1	Min.	8		1		0,00

5: Production Technology (HELIOS Green)

The planned operation times are found in the list of production orders. Unfortunately when opening a production order only the starting times of all operation steps are presented. Further details can be accessed by manually clicking on each production step and copying the starting time of the production step and the ending time of the production step.

All necessary data was collected and compared in an Excel sheets. One sheet is presented in figure 6. The planned times (A) are compared to the wanted/expected planned times (B)

In order to find errors first the exact way of the planning process is determined.

The planning process works backwards in time. The first input is the shipping date which can be found in de customer order. The shipping date occurs standard at midnight. The last production step within the process plan must end at the latest possible time. That is as close to midnight as possible.

Info	Operation	Start process	Int. op.		Start Operation	Processing		End
			A [h]	B		A[min]	B	
			ERP	SELF		ERP	SELF	
15-0843-001	Vychystání materiálu	18.06.2015 11:55	0	24	18.06.2015 11:55	0	1	18.06.2015 11:55
8-108-534-986	Frézování.F3	18.06.2015 11:55	1	1	18.06.2015 12:55	22	22	18.06.2015 13:17
83394	Zámečník, mechanik	18.06.2015 13:17	1	1	19.06.2015 06:17	1	1	19.06.2015 06:18
	PREDVRTANI	19.06.2015 06:18	1	1	19.06.2015 07:18	11	11	19.06.2015 07:29
24.04.2015 10:20	VRTANI	19.06.2015 07:29	1	1	19.06.2015 08:29	15	15	19.06.2015 08:44
18.06.2015 11:55	Sip - přesné vrtání	19.06.2015 08:44	1	1	19.06.2015 09:44	20	20	19.06.2015 10:04
	FREZOVANI F2V	19.06.2015 10:04	1	1	19.06.2015 11:04	18	18	19.06.2015 11:22
	Zámečník, mechanik	19.06.2015 11:22	1	1	19.06.2015 12:22	5	5	19.06.2015 12:27
	CHEMICKÝ NIKL	19.06.2015 12:27	40	40	26.06.2015 12:27	0	0	26.06.2015 12:27
	Zámečník, mechanik	26.06.2015 12:27	1	1	26.06.2015 13:27	2	2	26.06.2015 13:29
	OTK	26.06.2015 13:29	8	8	26.06.2015 21:29	1	1	26.06.2015 21:30
	Shipping	29.06.2015 00:00						

6: example Excel sheet with compared production times.

7.1.1.1 Interoperation time

The interoperation time for each operation is inserted in a number of hours. HELIOS Green only counts the actual working hours of the workplace in question. The working time is defined in the Calendar. Using the calendar a work shift can be made. Geniczech makes use of two different shifts, namely Jednosměn (single shift) and Dvousměn (double shift). The shift times are defined as followed:

Shift	First Shift		Second Shift		Total Time
	Start	End	Start	End	[h]
Jednosměn	6:00	14:00			8
Dvousměn	6:30	14:00	14:00	21:30	15

4: Shift times

Furthermore a list of holidays is inserted in the Calendar when Geniczech is closed.

Because of the use of different shifts for different workplaces the interoperation time is adjusted to the workplace.

For all workplaces that use a single shift the interoperation times is changed from 24 to 8 hours. This way the calendar interoperation time is 24 hours again because the interoperation time only counts within a shift.

If a workstation should change the number of shifts the interoperation time must be manually adjusted in order to keep the same interoperation time of 24 hours. In order to reduce the chance of an error, it is recommended that one person is in charge of inserting the interoperation time and the number of shifts for each work station in HELIOS Green.

The second error is that the interoperation time is planned **before** the start of the operation.

The interoperation time is used within Genizech as the combined time for the transport and quality control of all work pieces in a given production order. In reality this time obviously occurs after the production step and therefore must also be planned after the production step.

After consulting with Quort Systems (the IT company that is responsible for the support and implementation of HELIOS Green) it turns out that the interoperation time cannot be planned after the operation.

One work around is to plan an operation after each production step in the process planning with as operation time the desired interoperation time. Currently most of the interoperation times for the different workstations are similar. This means that the interoperation time represents reality adequately (the interoperation time of the next production step, which is planned before that operation, can be used as the interoperation time of the previous production step).

7.1.1.2 Outsourcing operations

For all outsourcing operations the interoperation time is used as the total production time for the given production step. The setup time and production time should therefore be zero minutes. During process planning the operation time is often used to determine the cost of the outsourcing operation. Because the same operation times are also used in the planning op the operations this leads to (large) errors. Process plans were found to produce ten parts with an operation time of 108 minutes. This leads to an additional production time of 2¼ day (1080 minutes of operation with 8 hours (480 minutes) of work in one shift). The problem can be fixed either by not using the operation time to determine the price of the outsourcing operation, or not using the operation time (for the outsourced operations!) in the planning process. The latter tactic was tried (there is an option in HELIOS Green to disable the use of the operation time for the planning) but this functionality does not work. The solution is stop using the operation time to determine the cost for outsourcing an operation.

7.1.1.3 Current time

The Planning process has no conception of the current time. If one or multiple of the operations or even the shipping date lies in the past it is still planned according to the normal rules. Nothing is (automatically) shifted in time. There is no functionality in HELIOS Green to change this, the only solution is to manually change the shipping date of order in such a way that the first uncompleted operation lays in the present again. (This can take a lot of time when there are hundreds of unfinished operations laying in the past.)

7.1.2 Planning of a business case

A sample of orders is planned using the build in simulation as described in section 6.2 in order to determine the working of this module. The errors presented in section 7.1.1. also occur in the simulation as expected (the same inputs ((inter) operation times)) are used.

A specific error in the simulation is the absence of the lead time of the base material. For the base material of a couple of the sample orders a lead time was inserted so see if it would show in the results but it did not. (Later it turned out that if you increase the quantity the lead time is taken into account, due to unknown reasons the material lead time is ignored if that material is ordered even if it is planned to be delivered at Geniczech after the start of the production in reality. The problem for this error is not found but it is passed on to Quort Systems to look at. Checking the simulated times is very time consuming since the results are not presented in a way as to easily manipulate the data. A screenshot of the simulation results is shown in figure 7.

7: Simulation results of one part 8-104-688-147-A-0001

7.1.3 Errors in Capacity planning

The capacity planning at Geniczech is similar to the regular planning process at Geniczech. When the regular planning process is executed all production times are allocated to their associated workplaces. This means that all the errors found in de MRP planning are transported to the capacity planning. Other errors that are specific to the capacity planning are described in the following subsections.

7.1.3.1 Outsourcing production

One major error in the capacity planning is that operations that, according to the process plan, would be produced at Geniczech that are outsourced due to under capacity remain in the capacity planning. The error is sent to Quort system and currently being treated. One solution could be to manually change the workplace for all outsourced operation to the outsourcing workplace (0-K). However this workplace cannot be selected. To test the principle the workplace of a handful of operations is changed to an unused workplace to check if there are any changes. It turns out that in principle this solution would work because when the MRP process is executed it will use the newly assigned workplaces for the capacity planning. Of course it would be much better if all production steps that have an k-order are automatically disregarded.

7.1.3.2 Errors in status of customer and production orders

Besides problems with respect to planning the production time, there also problems regarding which (part of) orders are planned and should be planned. Whether a production order is planned in the MRP and Capacity planning depends on the status of an order. A production order can have the following status:

Name	Translation	Comment
Pořízený	Free	Open for production
Uvolněný	Loose	Normal released for production status
Ukončený J	Terminated J	Automatically closed for production
Uzavřený	Closed	Not used
Ukončený A	Terminated A	Manually closed for production
Odloženo	Postponed	Not used

5: Overview order states

Normally when the process planning is completed the production order is released for production (status set to Uvolněný). As explained in the production section after completion of every production step the accompanying barcode is scanned and marked as complete. This changes the number of remaining parts to zero (in case that a part of the work pieces are completed, due to rejection or a brake, the number of completed work pieces can be inserted).

When the final inspection (OTK) is completed and that barcode is scanned the production order is automatically closed (Ukončený J). This information is, almost, in real time processed by HELIOS Green which is good.

However, only when the MRP process is executed the status of the production steps and orders in the capacity planning is processed. In the meantime the already completed production steps remain visible in de capacities as well as the closed orders. Since the MRP process is executed twice a day this is not a major problem but it is something to take into account with the planning table discussed in Chapter 8.

One problem has to do with automatically closed orders. An order is automatically closed when the barcode for shipping the production order is scanned. It will get the status “Ukončený J”.

It was expected that all open (due to not scanning an operation) production steps were removed from the planning. It turns out this is not the case with all orders with the status “Ukončený J”

A production order can be manually closed and get the status “Ukončený A”. All open production steps for orders with this status are not found in the planning.

The solution for cleaning up all open production steps for closed orders is to automatically change the status for every order from “Ukončený J” to “Ukončený A” at the end of the day.

There is no otherwise important difference between the two states.

7.2 Errors in improvement settings HELIOS Green

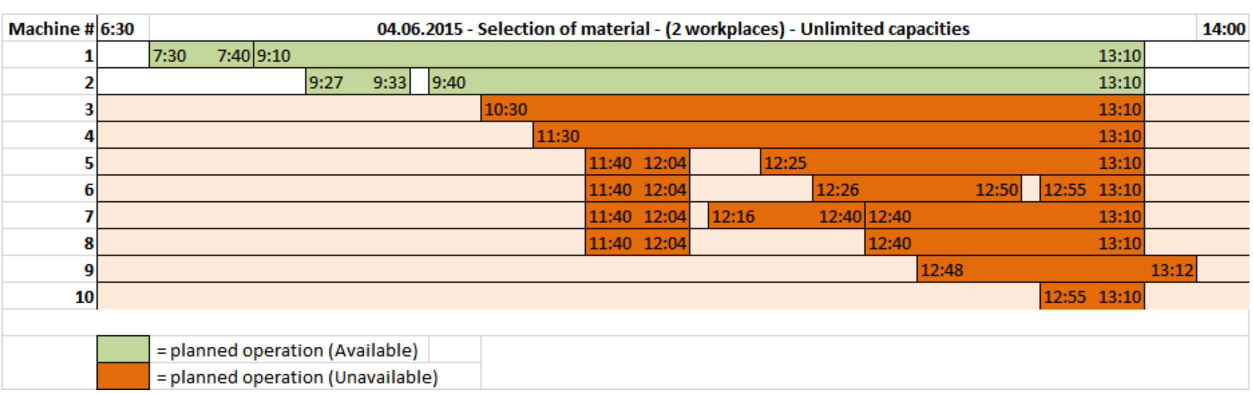
HELIOS Green has several settings to change the way operations are planned. In this section these settings are tested to see if they improve the production planning

It is recognised that this is not the correct way to configure an ERP system. In the normal way it is known how the planning process works and is configured in accordance with the reality of the company where it is implemented. In this case there is little knowledge on how the system works precisely. The main reason for this is that Quort Systems has implemented the system specifically for Geniczech. Many of the windows and settings of the standard version are still visible for the user. Therefore it is not known which parts of the system work properly and which do not. It would be better if Quort System would delete all not (properly) working functionality.

7.2.1 Limited vs. Unlimited capacity

The most important option is the choice between planning limited or unlimited capacities.

The current setting is to plan unlimited capacities for all workstations. When selecting this option the capacities are filled up according to the times generated by the planning process. A graphical representation of a queue to illustrate this is found in figure 8:



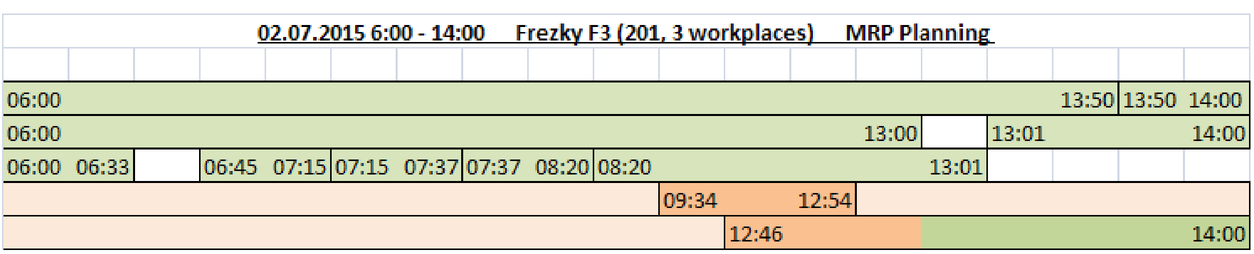
8: Unlimited Capacity planning

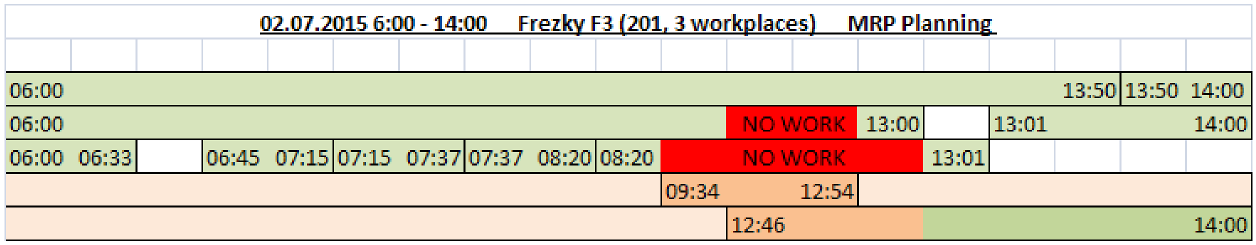
The example in figure 8 shows all operation on 04-06-2015 for conventional turning when there is unlimited capacity (unlimited number of machines). There are two conventional turning machines available (green bar)

There are two obvious errors with this way of planning: multiple operations must be simultaneously executed on the same workstation and more work must be executed in one shift than is planned. From 11:40 until 12:04, eight operations are planned where only two operations can be performed simultaneous. Some of these operations could be performed on machine 1 between 6:30 and 7:30. If all operation times are summed it turns out that the total operation time (presented by the sum of all bars in figure 8) is larger than the total available time on this shift presented by the first two bars (from 6:30 till 14:00).

To improve the capacity planning the capacities of some of the workstations are switched to limited in HELIOS Green. The planned times for a selection of orders is checked for the case with the limited capacities and the unlimited capacities. Unfortunately there is no clear documentation available which states how the planning process works precisely. Therefore the working of the capacity planning must be deduced from the results that are generated.

Observation of the planned capacities was done using tables with the start and end time given. In order to make sense of the data a graphical representation of a given shift for a given workplace is made. One example is shown in figure 9





9: Graphical representation LIMITED capacity planning for conventional milling machine

Figure 9 shows the planned orders on the Frezky F3 (milling machine) on 02-07-2015 in the morning shift (06:00 -14:00). The green bars present the orders and the rows the machine number on which the operation could be performed. At first sight (first picture) it looks like the limited capacity does not work properly (from 9:34 until 12:54 there are four operation planned where there are only 3 machines available. Between 12:46 and 12:54 there are even five simultaneous production orders in production. This should not be allowed.

Closer inspection resulted in the observation that some of the operations where split up. The red bars in figure 9 present two operations that where stopped temporarily in order to free up capacity to work on some other operations.

Due to the set-up time and logistical complexity the planning should not be allowed to split up a production order. Unfortunately there is no option to do this and no work around is found so far.

The planned capacities for some preselected orders were also compared with the case of limited capacities in order to find out how the order is determined between orders that should be produced simultaneously but cannot due to limited capacity. The planning order remains unclear but ordering on the basis of the following obvious parameters is excluded:

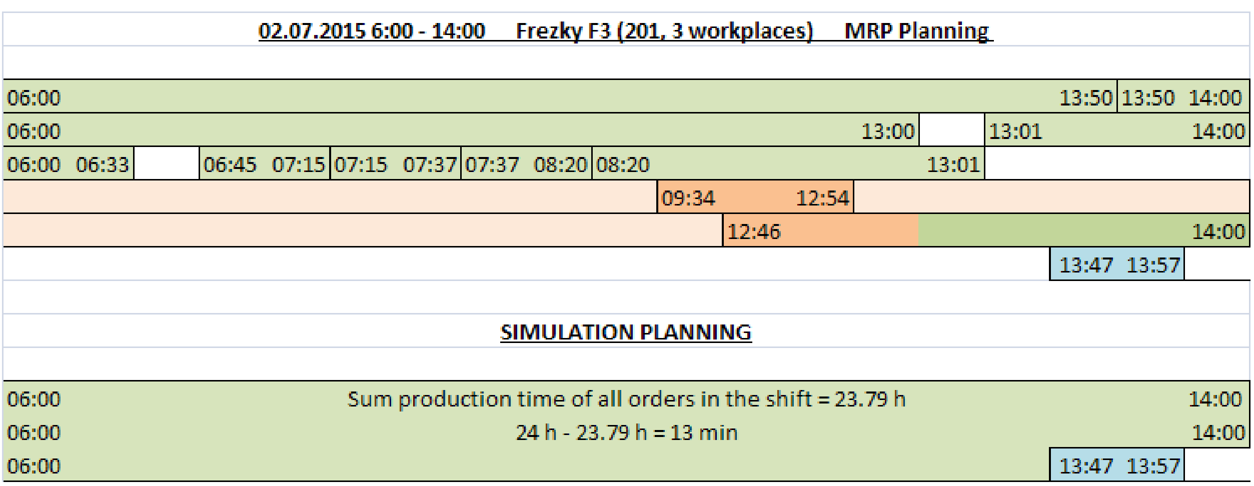
- Order determined by order number (higher or lower order number planned first)
- Order planned on shipping date

- Order planned on planned time using limited capacities (the actual priority assuming the times are accurate)
- Order planned on production time.
- Order planned on the basis of longest/shortest total production time.
- Orders planned on the longest /shortest production time before/after planned product

It could be possible that the planning system uses a more sophisticated algorithm to determine the order (minimize the total delay of all production orders for example). This is impossible to determine from the results an also does not seem likely.

In General the capacity planning is a Linear Programming (LP) problem with the objective to minimize the total lead time with restrictions (such as the shipping date) for which a penalty could be given.

Another error that occurs is observed when planning a business case. Figure 10 illustrates the error.



10: Planning of an delayed operation.

In this case the production of a ten minute operation (blue bar, figure 10) is planned on a milling machine (Frezky F3). Note that the planning of a business case plans the production forwards in time.

It is observed that the earliest available capacity occurs at 6:33-6:43. In the upper picture of figure 10 it can be observed that between these times two out of three machines (first two rows) have running operations and one would expect that time to be used in the planning of a business case but it is not.

It is observed that if there is enough free capacity in a shift (time in shift < sum of all production steps in that shift) the production step is planned in the following way:

- All production times of the operation steps in one shift are summed up (lower picture figure 10, in this case 23.79 hours).
- The capacity is filled up forwards in time, starting with the first workplace
- If there are multiple workplaces, if the first workplace is completely ‘filled up’ the second workplace is ‘filled up’ and so on.(In figure 10 the first two machines are ‘filled up’ between 6:00 and 14:00, the last machine is ‘filled up’ until 13:47)
- The operation in question will be planned at the first possible time according to this way of filling up the production capacity.(in figure 10 the operation is planned from 13:47 until 13:57. The operation itself takes 10 minutes to perform)

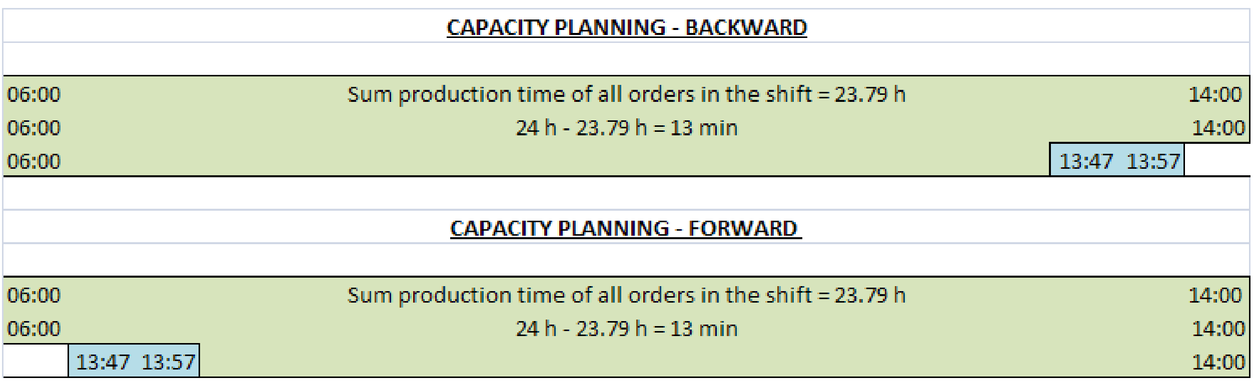
This is wrong because in reality there would be free capacity between 6:33 – 6:45 and under capacity between 13:47-13:57. (in figure 10 between 13:47 and 13:57 there are already three operations ongoing.

Why HELIOS Green plans the business case this way is a mystery. There is no benefit of planning the case this way.

Planning using limited capacities works pretty well. The production steps are shifted backwards in time to meet the capacity. It is recommended that information about the exact way of how the orders are shifted and which priorities are used is requested at Quort systems

7.2.2 Forward vs. backward capacity planning

There is an option to change the capacity from forwards to backwards planning. It turns out that the only difference it makes is how the capacities are 'filled up' and a new order will be planned using the planning of a business case when using limited capacities. As described in the previous section is the case of backward planning. In the case of forward planning the capacities are filled up similar only moving back in time. Figure shows the planned production time in both cases.



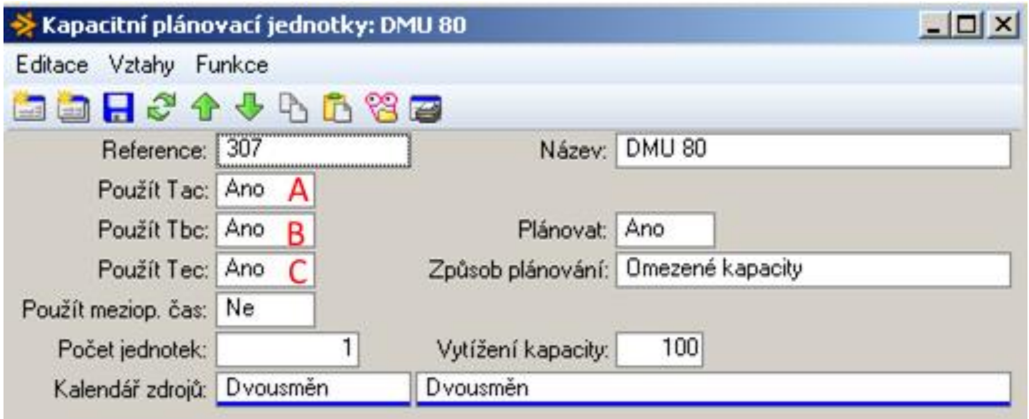
11 Difference forward - backward capacity planning

In both cases the planned times are inaccurate and therefore this option is not useful to improve the planning and should be ignored

7.2.3 Changing other settings HELIOS Green

There are some other options that are tested and the results are briefly discussed in this section

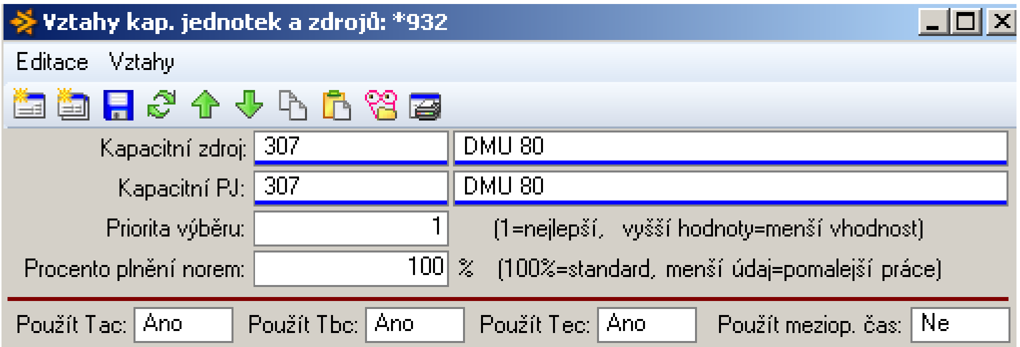
In figure 12the first menu within HELIOS Green is shown where multiple options can be changed for any given workstation.



12: window for changing times used in capacity planning

- Changing using the setup time (figure 12,A), production time (B) and inter operation time (C) does not change anything in either the MRP process or the planned capacities. It always uses all three times in the planning. In general there is no good reason to switch off the use of either of these times because they are essential for planning
- Changing the option not to plan a specific workstation has two results. The capacities for this workstation are not actually planned, which could be interesting. However in the MRP process the production steps are still planned but in a completely wrong way. The interoperation time is random and the planned operation times lay in many cases outside the shift for the given workstation. This function should not be used.
- Changing the productivity (vytížení kapacity) does not result in any changes.

For each workstation there is a second menu shown in figure 13



13: Window for changing times and efficiency used in capacity planning

- The result for changing using setup time, operation time and inter operation time are the same nothing chances..
- Changing the productivity does work in this menu and it works properly. If for example the productivity is set to 80% than the operation time from the process planning is equal to 80% the used operation time is 100 %. An Example for workplace = DMU80, productivity = 80%, set-up time = 40 min, operation time = 30 min, quantity = 4

$$Operation\ time\ (technology) = 40 + 4 * 30 = 160\ \text{min} \qquad (3)$$

$$Operation\ time\ (MRP, CP) = (40 + 4 * 30)\frac{100}{80} = 200\ \text{min}\ \ (+25\ \%) \qquad (4)$$

The new operation time is used in the MRP process as well as the capacity planning. This can be a useful feature. Geniczech collects data regarding planned and actual production times. These data can be collect for a given period, say a month, and the average productivity of the previous month could be inserted to plan the next month. These will lead to a more accurate planning.

7.3 User errors in planning process HELIOS Green

Except from a range of errors within HELIOS Green there are also a lot of errors in the planning procedure due to incorrect use of the system. These kinds of errors can be divided in two classes. The first class of errors are errors have to do with when and where the production steps are planned. The second class of errors are errors that have to do with whether a production step is planned or not.

7.3.1 Production times

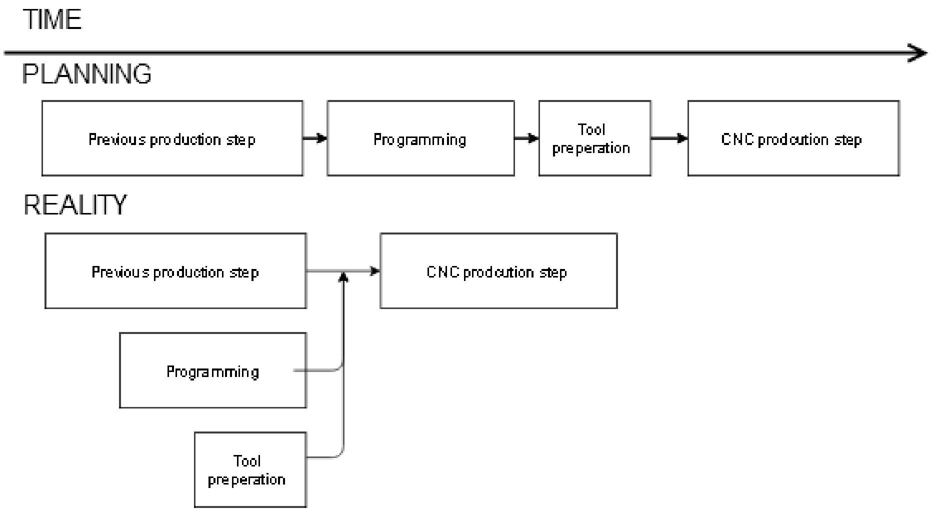
As mentioned in the production planning before every CNC operation the production steps "programovani" (programming) and "Seřizování" (tool preparation) are added with the following standard attributes:

	Workplace	Set-up [min]	Production time [min]	Inter operation time [h]
Programovani	Programming	0	1	24
Seřizování	Handwork	0	1	4

6:Standard operations before a CNC operation

The program can be written before the previous production step is completed. Instead of in-between two production steps it should be parallel to the previous production step in time. Figure 14 shows the connection between the operation in the planning and in reality. Unfortunately HELIOS Green does not have functionality to create such parallel production steps and therefore the programming time and tool preparation time are always used.

It is recommend to use a small setup time for both operations because the time needed does not scale with the batch size. It is also recommended to reduce the interoperation time to an hour. If there is something that needs to be fixed with regards to programming or tool preparation in reality than the setup time plus one hour interoperation time would be enough to solve the problem and therefore it better represents reality.



14: flowchart of planned production vs reality

Something similar can be said with regards to the tool preparation. It is a sub operation because it can be done without the previous operation being finished. Now there is always 4 hours planned for tool preparation while in reality it normally does not take any time, because the tool department prepared the tools while the previous operation was ongoing and the CNC operation using the tools can start immediately. Using the setup time for the tool and programming would be better because that time is quantity independent just like the operation performed.

The second problem has to do with the quality control. After every production step the work pieces are transported to the quality department. It would be better to add the quality control as a production step after each operation. This has many advantages. The quality department will be able to log all production times due to scanning the production step. It better represents reality.

When the real production times are better known the interoperation times can be reduced and therefore the total manufacturing time will be reduced.

7.3.2 Production steps in planning process

The main problem with planning only the real open production steps has to do with scanning of the production steps and closing the production orders.

7.3.2.1 Scanning production steps

As mentioned in process planning before every CNC operation the production steps “programovani” (programming) and “Seřizování” (tool preparation) are added. If the program already exists the programmer won’t scan the production step and it will remain open until the production order is manually closed. If the production step is scanned than the completed quantity is always set to one, all excess quantity remain as remaining quantity and therefore remains in the MRP process and capacity plan.

Similarly the tool preparation production step is only scanned when the CNC machine operator has to prepare the tools himself. This practically never happens because normally the tool department will prepare the tools and the machine operator collects them. The production step is included in the process plan for this case as to correctly log the operating time of the machine operator. It is better to process plan for the normal scenario and let the tool department scan the (sub) operation after they are finished.

7.3.2.2 Closing orders

When a regular order does not have any production problems the order is closed after the OTK step is scanned and when it is manually closed all production steps are remove from the planning. Unfortunately it does not always go this way. There are other orders or production errors can occur.

7.3.2.2.1 Closing production orders with production errors

When a production error occurs multiple scenarios are possible. The most important thing to do than is keeping the information in HELIOS Green accurate. Some scenarios are outlined.

<u>Part not repairable damaged and the customer still wants the original quantity.</u>

The quantity of all next production steps should be reduced to the amount of work pieces that can be completed up to specification.

A new production order must be issued and released for production for the remaining amount. Make sure to change the shipping date on the customer order to a realistic date such that the production planning is accurate.

<u>Part not repairable damaged and the customer accepts the reduced quantity.</u>

The quantity of all next production steps should be reduced to the amount of work pieces that can be completed up to specification.

<u>Part repairable damaged and the customer still wants the original quantity.</u>

If some of the parts can be repaired but previous operation must be done over it is best to create a new production order with the remaining production steps for those parts. Reduce the quantity on the production order of the original parts and proceed as normal.

At the moment there are many production orders open in the system because there are remaining work pieces at OTK and the production order does not close automatically.

7.3.2.2.1 Closing s-orders

A small part of the production orders consist of production to stock orders. These orders are manually inserted in the system by the business department depending on the customer demand and inventory status. In many cases the shipping date inserted is not accurate or the physical production order will never be sent to the production floor. In both cases the production orders remain open and the production times are still planned. Since this is a user process the only solution is that the person responsible for de s-order in the business department keeps track of the order. If the s-order is cancelled the production order should be manually closed. If the s-order is postponed, the shipping date should be adjusted accordingly.

7.3.2.2.2 Closing p-orders

P-orders that are issued for anything other than clamps to assist production should be treated the same as regular orders. Currently a lot of p-orders are created with an arbitrary shipping date. The production steps on these orders are in many cases not scanned upon completion. Also the OTK step is skipped. Because of this behavior these orders remain open in HELIOS Green and fill up the capacities. The solution is to make sure the p-order are treated similar to a customer order. Insert accurate shipping dates for when you want the product to be finished and maintain the discipline to scan all production steps and close the p-order upon completion.

7.3.2.2.3 Closing R-orders

In the past R-orders where used for the production of rejected parts. Currently R-orders are not used anymore. All R-orders that were still open in the system have been manually closed after inspection.

8 ASSESEMENT PLANNING TABLE

In order to simplify the capacity planning Geniczech can purchase the HELIOS Green planning table module. The task is finding out how the planning table works and asses if the planning table contributes to the planning process.

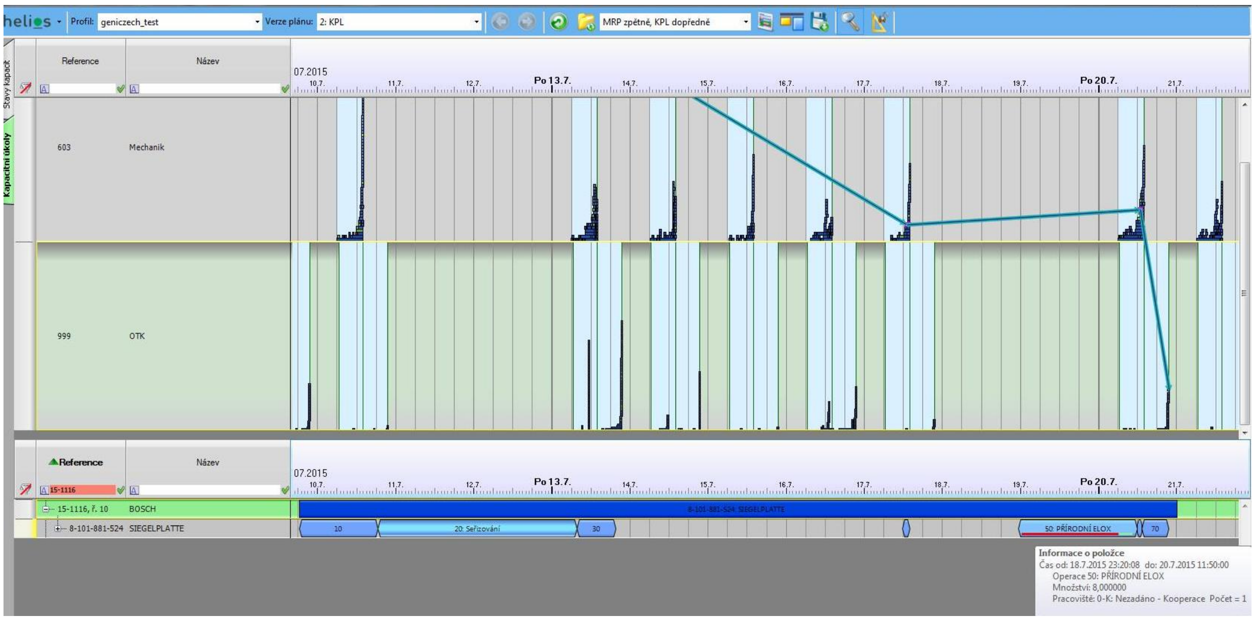
8.1 Goal of planning table

The main goal of the planning table is to prepare a work queue for all (planned) workplaces as to which part to produce when. Other than that, Geniczech has a large machine park with many similar machines. Many production steps can therefore be executed on multiple machines. Although one machine is in most case the most suitable, and is therefore chosen when the process is planned, there are alternative machines that could also execute the production step. The planning table should be used for balancing the machine load in the best possible way. That is minimising interoperation time and outsourcing of in-house operation and maximizing machine operation time.

8.2 Functionality planning table module

The planning table module consists of two windows that will both be discussed here. The first window gives a graphical representation of the workload per workplace per shift. It gives a clear overview of the total workload of all machines during one day up to a month. More functionality is not present.

The second window is basically one giant Gantt chart. All production steps are presented as time bars on their respective workplaces. This gives a nice insight in the workload for each station. When one of the production steps is selected the whole production order is shown connected with lines presenting the inter operation time. The production times for a sample of orders are checked and it is confirmed that the production times in the planning table are the same ones as in the capacity planning when the data is loaded to the planning table. The operation times and interoperation times are also similar.



15: Planning Table

The most important function of the planning table is moving the production steps. When a production step is moved the all associated production steps move with it. There occur many errors but to name the positive first:.

- The interoperation time is taken into account, if a production step is moved backwards in time all previous operations are also moved backwards in time keeping the correct interoperation time
- The moved production steps are planned within a shift. When a production step is moved outside its shift due to the present relations it will move to the optimal earliest or latest available shift.

Unfortunately there occur a lot of errors;

- A production step can be moved to all workplaces.
- A production step can be moved to a place on a workplace where no capacity is available (if the workplace has limited capacity).
- A production step can be moved beyond the present time.

There is an option to reduce some of these problems. It is possible to fix every production step, if a production step is fixed it will not move when one of the related production steps is moved.

There are also some issues with the interface, some are related to the way the planning is implemented at Geniczech and some are inherent to the planning table.

- It is difficult to move a product over a longer time period because one has to zoom in to select a specific production step and cannot zoom out while dragging it through the time.
- Some of the workplaces (that use unlimited capacity) have many operations planned simultaneously and therefore the bars become very high diminishing the overview.
- A production step can be moved after the shipping date without warning.
- It is difficult to move a production step directly next to another production step.
- Because the original capacity planning is used there are many production steps planned in the past, all these steps must be manually changed to the present. This is not a good way to spent ones time.

The biggest problem with the planning table is that there is no way to make permanent changes. There is a possibility to save the capacity plan. When this is done all data is rewritten and the new production plan is used throughout HELIOS Green. When the MRP process is started (and this must be done because the MRP process refreshes the production order status of all orders) all the old data is used again and the old workplaces are used.

There is also a planning button available in the planning table. The current functionality of this button is to go back to the last saved capacity plan.

All the remarks are sent to Quort Systems for them to solve, due to a contract dispute Quort Systems will not make any changes to the planning table before the end of the internship and therefore unfortunately the further implementation of the new planning system is stopped.

8.3 Conclusions planning table module

Before the decision is made whether or not to procure the planning table module it is recommended to first make sure that the capacity planning works properly.

The main functionality of the planning table would be to manually move the orders in time to the same workplace or another suitable workplace. It is recommended to explore the option to associate multiple workplaces to the same production step. During the MRP-Process the most suitable workplace that is available at the best available time can be selected.

9 ACTUAL PRODUCTION PROCESS

A very important aspect of a good implementation of the capacity planning is using correct inputs and the right strategy. Due to the scanning of the operations a lot of information is available. The actual (inter)operation times are compared with the planned times in order to access the reliability of the inputs and to check if the right strategy is applied.

9.1 Material lead time

In the MRP process the material lead time is either 0, 5 or 10 days depending on the supplier and if it is delivered from stock. In order to see if these assumptions are correct the material lead time data for the last six months is collected. Since Geniczech has too many base materials to plan individually, the data are grouped per supplier. The results can be found in APENDIX A. It is shown that using a standard supplier based lead time is a good approximation since the standard deviation is small, less than half a day. Only a decision must be made which lead time to use. the 95% percentile.is recommended This means that in 95% of the cases the material will be present when the production is started. Since there currently is no easy way to move the planned production up in time it is better to take a longer lead time as to ensure the production that cannot start due to unavailable material is minimal. The current assumed total production time is six weeks. With the material lead time from the 95% tile this can be realized in the planning. It is recommended that from time to time (for example every half year) the supplier lead times are evaluated and changes are made where necessary. When the planning and overall lead time will be reduced than it can be beneficial to use a smaller material lead time as well, suppliers should than be contacted to see if the deviation in lead time can be reduced.

9.2 Interoperation times

The current interoperation times in the MRP process range from one hour for the conventional operations, to 24 hours for the advance operations (ignoring that the interoperation time is used for total time outsourcing operations) In reality the interoperation time consists of a multiple times. In general the interoperation time is given by

$$T_{int} = T_{tranport} + T_{queue,quality} + T_{quality} + T_{tranport} + T_{queue,op} \quad (5)$$

Observing this process while at the quality department, It can be concluded that the real process including the waiting time for the operation (usually) takes less than one hour and up to two hours at peak moments. It only takes longer in case of special measuring or rejected parts. Unfortunately products do wait before they can be machined. An indication of these waiting times can be calculated and the results are presented in APPENDIX B. It is observed that the actual inter operation times are much higher. This is not surprising the results clearly show that the material is pushed through the system. When the base material arrives it is processed as soon as possible. When the material selection is completed it will be moved to the first operation and so on. There is no WIP control or any other constraints for a work piece to enter the production floor so the production floor is overloaded with products. This results in high inventory levels at all workplaces and a high production cycle time as stated by little’s law

$$Cycletime = \frac{WIP}{Throughput} \quad (6)$$

9.3 Production times

In order to further investigate the production flow the actual production times are compared to the planned production times. The results are presented in APPENDIX C. In APPENDIX C1 the total production time is shown for all completed orders in the period from 1.12015 till 1.6.2015.

There is a large spread in the total production time which is not surprising considering the variation in production orders. It is also observed that many orders exceed the total order time of 6 weeks (30 working days). The main reason for this is the high interoperation time due to overloading of the production floor.

In APPENDIX C2 the real production times for the specific workplaces are presented. The large spread shows that there is a lot of difference in the production steps for different orders on the same workplace. This is not surprising. One work piece might go to drilling for one hole in one plain, where another work piece goes to the same station for multiple holes in multiple planes. More interesting are the results in APPENDIX C3. Here the difference between the planned operation step and the real production time are compared and aggregated per work station. It is shown that there is large deviation between the planned production time and the actual production time. One of the reasons is that many parts are only produced ones. There is no chance to improve the production times in the process plan for these parts and close the gap between planning and reality. On average many workplaces have productivity around one. This means that for those stations on average the right amount of time is estimated during the process planning. It is recommended that the technology department frequently looks at the productivity data at the workplace to adjust for structural under/or over estimation of the planned production times.

10 RESULTS

The main task during the implementation of the new planning system is figuring out how the planning system in HELIOS Green works regarding this aspect the following results are achieved:

- It is known how MRP process and capacity planning works with respect to limited vs. unlimited capacities, forward and backward planning, use of inter operation time.
- The database is (almost) completely up to date. Over 20.000 operation steps are removed from the MRP process resulting in a reduction in execution time from 38 minutes to 8 minutes.
- The limitations and errors in the planning of the current version of HELIOS Green are known: No alternative machine scheduling possible, limited capacity planning splits up production steps; options like not using/using setup time ,production time and interoperation time do not work; Outsourced operations are still in capacity planning.
- The current working of the planning table is known and not beneficial before all problems in the capacity planning are solved and changes made in the planning table can be permanently saved. The planning table does provide clear insight and can have a positive effect on the capacity planning provided above mentioned problems are solved.

There is a large deviation between the production planning and the real production. The main reason is that the capacity planning is currently not implemented in the actual production.

11 RECOMMENDATIONS

Analysing the planning process and the actual production process at Geniczech it is observed that there is room for improvement in order to reduce the customer order time. A recommend approach is the following:

11.1 Planning in HELIOS Green

Implement the capacity planning using limited capacities in reality. The capacity process using limited capacities gives a priority for a given production step from a given order depending on the shipping date and next operation steps. Use these priorities as the queue for each workplace. Produce the part with the highest priority that is currently available. If the production order with the highest priority is not available locate that order and investigate why it is not ready yet. If necessary move it “manually” up in the queue by instruction in the machine operator.

11.2 Limiting WIP

Investigate limiting the WIP. One option can be the use of CONWIP. CONWIP stands for continuous Work In Progress. A CONWIP system can lay somewhere between a push and a pull system. It is very difficult to implement a pull system in a job shop because the production consists of low volume high mix. Therefore there is far less constant flow of products and there is neither benefit nor the possibility to create buffers for the production steps (in case of a single product for example).

LITERATURE AND SOFTWARE

Literature:

- General information Geniczech

  http://www.geniczech.cz/en/

- General information about HELIOS Green:

  http://www.helios.eu/en/products/helios-green/

- Information about planning of a business case module within HELIOS Green

  https://public.helios.eu/green/doc/en/index.php?title=Planning_of_a_business_case_-_Production_module

- Information about capacity planning HELIOS Green

  https://public.helios.eu/green/doc/en/index.php?title=Capacity_planning_%E2%80%93_Production_module

-

Software:

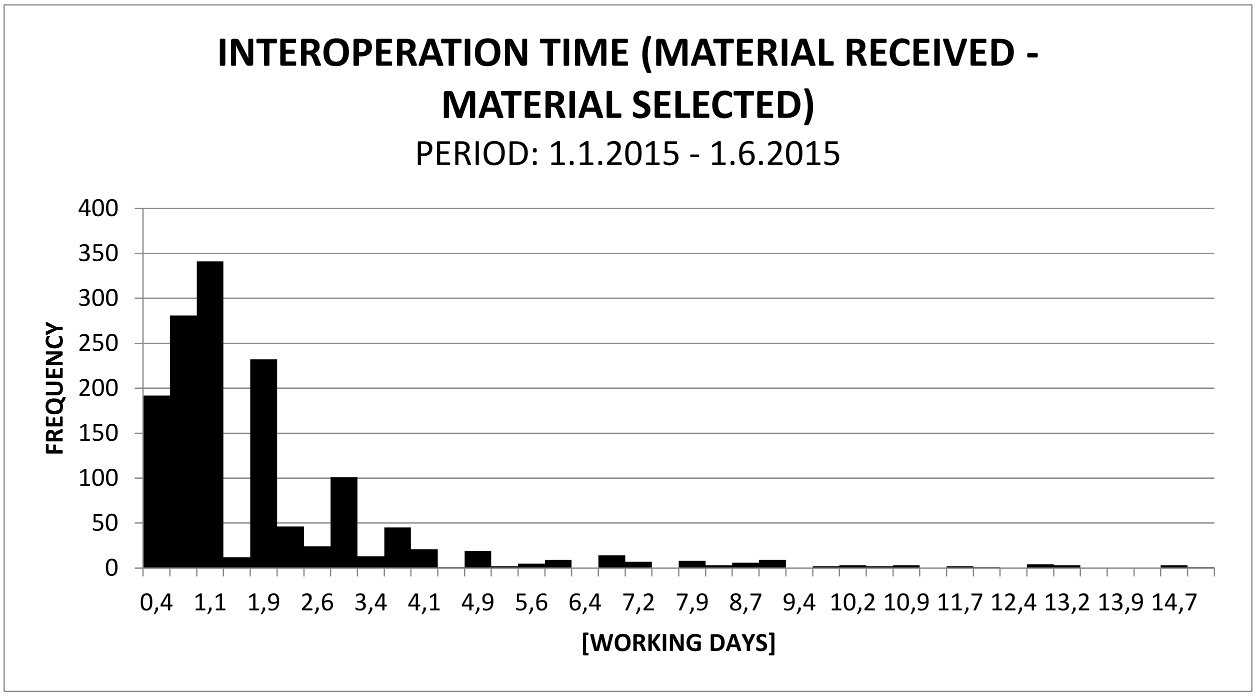
- HELIOS Green
- Microsoft Excel
- SpaceClaim (3D CAD)
- CamWorks (CAM)
- Microsoft Word

APPENDIX A – MATERIAL LEAD TIME

LEAD TIME - MATERIAL PURCHASING PERIOD: 01.01.2015 - 18.06.2015						
SUPPLIER	HELIOS [d]	AVG [d]	STD [d]	50% [d]	90% [d]	95% [d]
OVERALL	-	10.8	0.4	5.3	21.8	28.0
EHP GmbH Edelstahl Handel Profile	5	20.3	1.4	16.8	29.9	29.9
BLOHM CZECH s.r.o.	5	20.0	1.0	23.0	23.0	23.0
CRAVT	5	17.2	0.8	18.0	27.3	28.3
PK SERVIS CZ	5	13.2	0.7	11.0	21.1	24.2
VN-Ú s. r. o.	10	12.5	0.8	11.1	21.0	27.9
MURTFELDT PLASTY, s. r. o	10	11.7	0.5	11.9	22.4	24.8
KAJOmetal s.r.o	5	11.7	0.6	12.0	18.9	20.8
RAPID TRADE s.r.o.	10	10.5	0.6	9.8	18.2	18.2
MRB Sazovice	10	10.3	0.6	11.0	16.0	16.0
MISUMI EU	5	10.3	0.4	10.0	11.2	11.2
ProTech SpT s.r.o	5	10.0	0.7	7.5	21.0	25.8
PEŠÁK	5	9.8	1.5	8.9	17.0	19.1
FABORY	5	9.0	0.4	14.0	17.6	20.4
Boden Matte spol. s r.o	5	8.9	0.5	9.9	16.8	18.2
UCB TECHNOMETAL	5	8.6	0.8	7.5	15.1	15.6
CS STEEL a. s.	5	7.1	0.4	5.5	12.0	12.0
LASER TECHNOLOGY	10	6.8	0.9	4.8	17.1	17.1
TRIBON s.r.o	5	6.6	0.3	5.9	12.9	12.9
NEREZOVÉ MATERIÁLY s.r.o	5	6.4	1.1	3.8	16.9	19.6
JKZ BUČOVICE	10	6.3	0.2	6.1	8.7	8.7
BOGNER	5	5.7	0.3	4.0	9.3	11.9
STAPPERT, s.r.o	5	5.6	0.8	5.2	9.0	11.1
ZÁVITOVÉ TYČE VALENTA	5	5.6	0.2	4.1	11.8	13.1
FERONA	5	5.4	0.7	5.2	6.6	7.0
CZ TOP TRADE s.r.o Ústí 190	5	5.4	1.2	5.0	9.2	11.7
FEROPOL	5	5.2	0.4	4.9	8.0	9.4
SCHMOLZ+BICKENBACH	5	5.1	1.5	4.0	7.8	8.9
KÖNIG FRANKSTAHL, s.r.o	5	5.1	0.4	4.2	9.5	10.0
METAL SERVICE CENTRE P.O.BOX 123	5	4.7	0.8	4.1	7.0	9.0
GLEICH	5	4.6	0.6	4.1	6.9	7.0
FAVEX	5	4.4	0.3	3.1	9.6	11.1
ALUPA s.r.o	5	3.1	0.3	2.8	5.0	6.1
Zdeněk Holík ŘEZÁNÍ TVARU Z KOV. MAT	10	2.9	0.4	2.8	4.8	7.4
PRONEXT, s.r.o (Levá str.) sklad 7301	5	2.7	0.6	2.0	4.1	4.9
PRONEXT,a.s. (Pravá str.) Slad 7303	5	2.7	0.4	2.2	3.1	4.0
PRONEXT, a.s. (Rajnohová) Sklad 7302	5	2.1	0.1	2.1	3.0	3.5

APPENDIX B – INTEROPERATION TIME

B.1 Material received – material processed



B.2 Interoperation Time Production steps

INTEROPERATION TIME - BEFORE OPERATIONS

Period: 1.1.2015 - 1.6.2015

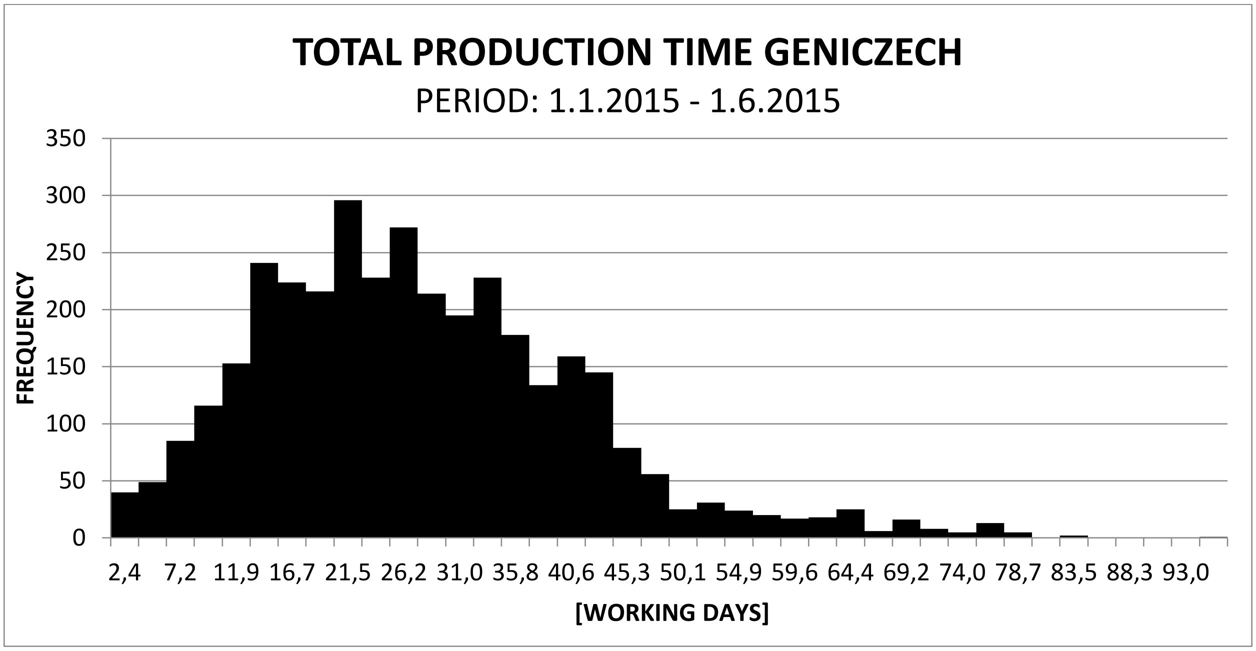
	HELIOS [h]	AVERAGE [h]	ERR [h]	STDEV [h]	INPUT [#]
Kooperace	24	199	176	183	75
Soustružení	1	163	163	157	1058
Programovani	24	137	114	116	788
STRZENI NIKLU	40	123	83	106	3
Frézování.F3	1	122	121	89	1706
WHN9B-HORIZONTKA	1	118	118	83	164
Seřizování	4	115	111	73	320
Horizontka	24	114	91	105	2
HAAS VF5	1	111	110	82	66
HAAS VF6	1	88	88	77	155
TVRDÝ ELOX	56	87	31	96	83
Drátovka	24	85	61	113	74
Obrážečka	24	82	59	90	25
Normalizační žíhání	32	82	50	46	151
Kooperace Zeka	0	81	81	171	23
ČERNÝ TVRDÝ ELOX	56	79	23	113	20
FREZOVANI F2V	1	76	76	50	690

RADIALNI VRTACKA	1	76	75	41	45
S 50 CNC	1	75	75	81	433
Rovnani D	1	73	73	56	4
Zámečník, mechanik	1	73	72	41	6826
Cementování	40	68	29	84	25
Goodway GS 4000	1	68	68	68	143
HAAS ES5-4OS	1	64	64	67	118
Sip - přesné vrtání	1	64	63	31	326
PORTÁLOVÉ CENT. MT1932	1	64	63	56	54
VRTANI	1	63	63	27	1854
Bruska na plocho	1	60	59	45	370
Stabilizační žíhání	32	58	26	68	4
Protahovačka	24	58	34	75	27
HAAS VF2	1	58	57	65	288
DMU 80	1	55	55	71	183
MCFV1050	1	55	54	60	224
Demontáž	1	54	54	35	6
PREDVRTANI	1	52	52	28	1458
Kooperace KOVOS	24	51	28	50	6
MAHO	1	50	49	58	100
Bruska na kulato	1	47	46	31	457
FV30 NC	1	46	46	20	298
Nátěr	40	46	6	73	536
DMU 100	1	45	45	24	38
Nitridování	40	44	4	71	29
PŘÍRODNÍ ELOX	32	43	12	55	145
ČERNÝ ELOX	32	42	10	72	93
CHEMICKÝ NIKL	40	41	2	54	316
Eloxování	32	36	5	63	13
TENIFEROVANI	56	36	-19	79	73
Žíhání	32	36	5	66	16
Kalení	32	35	4	54	97
Bruska vertikální	24	35	12	57	48
Bruska otvorů	1	32	32	24	250
Montáž	1	32	32	10	242
DMU60	1	32	32	34	192
Zinkování	24	32	9	56	260
Svarovani.D	1	32	31	31	23
FOSFATOVANI	24	30	6	45	435
Žíhání ke snížení pnutí	32	29	-2	55	320
OTK	8	26	18	7	5146
Zušlechťování	32	23	-9	70	29
Kooperace Juřík	24	23	-1	347	3
Pasivování	56	22	-33	47	43
Černění	24	17	-7	31	149
Hloubička	24	14	-10	78	24
Odmagnetování	1	10	9	7	6
Žíhání na měkko	32	5	-27	41	3

Přejímka zbytkového materiálu	0.1	3	3	3	4
SUI 50,80	1	1	1	9	2
ČERVENÝ ELOX	32	0	-32	60	3

APPENDIX C PRODUCTION TIMES

C.1 Real total production times Geniczech



C.2 Real operation times Geniczech

REAL OPERATION TIMES
PERIOD: 1.1.2015 - 1.6.2015

Název operace	Average [min]	STDEV [min]	Samples [#]
Average	125	201	9,640
Frézování.F3	107	175	1,251
VRTANI	53	54	1,228
PREDVRTANI	53	63	1,084
Soustružení	109	104	877
FREZOVANI F2V	84	93	574
Programovani	143	133	562
S 50 CNC	160	151	386
Bruska na kulato	80	84	372
Zámečník, mechanik	124	169	323
Bruska na plocho	117	145	303
HAAS VF2	265	371	266
FV30 NC	130	98	216
Bruska otvorů	98	92	210
Sip - přesné vrtání	88	81	206
MCFV1050	326	380	202
DMU 80	275	361	185
Seřizování	50	87	167

DMU60	136	252	161
HAAS VF6	324	423	145
WHN9B-HORIZONTKA	138	129	139
Goodway GS 4000	228	242	128
Svarovani.D	158	149	124
HAAS ES5-4OS	351	268	107
MAHO	209	192	98
Montáž	200	393	63
HAAS VF5	316	367	61
PORTÁLOVÉ CENTRUM MT1932	619	717	48
DMU 100	689	680	40
RADIALNI VRTACKA	57	61	34
DMU	232	173	23
OTK	27	26	12
Demontáž	55	56	6
Bruska vertikální	42	14	5
Rovnani D	46	42	4
SUI 50,80	61	30	3
Kooperace	185	131	2

C.3 Workplace specific performance

PRODUCTIVITY OPERATIONS

PERIOD: 1.1.2015 - 1.6.2015

Název operace	Average [ratio]	STDEV [ratio]	Samples [#]
Zámečník, mechanik	0.91	0.54	4448
VRTANI	1.07	0.54	1202
Frézování.F3	1.16	0.60	1120
PREDVRTANI	1.01	0.55	891
Soustružení	0.92	0.50	710
FREZOVANI F2V	1.06	0.52	510
Bruska na kulato	1.08	0.54	337
S 50 CNC	1.09	0.53	307
Montáž	1.12	0.52	240
Bruska na plocho	1.07	0.63	226
FV30 NC	1.09	0.50	193
HAAS VF2	1.04	0.60	167
Bruska otvorů	0.78	0.43	159
Sip - přesné vrtání	0.86	0.50	156
MCFV1050	1.02	0.49	155
DMU 80	1.39	0.73	123
Goodway GS 4000	0.99	0.38	111
WHN9B-HORIZONTKA	1.03	0.66	107
HAAS VF6	1.06	0.63	102
Svarovani.D	1.01	0.56	96

MAHO	1.00	0.38	89
DMU60	1.38	0.77	79
HAAS ES5-4OS	0.99	0.68	70
Programovani	0.87	0.57	63
HAAS VF5	0.96	0.61	40
PORTÁLOVÉ CENTRUM MT1932	1.34	0.74	27
RADIALNI VRTACKA	0.92	0.56	23
DMU 100	1.15	0.54	22
Seřizování	0.70	0.38	20
DMU	1.25	0.72	15
OTK	0.69	0.29	8
Demontáž	0.80	0.16	4
Odmagnetování	2.20	0.54	4
Bruska vertikální	0.55	0.08	3
Konzervace	0.80	0.28	2
SUI 50,80	0.92	0.11	2

APPENDIX D – PRODUCTION SHEET SAMPLE

	TECHNOLOGICKÝ POSTUP	Výrobní příkaz 085951
Zákazník LEN	Předmět POZ.1	Výkres 30118141/1
Obj.	4.00 KS	Zakázka 15-1264-001
022911358 022911358	Materiál 1458210146 10.260 M PROFIL JAKL 140x80x8	Jakost 11373 Délka: 2,563.00 Šířka:

Sestava, pozice, ks: 30118141, 10, 4.00

OP	STR	POPIS OPERACE	Pracnost celk. (hod)	Kód operace	Termín zaplánování
101	7	Vychystání materiálu		*04631667* 04631667	20.07
506	999	Mezioperační kontrola L=2563+/-2		*04631668* 04631668	21.07
107	603	Zámečník, mechanik		*04631669* 04631669	22.07
502	999	OTK NEPRODÁVAT SAMOSTATNĚ - JE SOUČÁSTÍ SVARKU		*04631670* 04631670	22.07

Expedice: 20.08.2015	Hmotnost: 0.00	*15-1264-001* 15-1264-001
Podpis technologa	Poznámky	Dodací list Dne

	TECHNOLOGICKÝ POSTUP	Výrobní příkaz **085954**
Zákazník **LEN**	Předmět **TRÄGER ZFT für CL, DB=1650**	Výkres **30118141**
Obj.	**4.00 KS**	Zakázka **15-1264-001**
Materiál		Jakost Délka: Šířka:

OP	STR	POPIS OPERACE	Pracnost celk. (hod)	Kód operace	Termín zaplánování
101	7	Vychystání materiálu		*04631678* 04631678	**22.07**
118	601	Svarovani .D + rovná		*04631679* 04631679	**24.07**
306	603	Pískování		*04631680* 04631680	**03.08**
504	504	Programovani		*04631681* 04631681	**06.08**
505	603	Seřizování		*04631682* 04631682	**10.08**
130	308	HAAS VF6 DLE PROGRAMU C.:15721,2,3,4,5 (verze 4 / 9.3.2015) ZHOTOVIT NA POSUNUTÍ - HOTOVĚ PŘÍDAVEK 2mm JE POUZE NA POZ.2 (130x130x22) + JEHLÍ		*04631683* 04631683	**10.08**
107	603	Zámečník, mechanik		*04631684* 04631684	**11.08**
307	0-K	Nátěr HLADKÁ BÍLÁ LESKLÁ RAL 9010 1000 KČ/KS		*04631685* 04631685	**11.08**
107	603	Zámečník, mechanik		*04631686* 04631686	**19.08**

Expedice: **20.08.2015**	Hmotnost: 0.00	*15-1264-001* 15-1264-001
Podpis technologa	Poznámky	Dodací list Dne

	TECHNOLOGICKÝ POSTUP	Výrobní příkaz **085954**
Zákazník **LEN**	Předmět **TRÄGER ZFT für CL, DB=1650**	Výkres **30118141**
Obj.	**4.00 KS**	Zakázka **15-1264-001**

Materiál	Jakost Délka: Šířka:

OP	STR	POPIS OPERACE	Pracnost celk. (hod)	Kód operace	Termín zaplánování
502	999	OTK		*04631687* 04631687	**19.08**

Expedice: **20.08.2015**	Hmotnost: 0.00 *15-1264-001* 15-1264-001

Podpis technologa	Poznámky	Dodací list Dne