



DEVELOPMENT OF THE PRODUCTION PLANNING PROCESS

Markus Toikka

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Abstract <p>The thesis was commissioned by a systems supplier of mechanical subassemblies called Komas. The subject of the thesis arose from the commissioner's desire to develop and decentralize his production planning processes to the production cell.</p> <p>The aim of the thesis was to create a tool that would assist in the production scheduling activity. The tool had to satisfy two needs. The first one was to automate and make the production scheduling activity more efficient and fluent. The second need involved calculating the optimal lot size for production.</p> <p>The workload of the project was focused on the preliminary study and the construction of the desired tool. During the preliminary study the current production planning process was carefully defined. Requirements of the desired tool were gathered and the cost structure of the supply chain was analysed. The construction phase meant designing the actual production scheduling tool. The two initial needs which were set for the desired tool had so different characteristics from one another, that two different tools were designed for the processes. Both of the tools were Excel based applications.</p> <p>The aim of the thesis was reached. The tools were delivered on time. Moreover, the benefits of the created production scheduling -tool were tangible and acknowledged among the key users. The benefits included an estimated 50 per cent reduction in the workload of the production planning process. The benefits of the lot size calculation tool, however, were inconsistent, as some areas of the supply chain could not be included in the calculation model.</p>		
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1 INTRODUCTION

This bachelor's thesis was commissioned by Komasa. Komasa is a system supplier of mechanical subassemblies. Komasa supplies its customers within the metal, vehicle, defence and electronics industry with mechanical components, hydraulic tubes as well as surface treatment. The company also provides assembly, logistics and product development services. Komasa has seven factories around Finland, with its headquarters located in Jyväskylä. The company also has international coverage, as one unit is located in Poland.

This thesis was focused on the company's machining unit in Vihtavuori. The Vihtavuori machining unit manufactures demanding machined components and subassemblies in accordance with the customer's requirements, by using multi-spindle bar lathes, CNC-controlled machine centres, grinding cells and cold pressing cells. Komasa machining unit in Vihtavuori had around 50 shop-floor workers and five clerical employees.

The Vihtavuori machining unit has two distinctive ways of operating. The production process was managed either on a make-to-stock or make-to-order basis. In make-to-stock production, the lot size ranges from 10 units up to 100 000 units. The customer order based production includes both vendor management inventory contracts and separate sales orders. The commissioner enlightened that their biggest current challenge in the manufacturing processes was to define the optimal lot sizes.

1.1 Business case

The Komasa machining unit in Vihtavuori had a development idea concerning their make-to-stock managed production planning process. The commissioner desired to decentralize their production planning activities from the office to the production cell. The production cell, however, was not able to carry out all the activities in a similar way as the current production planning process. Therefore, a tool was needed in order to further develop and implement the company's idea.

The production planning had two needs which the tool had to satisfy. The first need was to direct the production scheduling activity, and the second need was to be able to define the optimal lot size of the production. The commissioner's framework for the tool was that the tool should be implemented by either Microsoft (MS) Excel or Access software. The tool should take into account the whole supply chain of the commissioner. It was also told that the tool communicate with the company's information system.

Supply chain management is one of the main concepts of logistics today. Because the tool needed to consider the whole supply chain, it made the subject of the thesis very good for the field of logistics. Komasa had recently implemented an Enterprise Resource Planning (ERP) system. The ERP system was not able to produce all information that the planning function desired. It is very common that a new information system cannot respond to all the different needs of a company. Thus, either additional tools or further development of the information system is often needed. In this case an additional tool was needed. Building new information systems and managing business operations through them has been a growing trend over the past decade. This made therefore the subject of the bachelors' thesis very up-to-date. In this business case, the author also saw a great opportunity to further deepen and develop his Excel skills.

1.2 Study problem

Komasa desired a tool that would assist in the production scheduling activity. In make-to-stock production the production is steered with accordance to the inventory levels. According to the business case the biggest challenge of the current operations was to find the optimal lot size. The production scheduling and the lot size are thus interrelated subjects.

From the business case it was concluded that Komasa wanted more information into their production planning processes. There were two different kind of information needed. The production scheduling needed both real-time information about current inventory levels, as well as information regarding the optimal lot sizes.

The optimal lot sizes indicated that the company lack of information about the cost structure of their production operation. Therefore, the company was unable to base their lot size decisions on economical facts. The problem that the consignor experienced was how to be able to ensure the high service level of the warehouse while at the same time minimizing the working capital investments.

The purpose of the thesis was to bring up new information into the production planning process. The aim of the thesis was thus to create the desired production scheduling tool for Komasa. Interviews, observations and MS Excel were used as methods to carry out the work of this bachelor's thesis. Theories to support the aim of the thesis were searched under the topics of software development and production planning.

2 SOFTWARE DEVELOPMENT

Software development is a highly knowledge-based and human oriented area of engineering. In the software development the raw material is information. This chapter aim to draw a picture about some of the difficult issues in the software development.

A software system is developed as a project because each software is some what unique. In this text the word -process is used to describe the internal activities of the development project. The software development has been tried to transform process like in many attempts. The success on those attempts has been poor since the software development requires lot of personal decision making and creativity. Software development never can follow patterns presented in the literature straight forward. However the methodologies can be applied in various ways.(Haikala & Märijärvi 2004, 59; Sommerville 2007. 64)

The main contributors in the development process are often the expert in of the area where software is applied and the programmer. Computers and other software are used to develop the software so their contribution in the development process is undisputed. However, in this chapter the discussion of technologies is useless because

there exist only human problems in the software development project. (Stepanek, 2005; Lehtimäki 2006)

2.1 Development process

Software development includes four common development steps: specification, design, implementation and testing. While talking about the development project the steps of release and maintenance are very important to include. In the following paragraphs the characteristics of each step in the development project are presented. (Sommerville 2007)

Specification

The specification phase has several names such as a requirements specification, analysis and system analysis. In this text it is called requirements specification. The user requirements of the future software are gathered in the requirements specification phase. The user requirements are further translated into technical language. The outcome is called a software requirement and the produced document is a functional specification. The requirements study is maybe the most demanding and crucial phase in the development process. It requires intense communication between user/customer and programmer and also it forms a basis for the whole development process. (Haikala & Märijärvi 2004, 40.)

Design

The design phase describes how software should be built. The functional specification is used as an instruction in the design phase. The design phase is normally divided into stages of an architecture design and a component. The architecture design defines the set of the functional component and interfaces between the components. The output of the architecture design is the technical specification. The aim of the architecture design is to decrease the complexity of the software. The components should be independent and separable units in such a way that the change in one component would make as little impact as possible to the other modules. (Haikala & Märijärvi 2004, 40, 81.)

Construction

The components design describes the insights of the modules. The components design can contain several levels. The goal is to breakdown architectural design into such small parts that the implementation of each part can be later assigned to a single programmer. Sometimes module design, programming and module testing are handled as a phase of their own called implementation. Construction is not only programming but it is always designing different construction models, coding them and testing which is working best. Moreover the most work in construction phase is required by design and testing parts. Design is made in such detail that coding afterwards is somewhat typing it down. On the other hand, the design phase includes also the design of testing process and the actual testing and debugging takes the major part of the time consumed in the Construction process. (Haikala & Märijärvi 2004, 40, 81)

Testing

Testing is made in several levels. Three common levels of testing are component testing, integration testing and system testing. The component testing was discussed already earlier. Complexity of the software means that there exists vast amount of relations between the modules of the software. The continuous interaction between the components appears while the software is working (Stepanek, 2005, 9). Therefore, testing only modules is not enough. Integration testing examines interfaces and co-operation between the modules. At the end the system testing ensures that the software will deliver the functions of user requirements in a good level of performance. Testing is planned in the corresponding design phase. System testing is planned in the phase of requirements study, integration testing during architectural design and module testing during module design. The testing process is a systematic search of bugs and debugging. (Haikala & Märijärvi 2004, 40.)

Release

The release and maintenance become a great importance while carrying out software projects to the specific customer. Releasing and maintenance is kind of after sales service for the software project. Without them the software does not sell. It is not worth making perfect software if no one wants to use it.

Business software are often tailored to stream line and automate operations of the companies. This means usually great changes for the daily practices in the company. The change always meets resistance in the field. Software companies are in a key position to fight against the resistance because they have the most knowledge about the new software. Training sessions and technical support are vital during the release phase. The release phase means that a new way to work is taken into use and this specific software will support it. (Lehtimäki 2006, 175, 176.)

Maintenance

Especially in release phase but also after it the software needs maintenance. There exist no perfect software and the release phase should resist some level of bugs (Stepanek, 2005). Maintenance is divided into three categories: corrective, adaptive and perfective maintenances. Corrective maintenance is vital during the release phase because the number of bugs is then higher. In the release phase the maintenance should be very efficient since problems will increase the resistance among the users. Adaptive maintenance means that software is adjusted to the changes of the operational environment. Perfective maintenance includes bigger structural changes in the software. It can be also that the whole new functions are added to the old version. Maintenance is after-sales service of the software project. A certain level and time period maintenance service is often included in the software project contracts. (Haikala & Märijärvi 2004, 41.)

2.2 Development models

The life-cycle model means the approach to how the software is to developed, released maintained and finally discarded. In practice we can consider the life-cycle model as a development model since it could be said that the work around the software never ends. Different development models always include the process steps mentioned earlier. The main difference in different development models is how much emphasis is given for each phase and how many times the phases are repeated. One cycle of the development steps is called iteration. Two bottom end trends can be distinguished in the software development. These are the waterfall model and the

evolutionary model that is also called as incremental models. Haikala & Märijärvi 2004, 41-44.)

Waterfall model

Waterfall model is more like a traditional way to develop the software. The waterfall model aims to develop software in one increment. The increment means that there is added new function to the software. Therefore, in one increments means that software is developed to its existence in the first go. The requirements of the future software are gathered comprehensively during a requirements study and a returning from the design phase back to the requirements study phase should not be allowed. In the waterfall model the each phase produces deliverable to the upcoming phase. Deliverables serve as work instructions of the next phase. The purpose of the deliverables is to ensure that no work is done for nothing and that there is always access to earlier made decisions. (Sommerville 2007, 67-68)

In some phase of the waterfall model the development project goes out of the sight of the customer. This may have unfortunate consequences if the communication between the customer and the development team has not been working in a first place. When the customer finally gets the view of his new software the work has been already done so much that there is no turning back nor making change in any easy way. The other drawback in the waterfall model is that it pays a way too much attention to the details of the software. This applies to every phase of the development cycle. It is not uncommon that the project time is close to its end while the developers are still in the design phase and nothing concrete has been produced. The good thing in the waterfall model is that the architectural design can be made properly because the whole entity of the new software is taken into consideration. Also it is been argued that the project management is easier in the waterfall model. (Lehtimäki 2006, 151, 97)

Incremental or iterative

Evolutionary delivery models or incremental models are the other bottom end trend. In this text the term incremental models is used. Incremental models draw very opposite lines for development project than the bureaucratic waterfall model. Incremental model goes through different number of development cycles that all

produce working software. It can be that the first cycle is producing the core functions of the software and the next cycles are adding new functionalities to the core programme. This way to proceed causes difficulties for architectural designing. In incremental models the communication between the customer and development team is increased and this is not only because the number of development cycles is increased. Incremental models try to reduce fixed documentation between the phases since the documentation accumulates much workload but the documentation is rather used only once, during the next development phase.

On the other hand the customer is involved more closely in the various steps of the development process so that the customer would stay in track on what is going on in the project. In a same way within the development team the proof of each single task does not come up through the documentation of the work but the actual outcome of it. This effectively eliminates the event that during a course of the project nothing concrete gets done. The scope of the project and its duration is hard to predict but this is not the problem of incremental models but the whole software development. To fight against that problem the incremental models aim to implement those 80 percent of the functions which makes the most value for the customer but take only 20 percent of the time to produce. The higher customer involvement makes directing the development process harder. (Lehtimäki 2006, 152-153.) (Stepanek 2005)

2.3 Unique characteristics of a software development project

As a software is very different than the any other product also the development process of it is very different. The development happens in a project but the projects tend to fail.

According to Standish Group (2001) research, only 28 percent of software projects in 2000 succeeded outright. Some 23 percent were cancelled, and the remainder were substantially late (by 63 percent on average), over budget (by 45 percent), lacking features (by 33 percent) or, very often, all of those issues combined. (Stepanek 2005, 3.)

The field of software engineering knows well the reasons for this poor performance. The reasons are often related to insufficient plans, human research problems and

continuous change in projects as well as in the industry (Haikala & Märijärvi 2004, 54). The change in the industry also tends to be extremely rapid. It is argued that the problems in software development relate mainly to the actual development process and not the methods used in it. George Stepanek in his book “The Software development secrets, why software project fail” resolves the problems related to software development projects. He defines twelve unique characteristics (see the FIGURE 1) of the software project and then shows how ten of them make a straight conflict with the “hidden” assumptions that current project management knowledge includes. The following paragraphs presents how the unique characteristics come up in the three fundamental steps in project planning which includes defining scope, schedule and costs for the project.

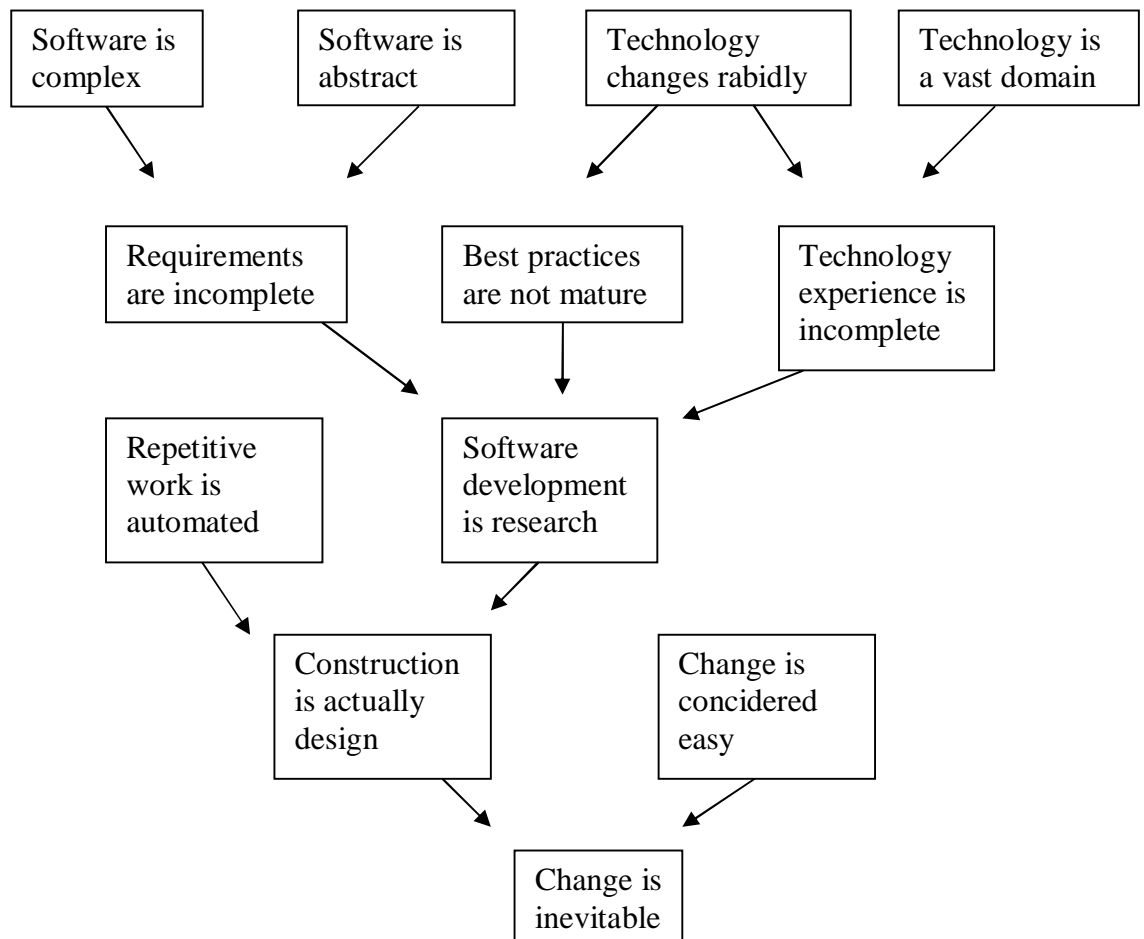


FIGURE 1. The twelve unique characteristics of the software development project. (Stepanek 2005, 8.).

Scope management

Fundamental steps of project planning are defining the scope, schedule and costs of the project. Scope definition provides a framework for the rest of the project plan and is therefore done at the very beginning. A conventional assumption is that the scope definition is sufficiently uncomplicated so that it can be made before the actual project starts. On the other hand it is assumed that the more detailed the scope definition is the more accurate it makes the rest of the planning efforts. (Stepanek 2005, 24)

The scope definition in the software development project is based on the requirements specification process. The requirements are always incomplete. It takes some time for the customer to understand how they really want their new software to work this is due to abstract nature of the software. It is universally approved that one third of the development process should be spent to the requirements gathering. This rule of thumb is a difficult issue in a project where there is an external customer. A separate project for requirements specification is a common approach to overcome this issue. The scope definition can be only carried out in a certain level of accuracy. If the scope definition is made too detailed it actually makes the outcome of the plans more inaccurate this is refer to the Stepanek's argument that the change is considered inevitable. Inaccuracies always mean rework since the plans are needed to redone. (Stepanek 2005, 27; Haikala & Märijärvi 2004, 53.)

Time management

The time management is the second topic in the project planning. The scope definition normally produces the work breakdown structure (WBS). WBS presents different activities to be carried out during the course of the project. Activity sequencing is the first step of the time management. It forms rigid order for the development project. The natural dependency often exists between the different activities at least in the traditional engineering areas. In the software development there are no intrinsic dependencies between the activities. Artificial relations are often formed to make the project plan look better. To be honest, there are no distinctively different activities in the software development. Construction is rather designing the software into existence. The waterfall model presents maybe the only distinctively different activities of the software development project which are so long that they can be called as an activity. Stepanek in his book tells that "the waterfall model has by now

been thoroughly discredited.” The risk level of the activity would be a better criterion to the sequence job. That kind of approach would reduce the uncertainty of the project in a later stage. (Stepanek 2005, 28-33)

The level of freedom in activity sequencing includes a big pitfall of the software development project. A clever project manager could decide to arrange the project into parallel activities. Of course the size of the project team would be increased but the first thing is that the customer would receive his products fast. The case is not as simple as that. One of the most difficult things in the software development is to catch the complexity of the software and to talk about it within the development team. This leads to the fact that communication may easily become the biggest overhead of the project. (Stepanek 2005, 36-37.)

The second thing in time management is to make activity duration estimation. Since the software development is research type of work, the activity durations are often very difficult to estimate. Only the specialist of the activity area would be capable of producing meaningful estimates. This especially is true in the software development because the technology is a vast domain. However such specialist presence is rare during the planning phase of the project. The project team usually is assigned only after the project planning. (Stepanek 2005, 34.)

Cost management

As it is seen so far, sufficient scope definition or workload estimations are awfully difficult to produce at the beginning of the software development project. The cost management follow the same rocky path by adding some new features.

The main cost contributor of the software project is the programmers. Among the programmers there is an order-of-magnitude difference in productivity as well as the price of the programmers. The abstract nature of the software requires talent from the programmer to be really good in his/her job. Also, the vast domain of the technology makes it difficulties for project manager to assess the skills of the programmers. The combination of the development team should be however carefully planned. The combination of the team has been noted to make a tremendous difference to the productivity. Every time when the new people are joining into the project team it

requires big effort from the team. The later the project is the more useless it makes to gain any extra help from the new members of the team. The allocation of the resources plays a very important role in the software development project. The project manager of the software project cannot think about these issues in as straight forward a manner as in some other engineering area. (Stepanek 2005, 37-40)

Change is considered inevitable in the context of the software development. The requirements change time after time while the customer becomes more familiar with the upcoming software. The customer assumes that making the change in the software is easy to carry out. Therefore, the threshold to introduce the change request is low. The project manager should always assess the impacts of the changes on the cost and make trade-offs between the change requests. (Lehtimäki 2006)

The software development is abstract and complex. The common project management principles do not apply well to the software projects. Therefore, anyone who might get involved to the software project should understand that the things in software development do not usually proceed as they are planned. Lot of team work and communication is needed to overcome the problems that are faced. As told, one of the most difficult things in the software development is to catch the complexity of the software and to talk about it within the development team.

3 PRODUCTION PLANNING SYSTEM

Production planning is strategic planning performed by the top management of the manufacturing company. Production planning is aggregate level planning. The aim of the production planning is to make decisions that would produce the best overall performance for the company. The key functional areas of the manufacturing company should therefore take part in the production planning process. (Vollman, Berry & Whybark 1997, 270-271.)

The marketing management and the financial department give the basic input into the top management strategic planning process. In the manufacturing company, the third basic input comes from the production management. The best overall result cannot be

achieved without taking into account the characteristics of the manufacturing process itself. The three key functional areas make up the basic trade-offs for the top management of the manufacturing company. (Russell & Taylor III 2003, 397.)

The production planning does not only produce plans for the manufacturing function but rather for the many functional areas of the manufacturing company. Production plan is the manufacturing part of the production planning. Other functional areas will produce their own plans based on the production planning process. In this way the different functions are kept in concert. To some extent the term “production planning” is misnomer and nowadays same process is better known as “sales and operations planning”. In this study the term “production planning” is used. (Vollman et al. 1997)

Manufacturing planning and control system

Manufacturing planning and control (MPC) system is one approach to discuss about the production planning. The production planning provides the main input to the MPC system. The other modules of the MPC are resource planning, demand management and master production scheduling. The production planning and the master production scheduling are the main functions of the MPC system. The both function gets major input from modules of resource planning and demand management. The MPC system and its relation to the other key functions of the manufacturing company is shown in the figure below. (Vollman et al. 1997 273.)

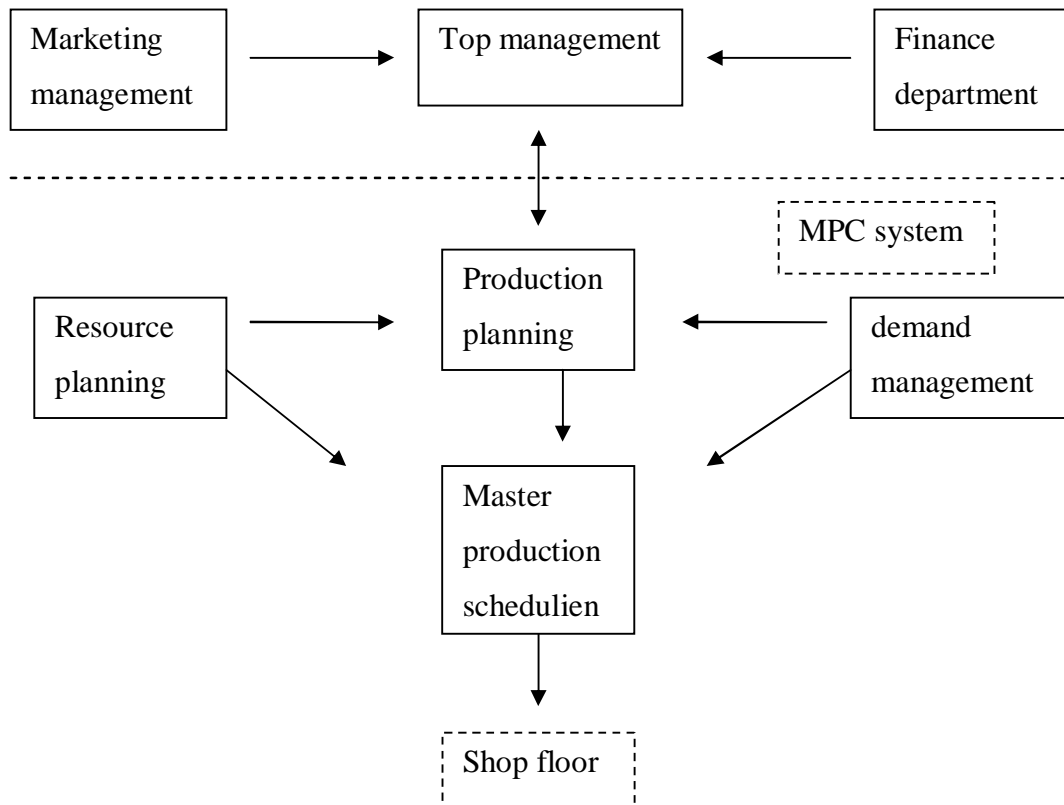


FIGURE 2. Manufacturing planning and control (MPC) system.
(Vollman et al. 1997, 271.)

3.2 Production planning

Production planning is the function that maintains the production process. It delivers production plans FOR the manufacturing process and reviews and possibly revises the plans on the monthly basis. The production plan is the top management's linkage to the manufacturing process. The production plans are delivered down to the master production scheduling where the plans are disaggregated. Production planning is seen on the operational level but it is based on the strategic decisions. (Vollman et al. 1997, 270,273)

The basic trade-offs

The basic trade-offs which the top management of the manufacturing company will face are: (Haverila, Uusi-Rauva, Kouri & Miettinen 2005, 402-404)

- high service level
- high capacity utilization
- minimization of inventories.

High service level

The service level in refers to the production process ability to respond to the demand of the market. Parameters that commonly define the service level are; ability to respond to the variation in the demand, lead time and the reliability of the deliveries. Often the supply chain cannot respond to the requirements of the market demand. Therefore the inventories are built up to fill the gap between the supply and the demand. (Haverila et al, 2005)

High inventories are an easy way to absorb the problem of variation in the demand to which the production capacity cannot respond. Lead time is the time from placing the order to receiving the delivery (Russell & Taylor III 2003, 465). Lead times are shortened dramatically due to inventories because they can eliminate the time needed for the whole production process. Reliability of deliveries means on-time deliveries as well as quality of the products delivered.

High capacity utilization

Capacity utilization rate tells how well the company is using its capacity. The machines make sense only while they are operating so capacity utilization should be as high as possible. Very high capacity usage rates can be achieved in the mass production and in the continuous production since machines are dedicated mostly to single products. On the other hand in batch production the machines or the production lines are normally used to produce several different products. (Russell & Taylor III 2003, 122.) Always when the machine is being set up for a different product the capacity utilization is suffering. To maximize capacity utilization in the batch production, it is needed to minimize the setup times. The minimization of the setup times is achieved by producing fewer but bigger batches. On the other hand, big batches results the growth of inventories and the quality of the production may suffers.

Minimization of inventories

Minimization of the inventories means simply less materials, semi-finished goods and finished goods in stock. The less inventory the company has the easier it makes the warehouse management. Especially quality problems and the scrap value tend to decrease while inventories are decreased. In the financial terms, the inventories equal to the working capital of the company. If the working capital investments are high, it means that the company's monetary resources are tied up, which obviously is not a good thing. Although the cost of the working capital investment is hypothetical the inventories cause also other costs. The other inventory related costs are warehousing costs and warehouse handling costs. (Sakki. 2001)

The basic trade offs make conflicts with each other constantly. By optimizing the one the two others are suffering. Making decisions which would optimize the overall operations is very difficult. The decision making easily covers so wide a range of variables that the optimization of whole entity does not make sense. The balance between the three will rarely produce the optimal overall result. It largely depends on the company and its processes which of the trade-offs should be emphasized most. (Könönen 2006)

One object can be defined which will improve the overall operations as a whole. By shortening the production cycle time, the production process can better answer the requirements of the market demand. The high service level can be maintained while reducing the inventories. Moreover, shorter production cycle time increases the ability of the production and therefore production planning receives at least a good potential for increasing the capacity utilization. (Haverila et al. 2005, 404)

While thinking of the issue of shortening the production cycle times, the process engineering and new technologies are the first things that come to mind. Also, as simple as manufacturing smaller lots can lead to the shorter cycle time. This is due to fact that queuing time between the phases of the production tend to increase while lot size is increased. (Haverila et al. 2005, 406) Nowadays the production of end-user items is increasingly scattered and component producers have highly effective

production processes and technologies. This leads to more importance in the logistics and the co-operation between the whole supply chain.

Production planning ability to re-act to the changes in the operational environment is very important. The best way to prepare changes is to study the supply chain and its causal relations. The change management of production planning includes internal and external components from the company perspective. External components includes lead time requirements of the customer, product variation between customers, accuracy of sales forecast, materials lead time and supplier reliability. External components make constraints for production planning. Internal components include the company and its organisational structure, capacity and resource management inside the company, batch size, inventory levels, product range & variety, production process cycle time and availability of the extra capacity. (Haverila et al. 2005.) Company should define the timeframe within which they are able make necessary changes to the operational levels. The issues like how fast the employees can be laid out and what are the possibilities to acquire new capacity are essential questions. (Vollman et al. 1997, 276)

3.3 Resource planning

Resource planning includes materials, human and financial resource parts. In this section we only take a look at the material resource planning since it is often the broadest and the most difficult matter of the resource planning at the manufacturing company. Here it is called purchasing. Perspective for the matter is given the fact that 70% of the Finnish industries turnover is going to the purchasing (Haverila et al. 2005, 459)

The target of materials purchasing is to ensure materials availability in the production process with minimum cost. Materials availability makes constraints for production planning. The materials management needs to deliver information about materials availability before production planning can function. The key information are lead time, materials availability in the parameter of the volume and the price. The

production planning evaluates how materials availability can be best adjusted to the requirements of demand. (Vollman et al. 1997, 273)

The price and the lead time of the material deliveries are the key elements while the production planning tries to assess the need for the inventories. Marketing management provides customer requirements and the demand forecast, which give an idea of the size of the gap between the supply capability and the market demand. The finance department gives constraints for working capital investments. The trade-off between high inventory levels and the long lead times has been set. (Russell & Taylor III 2003, 396-397)

Supplier relationships

Good sales forecasts are vital for the company. Based on the sales forecasts, the manufacturer can negotiate long term contracts with his supplier. In long term contracts suppliers are more willing to provide a better service level by means of frequent deliveries and better payment terms. Good supplier relations establish a strong base for the production planning. Further more, if the sales can be forecasted accurately enough, it may provide a basis for planning the production according to the customers' orders. (Könönen 2006)

The company should critically assess the source of material. The quality and reliability of deliveries are very important issues. The problems in these areas causes a great deal of work for the materials management. To reduce risk of the unreliable supplier the company can purchase materials from more than one source. However, in such case the company may lose the lot quantity discounts.

The daily work around the materials management depends much on the supplier relationships. The workload can be highly reduced if the order delivery practices are defined beforehand. Long term contracts can be access into that kind of situation. This may also lead to the improved reliability in the materials deliveries, since supplier gets more committed to the supply chain. (Materials management I, 2004)

In well planned customer-supplier relationship the customer may need to deliver long term materials requirements for the supplier. The supplier then reserves its capacity

according to customer's requirements and be ready make deliveries in agreed lead time once customer place the order. (Könönen 2006; Sakki. 2001)

The customer may also deliver the schedule of the materials requirements in monthly basis. The schedule often structure from fixed period and forecast period. Further the supplier serves customer with accordance of the schedule. The forecast period is not meant to be conclusive for producer but more as a directive to the supplier to make its own materials planning. Fixed periods are often from one to three weeks in duration. (Sakki. 2001.)

3.4 Demand management

Demand management aim to gather all the sources of demand. Further it aims to adjust the company's capacity to respond the market demand as well as possible. The main tasks of the demand management are the delivery time planning and the loading situation management. (Könönen 2006; Vollman et al. 1997, 273)

In the make-to-stock production the sales forecasts play a critical role in the delivery time planning. The inventories ensure the certain level of delivery capability and the lead times are rather fixed. Therefore the delivery time planning is not necessarily included in the daily practices of the make-to stock managed company.

(Tuotannonohjaus 2005, 20) Sometimes stockout may occur due to unexpected high demand. In such cases it is important that the delivery time can be defined quickly. Otherwise the customer easily turns to another service provider if possible.

Make-to-order managed manufacturing company's demand management may follow two distinctive strategies that affect delivery time planning. Usually a manufacturer will sell out its capacity for as long a period as possible. At the same time the company will secure his operations for a long period of time. In this position the company may have difficulties to obtain any new customers since the delivery times become so long. Also the other hidden danger lies in the long period strategy. Largely depending on the business, the prices of the raw materials and also the finished goods can develop into an unfavourable direction from the perspective of the producer. The

price level changes can be taken into consideration while making a contract, thus the problem is not significant.

The other strategy is the opposite one. Only short term capacity reservations are carried out. The company holds its capacity available as late as possible. Thus it is able to provide quicker delivery times and the price development does not cause difficulties. (Könönen 2006)

Loading planning is the activity of the delivery time planning. In the loading planning the capacity is loaded according to sales forecasts and/or customer order book. The capacity utilization can never high as 100%. This should be noticed in the loading planning. Scheduled maintenances, malfunctioning, lunch breaks etc. will decrease capacity utilization. Moreover, the bigger the product range and variety is the time more is needed for machine setups. (Russell & Taylor III 2003, 563)

Loading planning is made in rough cut basis to the loading groups (Russell & Taylor III 2003, 416). Loading planning is very demanding. A wide product range makes it even more difficult. It would be helpful to define some common parameter for every item so that capacity requirements would be easier to calculate the overall. In the long run the capacity usage plans and the actual capacity usage should be compared. The outcomes are very different the parameters should be evaluated and revised. (Tuotannonohjaus 2005)

3.5 Master production scheduling

Master production scheduling produces exact manufacturing schedules on the daily basis. The rough plans of production planning process are smoothed down and the aim is to efficiently load the daily capacity. Master production scheduling also includes activities from resource planning and demand management. (Vollman et al. 1997, 273)

Master production scheduling needs documents where can be seen what items are to be produced, how many of them are needed and when they should be ready.

According to the documents the tasks are shared between the loading groups. If the production plan is made too tight the capacity adjustments, like overtime working or use of external capacity can come to question. (Könönen 2006)

The materials orders are placed at the latest at the production scheduling level. A materials order in this phase can also mean the company's internal materials reservation. If the manufacturing process itself or the bill of materials is complex, the production scheduling can produce detailed working instructions in the shop floor level. In a simple case, the same documents that have been also used in production scheduling as well as in the shop floor level. (Tuotannonohjaus 2005)

The loading situation management is the activity of the production scheduling which has a direct linkage to the demand management. The mastery of loading situation requires real time information about capacity utilization of the loading groups and the capacity usage during the planning periods. The information of the available capacity and its time position is valuable information for the sales department and the company management. (Tuotannonohjaus 2005) The best way to improve the production process and to improve the quality of the production planning is to follow up and analyse the outcomes of the plans. (Könönen 2006)

4 PRODUCTION SCHEDULING TOOL

The production scheduling tool project took place from the beginning of April until the end of June 2007. A major part of the project was conducted at the company's premises, because there was a great deal of information that needed to be gathered. The sources of information were the personnel, as well as the information system of the company. The project contained four different phases.

- Preliminary study
- Implementation plan
- Construction
- Release

The start of the project was full of confusion. Therefore a thorough planning effort was set as the number one priority of the project. The phases of the project overlapped each other. Especially the implementation plan was developed widely side by side with the construction phase.

Describing the project in terms of workload, most of the effort was focused on the preliminary study and on the construction of the actual tool, while the actual implementation plan and the release received considerably less attention. The rest of the chapter will describe the first two phases of the development project in more detail. The created production scheduling tool is also introduced. The phases of the construction and the release are discussed to some extent in the analysis part of the thesis.

4.1 Starting point

The commissioner sent clear and informative materials about the background of the business case before the project was started. Their ideas about the scheduling tool were given in more detail during the first visit to the company. However, the subject in its broadness caused a great deal of confusion in the beginning. Especially the relationship between the production scheduling tool and the optimal lot size was hard to comprehend.

The production scheduling tool which they desired should take into consideration the following areas: raw material availability, machine production capability, semi-finished goods availability, finished goods availability and sales forecasts. This basically refers to the entire supply chain as a whole. The idea of the tool was that it should be informative so that people in charge of production planning and material procurement would get a better overview of his/her work.

Only a small part of the Komax machining unit's production was included in the problem scope. The case was limited to concern only one machine and one customer's products. The materials were procured from a single supplier. Materials transportation was outsourced to a third party service provider. The contract with the customer

included over thirty different products, with annual sales quantities varying from thirty to two hundred products.

The commissioner had a good picture of how the production scheduling tool should work. Certain key figures concerning the items would be drawn directly from the ERP –system to Excel. The key figures in Excel would be arranged and shown in such a format that the user could make an easy comparison between the items. Finally, the decision of the manufacturing order would be made based on the comparison.

Due to the high level of confusion in the beginning of the project, the main effort was focused on the actual planning of the project, while the implementation of the desired Excel tool was set as the secondary object for the project. The time for designing the project plan was limited to two weeks in the beginning of the project. The preliminary study was also planned to be carried out during that period. Any further accurate plans could not be made at that particular moment.

4.2 Preliminary study

The aim of the preliminary study was to verify the feasibility of the desired tool. The confusion around the case was also to be cleared up. The empirical study of the bachelor's thesis was conducted mainly during the preliminary study. The business area of the case and its terms were completely new to the author. As such a voice recorder was used during interviews in order to gather up all relevant information. Further plans were to be produced as a result of the preliminary study.

Three goals were set for the preliminary study. The first two goals were focused on the production scheduling tool as a whole, and the third goal was focused on the definition of the lot size. The modelling of the existing production scheduling process was set as the first goal. The requirements specification of the desired tool was the second goal of the preliminary study. The requirements specification was going to be a crucial phase because it would form the base for the whole development process. The feasibility analysis of the production lot size calculations was set as the third goal.

In order to define the economical lot size of the production it was needed to model the cost functions for the main processes of the supply chain.

4.3 Results of the preliminary study

4.3.1 Current production scheduling process

The production scheduling process was made partly in the production planning and partly in the production cell. The scheduling process was primarily based on the situation in the finished goods inventory, and secondarily on materials availability. The item situation was first evaluated in an Excel sheet. The most critical items were picked up and they were put into the preliminary schedule. The work numbers were further assigned for the critical items in the ERP system. The preliminary schedule was given to the production cell. The final decision of the manufacturing order was made in the production cell. (see appendix 1.)

The production planner made the situation evaluation in the ready made Excel sheet, called a TO –sheet (see appendix 2). The TO –sheet contained four key figures of each item. The key figures were: finished goods inventory balance, sales forecast quantity of the year, average item sales/week and inventory weeks of supply (IWS). The last two values were derived from the first two values. Every time the item situation was evaluated, the finished goods inventory balance needed to be updated in the TO –sheet from the ERP-system.

The criticality of the item situation was primarily based on the IWS figure and secondarily on the inventory balance. The IWS figure did not solely provide a realistic idea of the situation, although the IWS was derived from the inventory balance. If the sales forecast of the item was extremely small then even the small inventory value returned a relatively high IWS value.

Once the production planner had placed the work numbers in the ERP-system, the production cell was able to make the final decision for the manufacturing order. However, before the final decision could be made, the following matters needed to be

checked and evaluated. The first matter to was ensure the availability of raw materials. Although raw materials were in the warehouse, they also needed to be cut into the right size for the work piece. Secondly, the criticality of the finished goods inventory needed to be evaluated. The last thing to take into consideration was the setup of the machine. The goal was to keep the setup time of the machine to a minimum. During this stage the size of the work piece and the toolkit needed in the machine had to also be taken into account. Similar works were placed after one another whenever possible, as this would considerable minimize the need for expensive changeovers and machine downtime.

4.3.2 Requirements specifications

The commissioner had defined the requirements for the production scheduling tool quite well, and so the specification of the requirements was an easy task. The requirements were naturally based on the existing production scheduling process. The idea with the tool was to automate the existing process steps. The purpose was not only to ease the planning process but also to enable transfer of the whole scheduling process down to the production cell. Thereby also the production cell was largely involved in the requirement specification process. The final production scheduling tool requirement specification was as follows:

- The goal of production scheduling is to advise its user to perform production scheduling efficiently.
- The tool should be designed for the production cell level.
- The tool should bring up the required data in such an order that the user could make his/her decisions by taking only one look at the screen.
- The given data should be able to be updated by one press of a button.
- The information that is shown should contain the following data:
 - item ID
 - item name
 - finished goods inventory balance
 - inventory weeks of supply
 - materials inventory value

- material diameter
- lot size
- capacity requirement of the lot.

The definition of “capacity requirement of the production lot” was not made during the preliminary study, but at the release state of the production scheduling tool.

4.3.3 Supply chain study

The supply chain study was carried out mainly for the purpose of developing the lot size calculations. Nevertheless, a comprehensive supply chain study helped to understand the problem scope of the business case as a whole.

The supply chain contained five main parties, which were the customer, supplier, production planning, warehouse/logistics and the production cell. Transportation service providers were ruled out from the supply chain study because their essence in the context was limited. The supply chain figure below describes the position of each party in the supply chain. The figure visualizes two important things around the supply chain. The main attention should be paid to the interfaces of the information and the material flows. The relationships of the three parties inside the company should also be noticed.

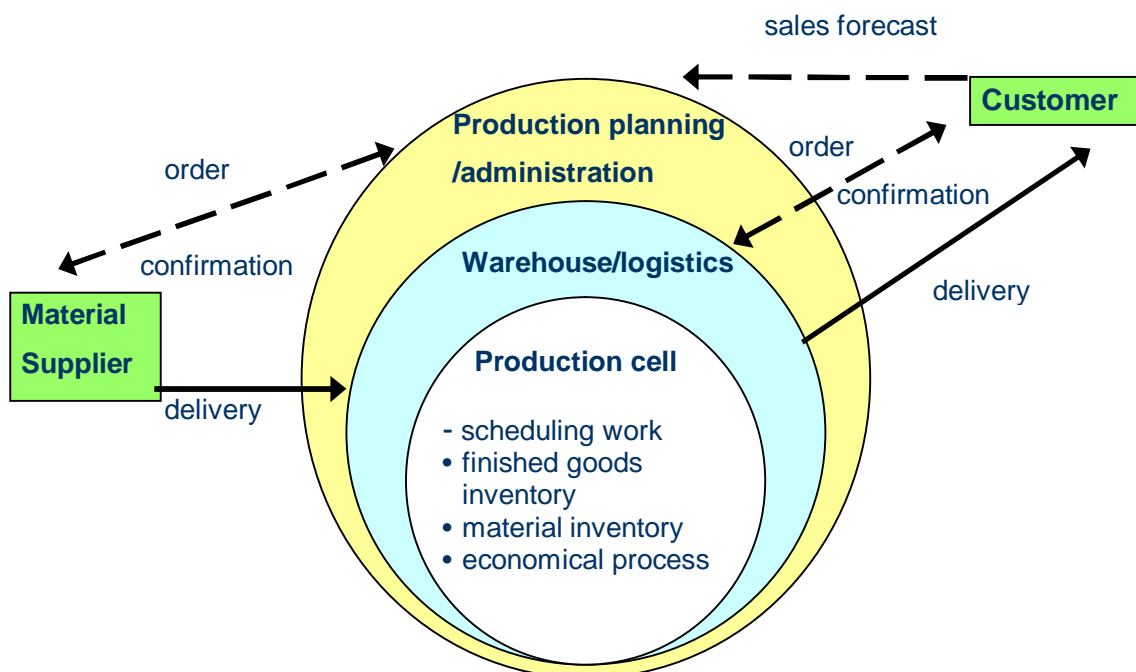


FIGURE 3. Picture of the supply chain structure.

The supply chain begins when the customer sends the yearly sales forecast to the commissioner. This is a pre-condition of the supply chain. Production planning receives the sales forecasts and transforms them into weekly consumption figures in order to get a better input to the planning process.

Purchasing

Materials purchasing was planned and executed by the production planning. The planner observed the sufficiency of the finished goods and raw-materials inventory. The order was placed if both the inventories were at critical levels. The material order was often placed many weeks before the actual manufacturing took place. This was due to three reasons.

The first reason was that, the customer required 100% reliability in deliveries. Neither lack of finished goods nor raw-materials was acceptable. The raw-materials were mainly purchased in bars. Before manufacturing, the bars needed to be sawn into a certain length. Since the sawing was very time consuming it was needed to be planned many days in advance. The third reason was that in each of the material orders it was tried to fit in as many order lines as possible.

The lead time of the supplier was one week. If the supplier had a stock out, the lead time could be up to four weeks. However, such incidents were luckily quite rare. Upon arrival, the warehouse logistics received the raw-materials. The quality check and labelling was performed before the raw-materials were placed in the warehouse and booked into the ERP system. Invoices were forwarded to the administration department.

Manufacturing

Manufacturing was performed by the production cell. Certain preparation activities needed to be done before the serial manufacturing could be started. This included the setup of the machine, as well as ensuring that both the raw-materials and the inspection tools were ready. As mentioned earlier, the sawing of the materials was planned and performed in advance, and was therefore taken into consideration in the

production scheduling. The preparation of the inspection tools was conducted simultaneously with the setup of the machines. Before serial manufacturing there was a need to even further adjust the machine setup. The adjustment was performed while machining the first item. Due to the setup adjustments, the manufacturing of the first item took approximately three times as long as the unit time in the serial manufacturing.

Warehouse and logistics

After the machining operation, the items were transferred back to the logistics department, that was responsible for the washing of the items. Preparation before the washing included programming of the washing machine and physically setting the items in the first washing cage. The rest of the washing cages could be prepared during the actual washing process. After the washing was complete the items were placed in the warehouse. At the same the items were booked into the ERP system.

The customer placed orders through the IT-based order system. The logistics department received the orders and confirmed them through the same channel. Orders were prepared on the preceding day of the actual delivery. The workload of the preparation depended on the order itself.

4.3.4 Feasibility of the lot size calculation

The supply chain study was the basis for building up the lot size calculations. At first, the feasibility of the calculation formulas was found out by making the cost structure modelling for the key processes of the supply chain. The calculation formulas were built up based on the cost structure models.

Cost structure modelling

In the cost structure modelling, the supply chain was divided into four key processes. The cost structure of each key process was defined carefully. The four key processes were: purchasing, manufacturing, washing and warehousing.

The purchasing process was defined to start from the planning of raw-material procurement and ending at the phase where the material was ready for machining. The

purchasing process included many tasks whose durations was very difficult to estimate. The purchasing activity did not have fixed procedures. The number of orders placed as well as the volume varied over time. Keeping the inventory levels at a minimum was the main guiding principle when ordering materials. Since the commissioner's production operated in a make-to stock basis, the question quite soon emerged whether to include the purchasing process into the lot size calculation or not.

The manufacturing process was defined to include the preparation tasks of the machine and the serial manufacturing. The cost calculation of the manufacturing process required the definition of the time consumed by the process as well as the cost of a machine hour. The machining times for each item were defined by the commissioner, along with the machine hour cost. The defined cost included labour costs, machine maintenance, depreciation space costs as well as average capacity utilization rate of the machine. Machine preparation times contained the following phases:

- planning the preparation phase
- upper tools change
- lower tools adjustment
- jaw change
- programming
- test drive

The preparation times were defined by the production cell during the project. One problem came up while defining the machine preparation times. Namely, the preparation time varied tremendously depending on the manufacturing order of items. The main problem was the changing of upper tools. The change of upper tools was required because the tool magazine of the machine lacked sufficient space. The upper tools change accounted for almost half of the entire preparation time.

The washing process was defined to start when the items were ready for washing and ended when the items were placed in the warehouse and booked into the ERP system. The cost calculation of the washing process required defining the elapsed time of the process, and the calculation of the machine hour cost. The man hour cost of the

washing process was defined by the commissioner. Therefore only the washing process time was needed to define. The washing process contained four phases which were: preparation, washing operation, finishing and transfer to warehouse. The time consumption of the washing process had to be defined as well. The common time consumption value was defined to all other phases except the washing operation.

The definition of the washing operation time was complex. In the actual washing operation the items were placed into washing cages, and sent to the washing machine. Washing machine process contained five phases. During the washing operation the washing cages were rolled through the washing machine. Therefore, the washing machine contained five washing cages at the time. Depending on the size of the item, the washing cage could house a variable number of products (see figure 4). The washing operation time for a certain lot size was thereby derived from the number of items fitted in the washing cage.



FIGURE 4. Items in a washing cage.

Warehousing was the last of the four main processes. It was defined to include the cost of the warehouse space and the cost of the inventory capital investment. The inventory carrying costs were easier to model, as only the buffer stock and its interest rate needed to be defined. For the warehouse space cost, it was needed to define the cost of one unit and the used warehouse area. The square meter cost of the facilities was defined by the commissioner. Square meter costs included rent, insurances, cleaning, heating, water, security service and maintenance. The use of the warehouse area was defined by the author with the help of the logistics staff.

Calculation formulas

According to cost structure modelling it was feasible to form calculation formulas from all key processes except purchasing. The problem with preparation times of the manufacturing process was thus soon overcome. The company made a decision to invest in a tool magazine for the machine and thus the upper tool change was eliminated from the cost structure.

The calculation formula for annual manufacturing process costs (AMC) where the yearly sales is D and the lot size quantity is q took the following form:

$$AMC = \frac{[F + M(q-1)] * M \text{ €/h} * D}{q}$$

- F = preparation time of the machine
- M = unit machining time
- $M \text{ €/h}$ = machine hour cost
- D = expected sales within the time period
- q = given lot size

The calculation formula for annual washing process costs (AWC) where the yearly sales is D and the lot size quantity is q took the following form:

$$AWC = \frac{\left[v + w + p \left(\frac{q}{r-1} \right) \right] * A\text{€}/h * D}{q}$$

- v = given value for preparation, finishing and transfer to warehouse
- w = washing operation time for first washing cage
- p = washing operation time for washing cages that follow the first one
- r = number of items that fit in one washing cage
- $A\text{€}h$ = man hour cost
- D = expected sales within the time period
- q = given lot size.

The calculation formula for annual warehousing costs (AIC) where the lot size quantity is q took the following form:

$$AIC = W1 * \text{€}/m^2 + \frac{(b + q)}{2} * \acute{a} * C$$

- $W1$ = the use of warehouse area of the item
- $\text{€}m^2$ = square meter cost
- b = size of buffer stock
- q = given batch size quantity
- \acute{a} = price of the item
- C = inventory carrying cost interest rate.

4.4 Implementation plan

Based on the preliminary study, the consignment looked feasible. The requirements specification of the desired tool made the implementation tangible. The lot size definition was a more complicated issue, but also feasible to a certain accuracy. The vision of the desired tool was to function as an informative data matrix. The exact optimal lot size was not feasible. However, it was feasible to construct the cost curve of the production process. It meant that the product of the lot size definition was not going to be directly applicable to the production scheduling tool, and as such the lot size definition was going to be implemented as a separate tool. The lot size calculation would be included into the production scheduling tool but the user needed to fill up that information.

MS Excel was chosen to function as a platform for both the tools. The architecture of the tools was going to follow the typical three-layer format which included: data access, business logic and user interface. Excel VLOOKUP -function was chosen as the method for data transfer between the layers. VLOOKUP is a data search feature in an Excel-application. The principle of the VLOOKUP-function is stated: "It searches for a value in the leftmost column of a table, and then returns a value in the same row from a column you specify in the table" (Excel user instructions).

The implementation of both tools was going to follow three phases. In the first phase the required data or the data access to the required data had to be defined. Then the data was positioned to the data access layers. The business logic was created in the second phase. The essential data was transferred to the business logic layer, where the data was further arranged and treated with calculations. The user interface was created in the third phase. The ideology of the user interface was different in both tools. The production scheduling tool required an interface where all items would be assessed at the same time. On the other hand, for the lot size calculation model, the interface which would assess one item at a time was going to be better.

4.5 Production scheduling tool

The production scheduling tool is a simple Excel application. It makes a list of the items and brings up different data related to each item. The core of the production scheduling tool's business logic was derived from the former production planning process. The scheduling tool has four features:

1. automate updates
2. master filter
3. manual filter
4. undo filter.

Master filter and undo filter are macros which aim to automate repeated tasks in the production scheduling process. The master filter automates the tasks of filtering and sorting the items into the most favourable order. The most favourable order is produced according to the figures of the inventory weeks of supply (IWS). The assessment of the situation is largely based on the IWS –figure.

Inventory weeks of supply (IWS)

During the course of the project the calculation formula of the IWS was further developed. In the production scheduling tool the figure of the IWS took into consideration also the time duration between the evaluation date and the last delivery date. The time duration was subtracted from the expected weeks of supply and therefore it reached a more accurate IWS -figure. In the calculation formula the change is seen below.

The former formula (IWS 1.0)

$$IWS1.0 = IB / \left(\frac{ASFQ}{52_weeks} \right)$$

- IB = inventory balance
- ASFQ = annual sales forecast quantity

The developed formula (IWS 2.0)

$$IWS\ 2.0 = \left[IB / \left(\frac{ASFQ}{52_weeks} \right) \right] - \left(\frac{CD - FD}{7_days} \right)$$

- IB = inventory balance
- ASFQ = annual sales forecast quantity
- CD = current date
- FD = the last finished goods delivery date

User interface

The layout of the user interface is a simple data matrix. It is not only easy to read but it also supports the VLOOKUP-function that is used in every cell of the data matrix. The user interface contains the title, data matrix and two push buttons. The data is set on the matrix so that each line represents one item. The data set includes the following information:

- the item ID
- the item name
- the finished goods inventory balance
- the inventory weeks of supply
- the material inventory value
- the material diameter
- the lot size
- the capacity requirement of the lot. (see figure 5.)

Microsoft Excel - PUMA MX2500 KUORMITUSTYÖKALU 1.0

Tiedosto Muokkaa Näytä Lisää Muotoile Työkalut Tiedot Ikkuna Ohje

D16 =JOS(PHAKU(A16;laskut;6;<0;PHAKU(A16;laskut;5;);PHAKU(A16;laskut;6;))

PUMA MX 2500 KUORMITUS TYÖKALU							
		Suodata		Palauta			
		VALMISTUOTE		MATERIAALI			
NIMIKE ID	NIMI	MÄÄRÄ (kpl)	RIITTO (vk)	MÄÄRÄ (kpl)	AIHIO d. (mm)	SARJA (kpl)	KUORMA (h)
V402	TIMSTERENGAS	23	0	epäselvä	Ø110	20	12
VB21	RUNKO	18	1	41	Ø117	20	9
VB21	RUNKO	27	4	#####	Ø107	20	12
VB21	RUNKO	23	5	0	Ø244	20	21
VB21	RUNKO	11	5	0	Ø244	20	9
VB21	RUNKO	17	5	107	Ø81,4	20	9
V402	TIMSTERENGAS	22	6	41	Ø122	20	14
V401	RUNKORENGAS	17	7	0	Ø170	20	9
VB21	RUNKO	26	7	epäselvä	Ø132	20	21
VB21	RUNKO	12	8	0	Ø244	20	9
VB21	RUNKO	28	8	0	Ø212	20	9
VB21	RUNKO	18	8	100	Ø91,4	20	9
VB21	RUNKO	18	8	0	Ø117	20	19
VB21	RUNKO	17	8	11	Ø107	20	9
VB21	RUNKO	23	9	57	Ø117	20	9

käyttäjällä / laskut / koneajat / asiakasennuste / vvalmistuote / vmateriaali / materiaalipaino

Valmis

FIGURE 5. User interface (master filter)

The data matrix also includes another common function of Excel, the IF-function. The IF-function is used in the cells of the IWS and the materials inventory value. The IF-function purpose is to eliminate inappropriate values of the IWS 2.0 calculation formula. The calculation of the IWS 2.0 will not deliver a good result if the finished goods delivery data is not valid. This may occur if the delivery date does not exist or if the delivery date is too old. (see appendix 3.)

The cells of the material inventory value uses the IF-function to find out material inventory booking errors. A booking error may occur because the materials are purchased in bars as well as ready cut pieces. The unit measurement of the material is normally set as kilograms in the ERP -system. If the material is purchased as “ready cut pieces”, it might happen that the material is booked into the system in the wrong unit. Such discrepancy then causes problems in the materials inventory calculation. (see appendix 4)

Functions

The production scheduling tool created satisfies all the requirements that were mentioned in the requirements specification except for the lot size. The tool gathers up the register of the items concerned. It updates the situation by taking three key factors into account: sales forecasts and inventory levels of both the finished goods and raw materials. The production scheduling tool has four features which the user may apply.

1. The first feature is automated updating. The application will automatically update the data from the company's ERP –system whenever the user opens the application. When the tool is open the updating occurs every thirty minutes. The inventory balances are the main data that is updated
2. The second feature is the master filter. The master filter aims to filter only the most critical items on hand, and thus make the evaluation and comparison of the items more efficient. In its normal position the user interface shows a list of all the items, about 30, in a random order (see appendix 5). The user interface contains a push button that triggers the master filter. The master filter filters fifteen items having the smallest IWS figure, located in column D. Further, the item lines are sorted to the ascending order according to IWS figures. In addition, the function transforms the font size and the outlook of the table into an easy-to-read format. (see figure 5.)
3. As a third feature the user may perform the filter task manually according to his/her own preference. For example, the user may filter all such items which are made from the material having a certain diameter, or sort the item lines according to material availability. The manual filter is set on the matrix at all times. (see appendix 6.)

The fourth feature of the production scheduling tool is the undo filter. The undo filter is opposite of the filtering function. It restores the data of all the items back on the screen and releases all the formats. The undo filter has its own push button on the right hand side of the master filter button.

Use

The use of the production scheduling tool is designed to be user-friendly, which should support the user level. The user opens up the scheduling tool and he/she sees the overall item situation on the screen. To make the evaluation of the data more efficient the user may either click the master filter or do the filtering manually. When the user has made up his mind about the next production sequence, he will carry out the actual scheduling and manufacturing process through the company's ERP system.

4.6 Lot size calculation model tool

The lot size calculation model tool draws the cost curve of the annual costs of the production process with respect to the lot size. It is not a complete model of the whole supply chain. The calculation model tool included information of 25 different products.

The user has four sheets at his/her disposal. In the first sheet, called $T(q)$, the user chose the item that he/she wants to observe from the pull down menu. After having chosen an item the user may look at the cost structure matrix and the related cost curve graph of that particular item. In case there is a need to view the graph in greater detail, this can be done by choosing the next sheet called "käyrä", which presents the same graph on a much larger scale. If the user wishes to study the costs structures of the production or warehousing costs in greater detail, he/she may go further to the $P(q)$ sheet (see appendix 8) or to the $S(q)$ sheet (see appendix 9). The information shown on the sheets of the "käyrä", $P(q)$ and the $S(q)$ are always related to the item which was chosen on the $T(q)$ sheet.

The cost curve graphs expresses three different cost functions: the inventory carrying cost, the production cost and the total cost. The total cost function is the sum of two other cost functions. Each of the cost functions represents the annual total costs with respect to the lot size.

In order to find the optimal batch size of production, one must look at the cost curve graph. The x-axis on the graph represents the batch size and the y-axis represents the

annual costs. The total cost curve is expressed in dark blue colour. The optimal area for the lot size should be found at the point where the total cost curve is at its lowest.

5 ANALYSIS

The analysis chapter contains three sections. The first section includes the feedback given by the users of the production scheduling tool. The topics raised from the feedback are discussed in more detail at the end. In the second section the lot size calculation model is analyzed in more detail. The analysis points out the parts of the supply chain that were ruled out from the created calculation model. Further, the parts and their cost contribution are analysed in the context of economic lot size calculation theory. The last section analyses the project of production scheduling tool as a whole.

5.1 Production scheduling tool

The production scheduling tool was fairly easy to build because the customer had a very good vision about its content. The tool fulfilled the requirements set by the customer. The inventory weeks of supply formed the basis for the existing production planning process. The calculation formula of the inventory weeks of supply was further developed during the course of the project. This was one of the main achievements in the project.

5.1.1 User feedback

User feedback and comments of the production scheduling tool was obtained three months after the release of the tool. The users were asked four questions.

- How often has the tool been used?
- Has the production planning process changed since the usage of the tool?
- How much quicker compared to earlier can the production planning process be performed?
- Have there risen ideas on how to improve the tool?

Three users who had mostly been in contact with the tools took part in interviews. One worker was from the production cell and two were from the production planning. The production planner who was in charge of the planning work at the time when the tools were designed was shifted to other duties. This made the interviews somewhat problematic. Although the tool had not been used to a very large extent, the users had nonetheless, received a very encouraging understanding of the possibilities that the tools could provide.

Production planner I

The production planner who was nowadays responsible for the planning tasks was interviewed first. His main activity was the purchasing of raw-materials. The tool was used twice a week to check the inventory status. The credits were given for the overview which the tool had given. However, the accuracy of the materials inventory was discredited, as it was said to be unreliable. The planner also suggested an improvement. As he desired that the data matrix could be sorted according to a certain material diameter. The planner however, did not know that the manual filter function of the tool actually was allowing the user to do just that (see appendix 5).

The production planner did not need to make planning efforts to the manufacturing scheduling anymore. Although the production planner still assigned the work number into the ERP system, the main task of evaluating the critical items was eliminated. Lastly, the question about the adding new items in the tool was also introduced. All in all the production planner was very satisfied for the tool in overall. (Matzei, P. 2007.)

Production planner II

The former production planner was interviewed as second. The former production planner had not used the tool at all but he was greatly involved in its designing process. After a short observation and assessment of the production schedule tool he estimated, that the tool would provide at least a 50 per cent reduction in the workload of the manufacturing scheduling and a 50 to 70 per cent reduction in the workload of raw-material purchasing. The former production planner was also satisfied with the tool. (Salonen, J. 2007.)

Production cell

Lastly, the senior worker of the production cell was interviewed. Although he had only used the tool a few times in the production cell, he was already convinced that the tool was going to be of great assistance in the production scheduling. Previously it was needed to run back and fourth between the production planner and the warehouse in order to obtain the information which was now seen immediately on the screen. A rough estimation was made that the time consumed to the scheduling had been reduced to half of what it had previously been. (Ylönen, M. 2007)

5.1.2 User feedback evaluation

Three issues arose during the feedback discussion. One of them was the reliability problem of the materials inventory value. This problem was difficult, since the problem did not lie in the production scheduling tool, but in the commissioner's database. The second issue was the updating of new items into the production scheduling tool. An issue that was very essential to the whole context of the thesis. The third issue, regarding the usage of a manual filtering function was already discussed earlier.

Materials inventory problem

Materials management was the most obvious problem area of the commissioner. The problems were also reflected into the production scheduling tool. Four reasons for the materials inventory accuracy problem were identified.

The first reason was that the materials inventory balances could simply be incorrect. The second reason was that there may exist more than one corresponding material inventory figure to the same item in the database. As the production scheduling tool is only capable of using one of the figures.

The inconsistency of the unit measurements was the third reason for the problem. The raw-material inventory values are expressed as the number of finished goods capable to be manufactured. The inventory value is derived from the material inventory balance and the material consumption of the one item. The calculation of the

inventory value cannot be produced if the unit measurements of the two components are different. (see appendix 3.)

The fourth reason for the inaccuracy is related to the material diameter. The material diameter values are given by the customer. The diameters of the used materials in Komax are not necessarily the same. The author decided to use the values given by the customer because the purchasing policy of the commissioner lacked consistency.

The new item update

The new item update into the production scheduling tool was difficult. The architecture of the tool enabled the update of a new item fairly well but the user interface's automated functions did not. The actual updating only required the adding of a new item into the tool's item register. Also the business logic line needed to be copied for the new item. Copying the code line was all that was needed in order to bring the new item into the user interface. The new item could be added into the tool but automated filtering function would not take this into account. The macros of the master filter and the undo filter functions were needed to be re-recorded if the new item wanted to be included into the functions. Recording the macro is a complex job, and due to that fact, there have not been produced any instructions for the macros re-recording job.

5.2 Economic lot size calculations

The feedback concerning the lot size calculation tool could not be obtained, since the calculation model tool never reached the users. The calculation model was introduced for the new production planner during the last visit at Komax.

The economic lot size was defined by forming the cost curve of the production process. The calculation formula of the cost curve does not take into consideration all costs of the supply chain. Therefore, the readings of the cost curve cannot be seen as an absolute fact but rather as a guideline. When lot sizes given by calculation model were compared to lot size manufactured earlier it was seen their similarity. Therefore, it be concluded that in some level the lot size calculation model produces good results.

5.2.1 Economic lot size theory

The economic lot size aims to define the minimum production and storage costs. It however, requires a rather constant level of demand over the year in order for the calculation to be reliable. The components of the economic lot size (ELS) calculation formula can be divided in the three categories according to their relation to the lot size. The general form of the ELS cost are presented below. (Lehtola, P 2007; Lial, Greenwell, Ritchey 2001, 767.)

$$ELS = \frac{f * M}{q} + g * M + \frac{k * q}{2}$$

- M = total number of units produced annually
- q = lot size
- f = fixed setup cost to manufacture the product
- g = cost of manufacturing a single unit of the product
- k = cost of storing one unit of the product for one year.

The first category costs are directly related to the lot size. It also takes into consideration the inventory carrying costs. The first category costs takes the following form.

$$\frac{k * q}{2}$$

The second category costs are inversely related to the lot size, meaning that the bigger the lot size the less the cost. This category includes all the fixed costs of preparing each production lot. The second category costs takes following form.

$$\frac{f * M}{q}$$

The third category costs have no relation to the lot size at all. They may only have a relation to the total number of production. These costs only raises the total costs. It could be said that, the bigger the contribution of the third category costs to the total costs, the less importance the optimal lot size has with respect to the cost.

$$g * M$$

5.2.2 Excluded areas of the supply chain

The areas of the supply chain which were ruled out from the calculation model were purchasing, production scheduling, sawing, inspection tools setup, order preparation and finished goods transportation. In the following paragraphs the cost structure of the mentioned areas are analysed and placed into the previously mentioned cost categories.

Purchasing

Purchasing was excluded from the calculation model because the cost structure of it was not feasible to model. However, it can be said that there is a loose relation between the costs of the purchasing and the size of the production. Since one purchase order may contain several order lines, the costs related to purchasing needed to always be shared between the items that were ordered. Therefore, the purchasing costs cannot be directly directed to the lot size, even though the raw materials are purchased in the same amount as they are needed in the production lot. The conclusion would thus be that purchasing would belong to the third cost category.

Production scheduling

The production scheduling was done during the machining. Therefore, the scheduling task will not produce any separate costs if the production cell performs the scheduling task. The production scheduling tool now enables the production cell to perform the

scheduling task alone. Therefore the production scheduling costs are eliminated from the problem scope.

Sawing

The sawing of raw materials was included into the purchasing process in the cost structure modelling. So therefore, the sawing was also excluded from the calculation model. It would be reasonable to consider the sawing also as a separate phase in the production process, because most of the raw materials were sawn by the commissioner. The sawing only needed man power for the preparation tasks. After the preparation the machine could operate on its own.

Currently the sawing could be considered as a member of the second cost category, as it was inversely related to the lot size. This was due to the fact that materials are only bought as much as they are needed in one production lot. Therefore also the cost of sawing appears as many times as the items are manufactured in series.

Inspection tools setup

The setups of the inspection tools were done simultaneously with the machine setups. Therefore, each time the production lot was manufactured the cost was accumulated. The costs of the inspection tools setup belongs to the same cost category as the sawing.

Customer order preparation and transportation

The preparation costs of customer orders as well as the transportation cost of the finished good deliveries were excluded from the calculation model, since they were related to the size of the customer order rather than the lot size. Therefore, these costs also belong to the third cost category.

The cost contribution of the areas that were excluded from the calculation model was notable. Especially purchasing, that included several costs such as materials planning, transportation, receiving costs, invoice booking and sawing. The excluded areas contained only the second and the third category costs. Therefore, if the sawing and the inspection tools setup were to be included in the calculation model, the optimal lot size would be bigger. Whereas, if also the purchasing, the customer order preparation

and the transportation would be included in the total cost, the curve would show a flatter shape, meaning that the optimal area would not be so exact. As a sum up it is said that, the benefits of the calculation model are intertwined with the user's ability to assess the cost curve and the cost functions.

5.3 Thesis analysis

The aim of the thesis was to design and implement the desired production scheduling tool. To carry out the project with a high planning effort was set as the number one priority of the project, regardless of the outcome of the project.

All in all it can be said that the project was a success. The emphasis on the good planning came up several times during the project. The preparation for the project was demanding but the efforts paid off during the preliminary study. The amount of information received from the preliminary study was vast. At this point, it could be said that the only way out from that situation was a systematic approach towards the planning. At the construction phase of the project the work was a continuous loop of trial by error, which also meant that the plans had to be reviewed and revised frequently.

The production scheduling tool was released on time. The customer requirements were fulfilled with the exception of the lot size definition. The lot size definition was however, delivered within a certain accuracy. The emphasis on the planning suffered somewhat when the project proceeded towards the end. The important phases of the releasing and the maintenance were not carried out in the best possible manner. A user manual was not created because the production scheduling tool was seen as a very simple application. However, it was recognized later on that all of the functions of the tool was not known among the users. Especially the lot size definition tool had not even reached all of the users.

The theoretical background of the thesis also served the purpose of the thesis well. Many of the issues in the theories turned out to be tangible during the project. Below are listed some of them.

- The requirements of the software are always incomplete. The last addition to the production scheduling tool requirements was introduced after the release of the presentation.
- The construction of the software is actually designing it into existence. This holds a great deal of truth, as the activities or tasks of the construction phase were very hard to define at the starting point. The whole construction phase was actually defining and designing the tasks, and once the task was designed the construction had also been done.
- The importance of the release phase was underestimated. As simple as the production scheduling tool was, the user nonetheless, desired more support in order to get everything out of the scheduling tool.

As a closure to this chapter, it can be stated that the subject of the thesis was very new to the author. It would have therefore been a considerable advantage if there had been an opportunity to previously study the topic.

6 CONCLUSION

There was an undisputed conclusion among all of the involved parties that the aim of the project had been reached. The customer requirements were fulfilled and the tools were delivered on time. Most of all, the core formula of the whole production scheduling ideology had been further developed. The person who now performs the scheduling tasks has not only a better, but also an instant overview of the current situation.

Both the commissioner and the users of the developed production scheduling tool were very satisfied with the outcome of the project. The commissioner's attempt to decentralize its planning process to the production cell level paid off. All parties had recognized the benefits of the tool. Most of the feedback obtained from the users was positive, and it became clear that the users had grasped the achievable benefits of the scheduling tool. However, the credibility of the feedback can be somewhat questioned, as some of the users had very limited experience of using the scheduling

tool. Nonetheless, according to the senior member of the production cell there should not be any further doubts regarding the benefits of the tool when comparing the vast change between the previous production planning process and the process of today.

The initial vision that the commissioner had about the desired tool laid a strong foundation for the success of the project. Also the great emphasis on the careful planning of the project was seen as a cornerstone for the success. The criticality of the careful planning came up several times during the course of the project, sometimes in a negative way, but generally in a positive way. By taking into the consideration the fact that the branch of the business as well as the activities carried out in the project were completely new for the author, the end result can definitely be considered a success.

Although the lot sizes calculations were not defined to their full extent, the analysis based on the cost structure modelling of the supply chain may deliver beneficial information to the commissioner. If the commissioner further realises the knowledge of the cost structure analyses, he may use it for restructuring parts of the supply chain into the format where their cost accumulation would be clearly proportional to the lot size. Thereafter, the specific economical lot sizes would be even more accurate..

As a suggestion for the future, the author saw that if the finished goods warehousing were to be based on a consignment stock principle, the activities of the customer order preparation as well as the transportation would become more or less directly proportional to the lot size. This would most likely also decrease the workload of the warehouse as well as the transportation, as bigger batches could be delivered at a time. This could lead to an elimination of the current buffer stock existing in the commissioner's warehouse. As a consequence, this would also release a considerable amount of warehouse floor space, which could be used for other more productive purposes.

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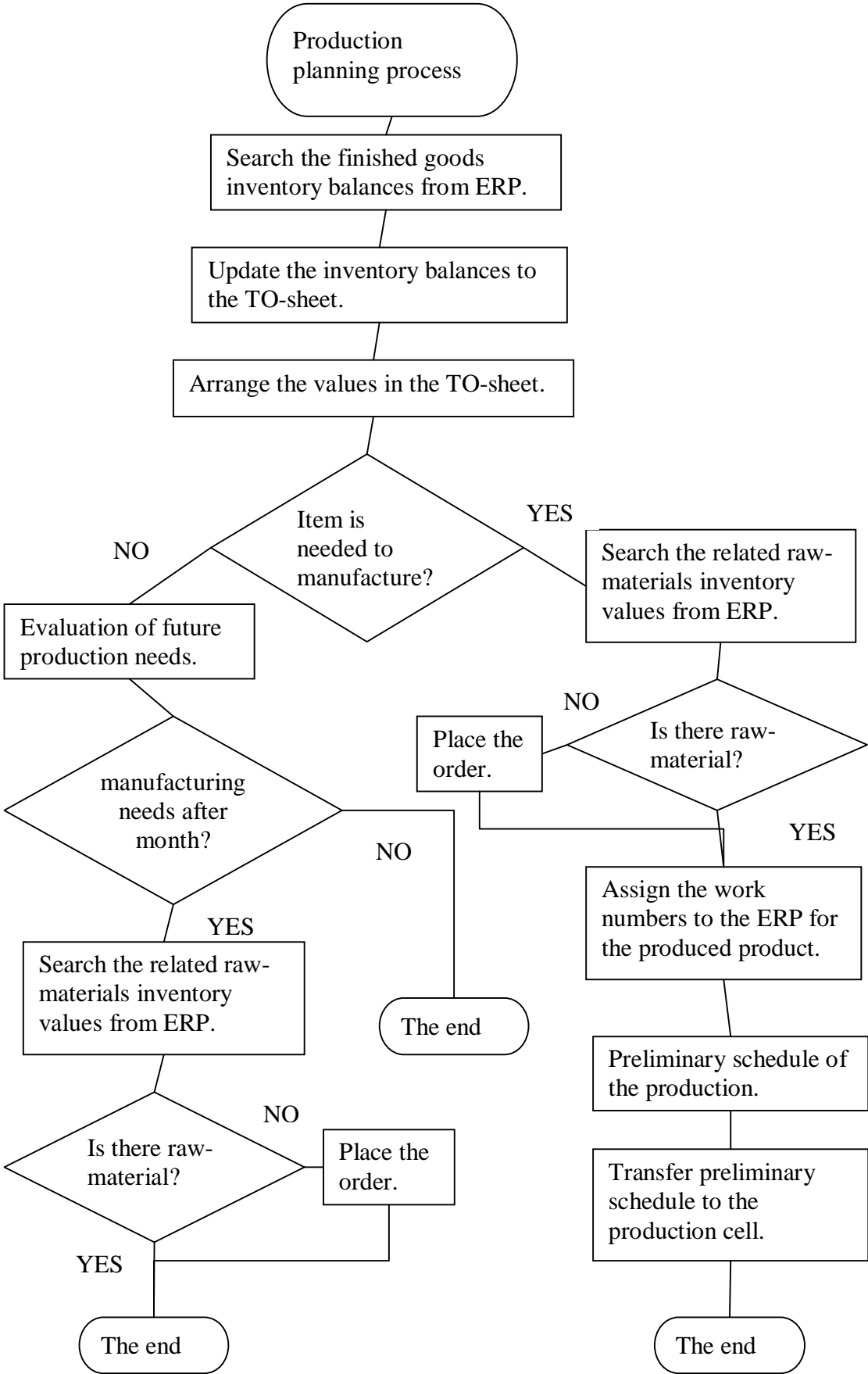
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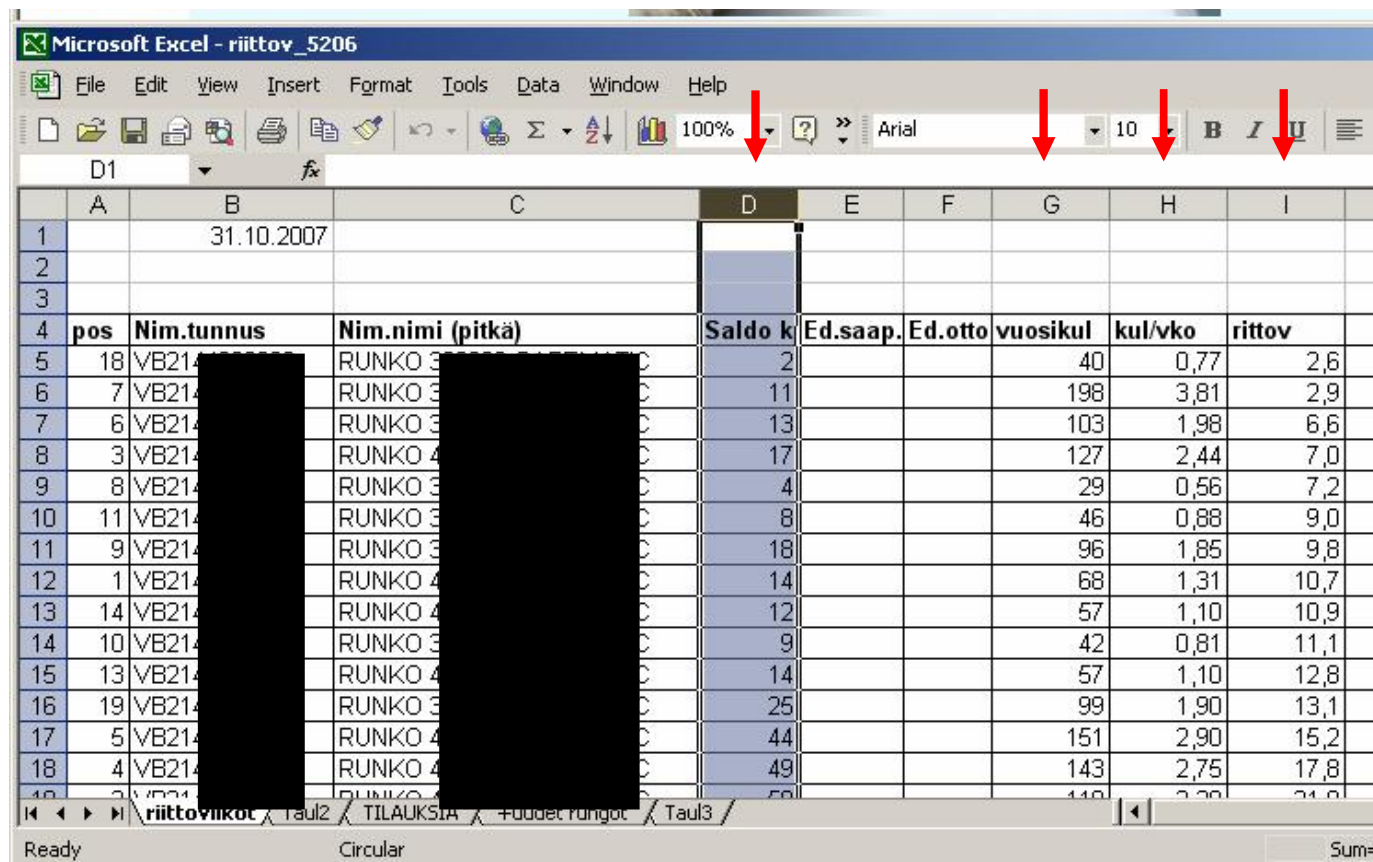
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Appendix 1. Production planning process flow chart



Appendix 2. TO-sheet

Red arrows point the columns which includes the key figures of each item.



The screenshot shows a Microsoft Excel spreadsheet titled "riittov_5206". The spreadsheet contains a table with columns A through I. Red arrows point to columns D, G, H, and I, indicating they contain key figures. The table data is as follows:

	A	B	C	D	E	F	G	H	I
1		31.10.2007							
2									
3									
4	pos	Nim.tunnus	Nim.nimi (pitkä)	Saldo k	Ed.saap.	Ed.otto	vuosikul	kul/vko	riittov
5	18	VB214	RUNKO 3	2			40	0,77	2,6
6	7	VB214	RUNKO 3	11			198	3,81	2,9
7	6	VB214	RUNKO 3	13			103	1,98	6,6
8	3	VB214	RUNKO 4	17			127	2,44	7,0
9	8	VB214	RUNKO 3	4			29	0,56	7,2
10	11	VB214	RUNKO 3	8			46	0,88	9,0
11	9	VB214	RUNKO 3	18			96	1,85	9,8
12	1	VB214	RUNKO 4	14			68	1,31	10,7
13	14	VB214	RUNKO 4	12			57	1,10	10,9
14	10	VB214	RUNKO 3	9			42	0,81	11,1
15	13	VB214	RUNKO 4	14			57	1,10	12,8
16	19	VB214	RUNKO 3	25			99	1,90	13,1
17	5	VB214	RUNKO 4	44			151	2,90	15,2
18	4	VB214	RUNKO 4	49			143	2,75	17,8
19	3	VB214	RUNKO 3	58			118	2,28	21,8

Appendix 3. If-Function (inventory weeks of supply)

Below is seen a part of the business logic of the production scheduling tool. The column E holds the figures of the IWS 1.0. On the other hand the column F holds the figures of the IWS 2.0.

	A	B	C	D	E	F	G	H
1		x = ei löydy tietokantahaulla valmistuotevarastosta					tämä päivä	
2							15.11.2007	
3			Valmistuotteet					
4			vuosimenekki	saldo	Riitto	Riitto special	viimeisin toimituspäivä	Aihion d.
5	V3046		51		28	29	0.1.1900	Ø86,4
6	V3079		15		5	17	31.1.2007	Ø122
7	V3080		20		16	42	0.1.1900	Ø112
8	V3080		55		30	28	0.1.1900	Ø122
9	V4042	x	146	#PUUTTUUI	#PUUTTUUI	#PUUTTUUI	#PUUTTUUI	Ø132
10	VB214		92		23	13	18.9.2007	Ø244
11	VB214		184		26	7	18.9.2007	Ø132
12	VB214		98		18	10	13.9.2007	Ø117
13	VB214		27		7	13	6.8.2007	Ø173
14	VB214		41		11	14	13.9.2007	Ø244

This picture represents the If-function which is applied to the inventory weeks of supply cell in the user interface layer. The function either draw the IWS 1.0 figure or IWS 2.0 figure from the business logic layer.

=JOS(PHAKU(A14;laskut;6;<0;PHAKU(A14;laskut;5;);PHAKU(A14;laskut;6;))

	A	B	C	D	E	F	G	H
1	PUMA MX 2500 KUORMITUS TYÖKALU							
2								
3				Suodata	Palauta			
4								
5				VALMISTUOTE	MATERIAALI			
6	NIMIKE ID	NIMI	MÄÄRÄ (kpl)	RIITTO (vk)	MÄÄRÄ (kpl)	AIHIO d. (mm)	SARJA (kpl)	KUORMA (h)
12	V40206	TIIVISTERENGAS	23	0	epäselvä	Ø110	20	12
14	VB2144	RUNKO	18	1	41	Ø117	20	9
16	VB2144	RUNKO	27	4	#####	Ø107	20	12
20	VB2144	RUNKO	23	5	0	Ø244	20	21
21	VB2144	RUNKO	11	5	0	Ø244	20	9

Appendix 4. If-Function (materials inventory)

The picture below represents the inconsistency between the unit measurements of the material inventory balance (MBI) and the material consumption of one item (MCI). Column J holds the unit measurement of the MBI and column M holds the unit measurement of the MCI.

	A	J	K	L	M	N	O	P
3		Materiaalien						
4		Saldo	yksikkö	per/kpl	yksikkö	saldo kpl	saldo vara	Sarj
5	V30		235,00 kg		1,60 kg	147	epäselvä	
6	V30		73,00 kg		4,00 kg	18	epäselvä	
7	V30		0,00 kg		3,10 kpl	0	epäselvä	
8	V30		73,00 kg		3,70 kg	20	epäselvä	
9	V40		#PUUTTUU!	#####	#PUUTTUU!	#####	#PUUTTUU!	epäselvä
10	V40		#PUUTTUU!	#####	#PUUTTUU!	#####	#PUUTTUU!	epäselvä
11	V40		#PUUTTUU!	#####	#PUUTTUU!	#####	#PUUTTUU!	epäselvä
12	V40		0,00 kpl		1,00 kpl	0	epäselvä	
13	V40		0,00 kpl		1,00 kpl	0	epäselvä	
14	V40		73,00 kg		5,00 kg	15	epäselvä	
15	V40		0,00 kg		4,15 kpl	0	epäselvä	

This picture represents the If-function which is applied to user interface cell of the materials inventory value.

=JOS(PHAKU(A12;laskut;11;)=PHAKU(A12;laskut;13;);PHAKU(A12;laskut;14;);PHAKU(A12;laskut;15;))

	A	B	C	D	E	F	G	H
1	PUMA MX 2500 KUORMITUS TYÖKALU							
2								
3			Suodata		Palauta			
4								
5			VALMISTUOTE		MATERIAALI			
6	NIMIKE ID	NIMI	MÄÄRÄ (kpl)	RIITTO (vk)	MÄÄRÄ (kpl)	AIHIO d. (mm)	SARJA (kpl)	KUORMA (h)
12	V4020	TIIVISTEREN	23	0	epäselvä	Ø110	20	12
14	VB214	RUNKO	18	1	41	Ø117	20	9
16	VB214	RUNKO	27	4	#####	Ø107	20	12
20	VB214	RUNKO	23	5	0	Ø244	20	21
21	VB214	RUNKO	11	5	0	Ø244	20	9
22	VB214	RUNKO	17	5	107	Ø81,4	20	9

Appendix 5. User interface (plain)

PUMA MX 2500 KUORMITUS TYÖKALU							
Sugdata				Palauta			
VALMISTUOTE				MATERIAALI			
NIMIKE ID	NIMI	MÄÄRÄ (kpl)	RIITTO (vk)	MÄÄRÄ (kpl)	AIHIO d. (mm)	SARJA (kpl)	KUORMA (h)
V304	TIIVISTER	28	29	147	Ø86,4	20	11
V307	TIIVISTER	5	17	18	Ø122	20	14
V308	TIIVISTER	16	42	epäselvä	Ø112	20	10
V308	TIIVISTER	30	28	20	Ø122	20	17
V400	RUNKORENGAS	40	18	0	Ø170	20	14
V402	TIIVISTERENGAS	23	0	epäselvä	Ø110	20	12
V401	VASTARENGAS	31	13	15	Ø122	20	12
VB21	RUNKO	18	1	41	Ø117	20	9
VB21	RUNKO	14	16	250	Ø143	20	14
VB21	RUNKO	27	4	#####	Ø107	20	12
V403	VÄLIRENGAS	38	14	0	Ø110	20	14
VB21	RUNKO	7	13	#####	Ø173	20	14
V403	VÄLIRENGAS	16	14	51	Ø122	20	9
VB21	RUNKO	23	5	0	Ø244	20	21
VB21	RUNKO	11	5	0	Ø244	20	9
VB21	RUNKO	17	5	107	Ø81,4	20	9
V403	VASTARENGAS	29	11	epäselvä	Ø110	20	9
V403	VASTARENGAS	28	11	69	Ø122	20	11
VB21	RUNKO	17	16	34	Ø163	20	14
VB21	RUNKO	14	11	0	Ø190	20	15
V402	TIIVISTERENGAS	22	6	41	Ø122	20	14
VB21	RUNKO	29	38	#####	Ø153	20	11
V401	RUNKORENGAS	17	7	0	Ø170	20	9
VB21	RUNKO	37	35	59	Ø91,4	20	9
VB21	RUNKO	26	7	epäselvä	Ø132	20	21

Appendix 6. Manual filter

Microsoft Excel - PUMA MX2500 KUOMITUSTYÖKALU 1.0

Tiedosto Muokkaa Näytä Lisää Muotoile Työkalut Tiedot Ikkuna Ohje Kirjoita kysymys

110% Arial 18 B I U

D16 =JOS(PHAKU(A16;laskut;6;<0;PHAKU(A16;laskut;5;);PHAKU(A16;laskut;6;))

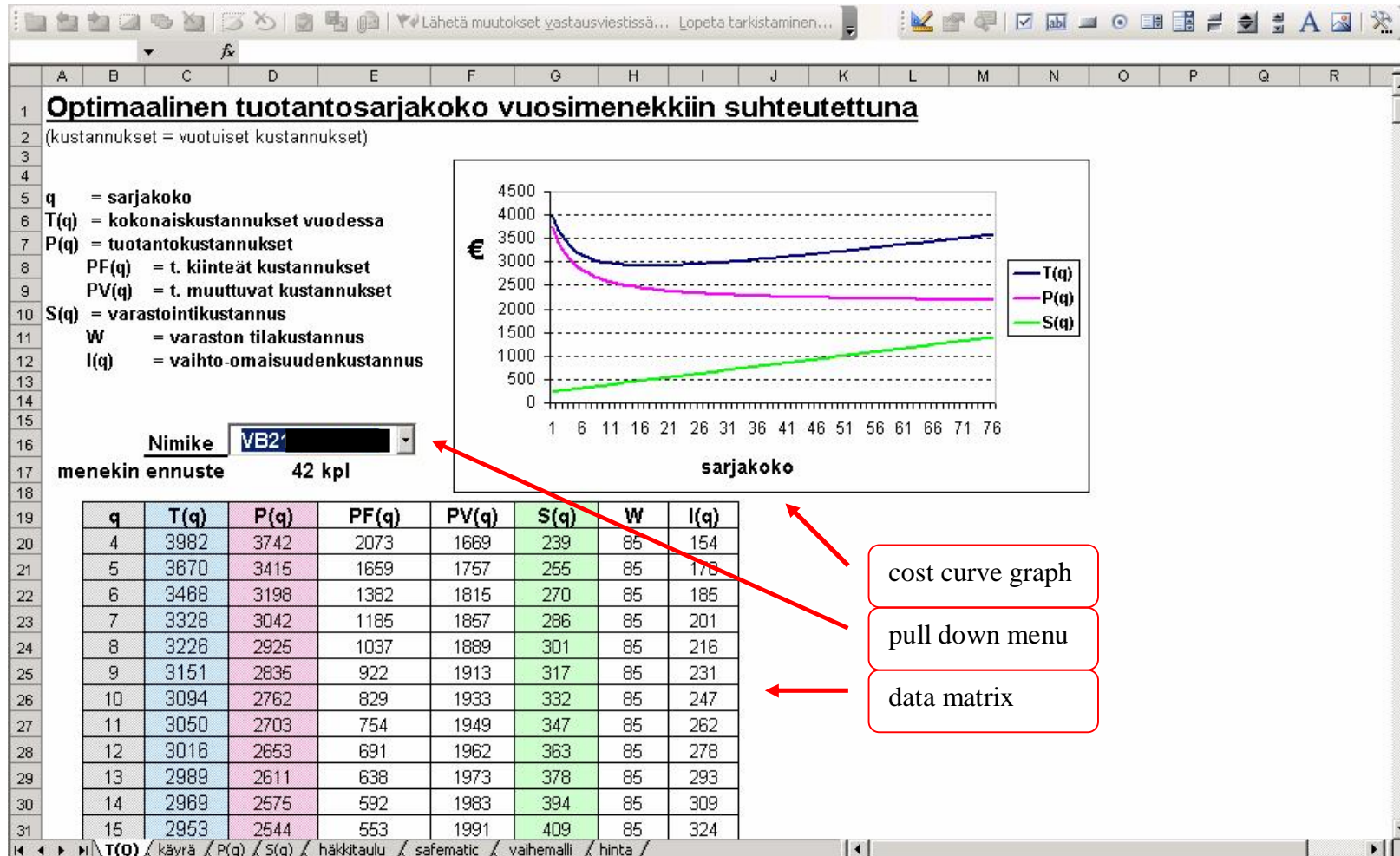
	Suodata		Palauta				
	VALMISTUOTE			MATERIAALI			
6	NIMI	MÄÄRÄ (kpl)	RIITTO (vk)	MÄÄRÄ (kpl)	AIHIO d. (mm)	SARJA (kpl)	K (h)
12	TIIVISTERENGAS	23	0	epäsel	Lajittele nousevasti Lajittele laskevasti	20	
14	RUNKO	18	1	41	(Kaikki) (Valinta...) (Ehdot...)	20	
16	RUNKO	27	4	#####	Ø107	20	
20	RUNKO	23	5	0	Ø110	20	
21	RUNKO	11	5	0	Ø117	20	
22	RUNKO	17	5	107	Ø122	20	
27	TIIVISTERENGAS	22	6	41	Ø132	20	
29	RUNKORENGAS	17	7	0	Ø170	20	

käyttäjän laskut koneajat asiakasennuste vvalmistuote vmateriaali materiaalpaino

Piiriä Automaattiset muodot Valmis

Käynnistä Työkalu LIITTEET Microsoft Excel - PUM... Figure (Master filter) - Mi... 17:30

Appendix 7. Lot size calculation model T(q) sheet



Appendix 8. Lot size calculation model P(q) sheet

Microsoft Excel - sarjakoko 1.0

Tiedosto Muokkaa Näytä Lisää Muotoilu Työkalut Tiedot Ikkuna Ohje Kirjoita kysymys

E13

4

5 Tuotantokustannukset $P(q) = PF(q) + PV(q)$

6 T. kiinteät kustannukset $PF(q) = [F \cdot M\text{€}/h + v \cdot A\text{€}/h] \cdot D/q$

7 T. muuttuvat kustannukset $PV(q) = [M(q-1) \cdot M\text{€}h + (w + p(q/r - 1)) \cdot A\text{€}h] \cdot D/q$

8

9

10

nimike ID	q	P(q)	P(q)/T(q)	PF(q)	%	PV(q)	%
VB2	16	2517	86 %	518	21 %	1999	79 %

11

12

13

14

15

16

konetunti kust.	M€/h	
tukityötunti kust.	A€/h	
työstön koneaika	M	0,8 h
koneistuksen valm. aika	F	3,0 h
tukitöiden valm. aika	v	0,4 h
pesuprosessin aika	w	0,3 h
pesun vaiheaika	p	0,1 h
nimikettä/pesuhäkki	r	1 kpl/häkki
nimikkeen menekki	D	42 kpl/vuosi

koneistuksen asete ajat:	
suunnittelu	0,05 h
leukojen vaihto	0,33 h
ala terät	0,25 h
ohjelmointi	0,05 h
yht.	0,68 h

17

18

19

20

21

22

23

24

25

26

27

28

T(Q) / käyrä / P(q) / S(q) / häkkitaulu / safematic / vaihemalli / hinta

Piirrä Automaattiset muodot

Appendix 9. Lot size calculation model S(q) sheet

Microsoft Excel - sarjakoko 1.0

Tiedosto Muokkaa Näytä Lisää Muotoile Työkalut Tiedot Ikkuna Ohje Kirjoita kysymys

D13

Varastointikustannukset

Varastointikustannukset $S(q) = W + I(q)$

Varaston tilankäyttökustannus $W = W_1 * \text{€/m}^2$

Vaihto-omaisuuden kustannus $I(q) = (b + q)/2 * \text{á} * C$

nimike ID	q	S(q)	S(q)/T(q)	W	%	I(q)	%
VB2140000000	16	425	14 %	85	20 %	339	80 %

nimikkeen tilankäyttö	W_1	1 m ²
tilan neliökustannus	€/m ²	7,1 €/m ² /kk 66,2 €/m ² /vuosi
nimikkeen arvo	á	308,5 €
pääoman korko	C	10 %
asiakkaan hankintaerä	t	3 kpl
varmuusvarasto	b	6 kpl

T(Q) / käyrä / P(q) / S(q) / häkkitaulu / safematic / vaihemalli / hinta /

Piirrä Automaattiset muodot