SAVONIA

THESIS - **BACHELOR'S DEGREE PROGRAMME**
TECHNOLOGY, COMMUNICATION AND TRANSPORT

MANUFACTURING PERFORMANCE METRICS

Junttan Oy

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THESIS
Abstract

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Abstract

The goal of this thesis was to define and implement metrics in ERP system for measuring the performance of client organization’s internal manufacturing unit. It was known beforehand that not all metrics could be necessarily built into the ERP system, and for those metrics it would be enough to have instructions for fetching data into external data analytics software. Building the metrics to the external software would then continue after this project.

The project was started by getting familiar with the relevant theory materials and the company’s overall strategy and goals. The metrics were defined from this basis. The next step after the definition was to research and evaluate the best options for implementing these metrics.

The results of this project include the defined metrics, the partially implemented metrics in the ERP software, and the instructions as well as the data source information for creating metrics in external data analytics software.

Keywords

manufacturing performance, lean, entreprise resource planning software, performance metrics

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Tiivistelmä

Opinnäytetyön tavoitteina oli määritellä ja toteuttaa ERP-järjestelmään mittarit asiakasyrityksen sisäisen valmistusyksikön tuotannon tehokkuuden mittaamiseen. Jo etukäteen oli tiedossa, ettei kaikkia haluttuja mittareita välttämättä pystyisi toteuttamaan ERP-järjestelmän sisällä. Näiden mittarien kohdalla todettiin riittäväksi määritellä ohjeistus datan löytämiseksi järjestelmästä ulkoista data-analytiikkaohjelmistoa varten. Itse mittareiden toteutus ulkoisessa ohjelmistossa tulisi tapahtumaan tämän opinnäytetyöprojektin jälkeen.

Projekti alkoi relevanttiin teoriamateriaaliin ja yrityksen strategiaan perehtymisellä. Tämän pohjalta määriteltiin oleelliset mittarit. Määrittelyn jälkeen oli vuorossa mahdollisten toteutustapojen etsintä ja arviointi.

Opinnäytetyön tulokset sisältävät määritetyt mittarit, ERP-ohjelmiston sisälle rakennetut mittarit sekä ohjeistukset ja informaatiolähteet puuttuvien mittareiden rakentamiseksi ulkoiseen data-analytiikkaohjelmistoon.

Avainsanat
tuotannon tehokkuus, lean, toiminnanohjausjärjestelmät

CONTENTS

1 INTRODUCTION

1.1 Background

The subject of the thesis was given by the customer, Junttan Oy. Junttan Oy is specialised in manufacturing pile driving machines for contruction companies. Company factory and headquarters are located in Kuopio, Finland. Company employees around 200 people and has revenue of approx. 50 million euros.

The focus of this thesis is Junttan Oy’s factorys component manufacturing unit, which is specialized in producing the most complex welded and machined structures for pile driving machines. Component manufacturing unit works as an internal subcontractor for factorys assembly unit and spare part sales. Currently component manufacturing unit does not serve its customers (assembly and spare part sales) as well as it could. Delivery times are more often late than not, and throughput times vary a lot. This makes the production planning difficult in the assembly line. Buffer storages have to be larger, and process optimization is difficult.

1.2 Purpose and goal of the thesis

Thesis is one part of company’s ongoing development of operations management. The goal of this ongoing improvement project is to shorten the lead times, decrease costs and improve customer service.

The main goals for this thesis is to define and create performance metrics for component manufacturing unit which allows managers to measure the performance of current operations, make operations management more transparent, link the component manufacturing unit closer to the whole factory’s production planning, and start developing the operations inside the unit. In addition to past performance measurements, metrics should also show the current situation of production, to make unit’s internal operations management and production planning easier.

1.3 Reasons for performance metrics

The company has already decided to build a performance measurement system, so analyzing the need for it is not necessary. Reasons are known problems, for example long delivery times for upper carriage rigs, varying processing times and lack of process visibility. Lack of visibility and long throughput times are the main problems. It is already known that the data needed for metrics is available in the ERP system, but the problem is to make it informative, visual and more easily attainable.

Company also has a strong drive for developing processes according to lean principles. Lean strongly urges to make the production control visual and easy to understand, with a possibility to get good overall picture of the state of the production with just one look.

1.4 Implementation

One part of companys ongoing operations management development is an ERP system version update project, which was finished just before the beginning of this thesis. ERP system update is strongly linked to the creation of performance metrics, since the new version is supposed to have much better abilities for visualizing existing data.

Thesis will include defining and choosing the correct measures, evaluating the possibility for implementing them, making the implementation and finally testing the metrics and evaluating results. Defining the metrics is done in companion with the company managers with the aid of relevant theory material. In the implementation phase it is evaluated if the chosen metrics can be built inside the ERP system, or if external data processing software is required. The implementation of the metrics is done based on this evaluation.

2 PERFORMANCE MEASUREMENT THEORY

2.1 What is performance

Performance measurement and management are one of the main elements of overall management in any organization. The word performance is used widely and frequently at the field of management. However, more often than not the precise definition for performance is missing. Many times, performance is equated with efficiency and effectiveness. In other sources it may be identified as competitiveness, growth, lean production or cost reduction. In the context of business excellence, performance can be shortly defined as "doing today what will lead to measured value outcome tomorrow" (Neely 2002). In a wider context performance is almost always at least something from the following list:

- measurable by either a number or an expression that allows communication (e.g., performance in management is a multi-person concept);
- to accomplish something with a specific intention (e.g., create value);
- the result of an action (the value created, however measured);
- the ability to accomplish or the potential for creating a result (e.g., customer satisfaction seen as a measure of the potential of the organization forfuture sales);
- the comparison of a result with some benchmark or reference selected – or imposed – either internally or externally;
- a surprising result compared to expectations;
- acting out, in psychology;
- a show, in the "performing arts," that includes both the acting or actions and the result of the actions as well as the observation of the performers by outsiders;
- a judgment by comparison (the difficulty here is to define who the "judge" is, and to know on which criteria the judgment will be formed). (Neely 2002, 67-68)

The performance tree shows visually how different aspects inside and outside company link to customer satisfaction. Every company should define uniquely how the concept apply to their situation. This tree model helps managers to understand how the companys processes link to each other, and where sub-processes lie in the big picture. The tree models also visualizes how performance and value is created in an organization; everything starts in the roots and will eventually lead to customer satisfaction and finally to income and profit. The model also gives a hint of the challenges which lie in creating and managing performance metrics; the whole company's metrics and operations should be linked together, and sub-optimizing only one area may not show any positive effects on the end results. (Neely 2002, 70-71)

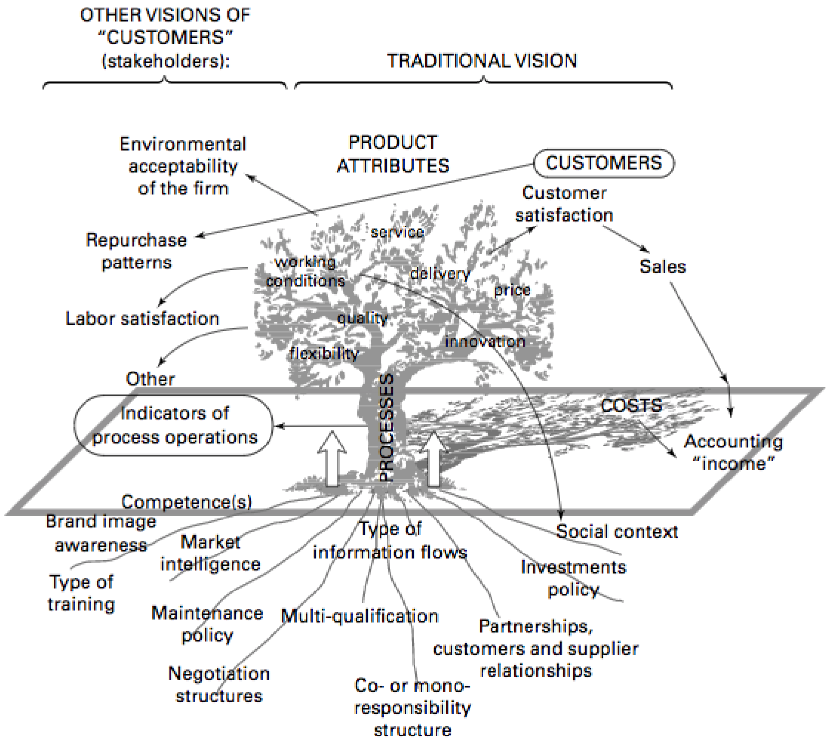

FIGURE 1. The performance tree (Neely 2002, 69)

2.2 Performance measurement

According to Neely (2002, 149-150), the optimal performance measurement system would fit into the following framerwork:

1. The amount of measures need to be limited to only the most essential to avoid cognitive overload.
2. The non-financial measures should work as leading performance indicators, the financial metrtics being the lagging ones.
3. The metrics should be applicable throrough the organization, meaning that the metrics should allow performance to be compared between units.
4. The measurement system has to be stable. Metrics should evolve slowly to maintain the awareness of long-term goals and concistency of people's behavior.
5. Employees should be rewarded when performance on these metrics is good. The performance on both non-financial and financial metrics needs to be the leading indicators of financial results.

2.3 Balanced Scorecard

It has been noted ages ago that relying solely on financical metrics in companys management does not produce optimal results. Some companies have tried to make financical metrics more relevant, others say that financical results will follow after operational measures have been improved. Best option is usually to use combination of both. Widely used framework for this is Balanced Scorecard by Norton & Kaplan. The balanced scorecard links financical metrics to operational measures on internal processes, customer satisfaction and innovation and improvement activities. (Kaplan & Norton 1992.)

The key concept in balanced scorecard is to limit the amount of metrics to include only the most essential ones. This is done to minimize the information overload and force the managers to focus on what is important. (Kaplan & Norton 1992.)

Balanced scorecard builds its foundation on customer value. The concrete idea of balanced scorecard is to translate companies general mission on customer service into specific measures. Customers' needs can be divided roughly into four categories: time, quality, performance and cost. To make balanced scorecard work, companies should set goals for these customer needs and then create metrics to support them. (Kaplan & Norton 1992.)

To create value for it's customers, companies must have their internal processes working smoothly. After all, the level of customer service is just the result of company's internal processes. To satisfy customer needs, managers must focus on critical internal operations. (Kaplan & Norton 1992.)

However, even with well-thought balanced scorecard there is a great risk of failing. As mentioned previously, the purpose of balanced scorecard is to translate company's strategy into specific metrics. This does not remove the risk of failing to turn improved operational performance into improved financial performance. One example of this kind of situation is when company does not continue the operational improvements with another round of actions. Cycle-time reductions may increase operational performance, but at the same time it frees up production capacity. This capacity should either be put into use or removed. (Kaplan & Norton 1992.)

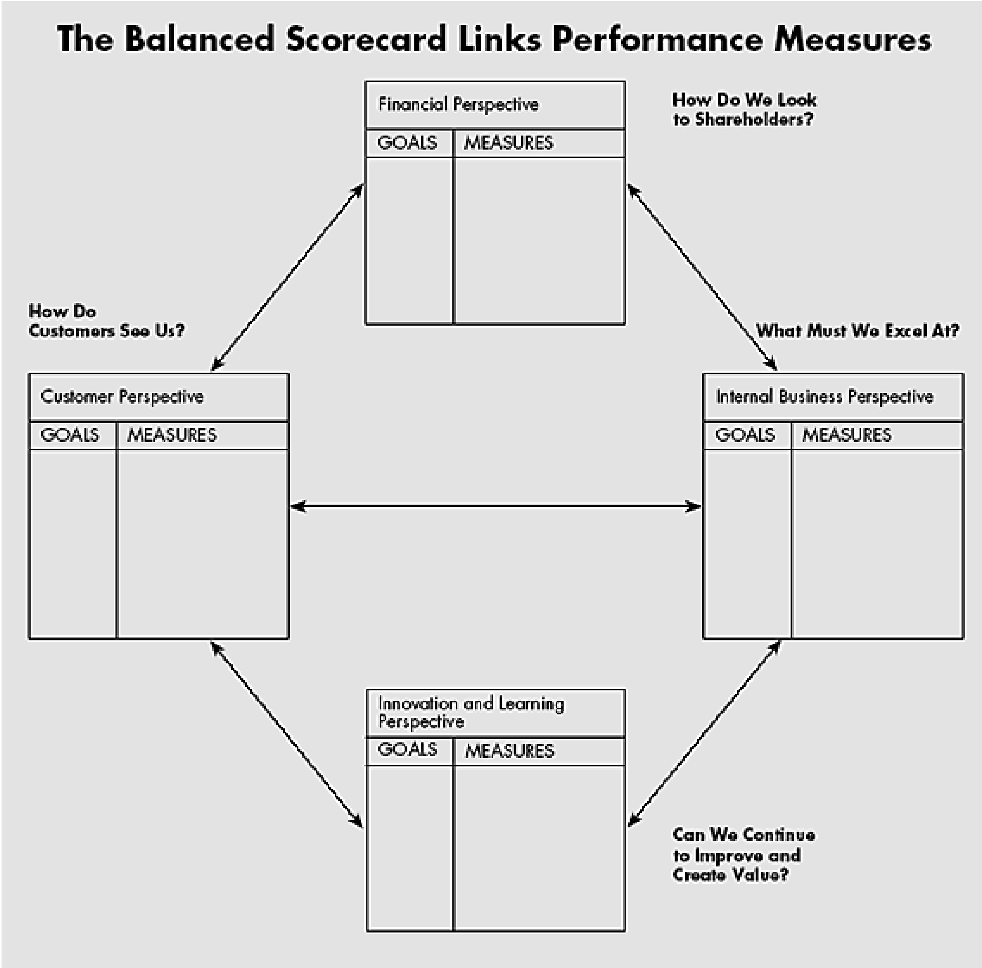

FIGURE 2. The Balanced Scorecard links performance measures. (Kaplan & Norton 1992.)

2.4 Reasons for measuring operational performance

The most ultimate goal of every business operating on free markets is to produce profit for its owners. This is the foundation for operational performance mearurements as well. For an organization to be profitable, it should avoid producing waste in any means. Waste may indicate lack of process quality, lost sales due long delivery times or any other means which make the company less profitable. In this sense, the level of operations management is able to make or break virtually any business. Functions of the operations in a company defines the ability to compete by providing the possibility to respond to customer needs and capability for future competitiveness. (Slack, Brandon-Jones & Johnston 2013, 38.)

Performance metrics are important for translating organization's strategy to more tangible format. Strategy and metrics are closely linked together; metrics withour strategy does not benefit anyone, and strategy without metrics is useless. Many times company's strategy is too abstract concept to grasp, and metrics are the way to communicate organization's purposes for everyone to understand. (Melnyk, Stewart & Swink 2004, 209-218.)

If a company doesn’t have good performance metrics, the risk of employees being busy without producing much measurable results increases. Effective performance metrics will turn top management’s talk to a clearly understandable direction which will improve results at the process level. (Donovan 2018.)

2.5 Continous development and performance metrics

To stay competitive in todays fast-paced and ever-changing markets, companies must develop the level of operations continuously. Measuring process performance is vital, since without relevant measures it is virtually impossible know the impact of process development projects. Not having measures usually also indicates lack of effort for development at all. Making processes transparent brings problems to the surface easily and in no time and reacting to them can be done fast. Often problems which have happened in the processes weeks or months ago are impossible to solve afterwards. (Bond 1999, 1318-1334.)

Optimal metrics work as an information source and show areas in production which need development. Metrics help operative managers to notice problems fast and with no effort. They help decision making by bringing factual data to decision making process instead of mere subjective opinions. (Arveson 1998.)

2.6 Economical effects and operational goals

The effects of operational performance to organizations economics can be divided in to five categories. These five categories are costs of producing services or products, increased customer satisfaction caused by better quality and service, decreased operational risks, decreased capital invested and making future innovations possible. (Slack, Brandon-Jones & Johnston 2013, 40-41.)

From the basis of these financical effects, the goals of operative performance can be also summarized to five categories. For an organization to stay profitable, competitive and achieve customer satisfaction it must:

- Do things with high quality and right at first time
- Respone fast to customer needs, ie. make order to delivery time shorter
- Stay in schedule, ie. keep promised delivery times
- Be flexible = adjust to changing environment and customer needs enough and with suitable speed
- Do things efficiently = produce products and services efficiently enough they can be priced to suite market and company being simultaneously profitable (Slack, Brandon-Jones & Johnston 2013, 43-44.)

In short, a company with world class operational performance produces high quality products, with short order-to-delivery times, in promised time, with flexibility and cost-effectively. (Slack, Brandon-Jones & Johnston 2013, 46.)

However, even with these definitions there may still be confusion about what these terms really mean in practice. For example, flexibility can be used either in the context of varying production volumes, or company's ability to introduce new products rapidly. The following framework can be used as a basis when defining company's operational goals in a more specific level. (Neely, Gregory & Platts 1995, 83.)

Quality	Time	Flexibility
Q1: Performance	T1: Manufacturing lead time	F1: Material quality
Q2: Features	T2: Rate of production introduction	F2: Output quality
Q3: Realiability	T3: Deliver lead time	F3: New product
Q4: Conformance	T4: Due-date performance	F4: Modify product
Q5: Technical durability	T5: Frequency of delivery	F5: Deliverability
Q6: Serviceability		F6: Volume
Q7: Aesthetics	Cost	F7: Mix
Q8: Perceived quality	C1: Manufacturing cost	F8: Resource mix
Q9: Humanity	C2: Value added	
Q0: Value	C3: Selling price	
	C4: Running cost	
	C5: Service cost	

TABLE 1. Operational goal framework (Neely, Gregory & Platts 1995, 83.)

2.7 Lean

Lean manufacturing, or in short just lean, is a systematic way for a company to eliminate waste (=non-value adding activities) while maintaining productivity. Lean philosophy has its root in Japan, more specifically at Toyota factory. Lean in itself is not a goal, instead it is all about continuous improvement. (Earley 2018.)

The foundation for lean thinking is customer value. All activities performed in a company should in some way provide value to the end customer. This is not limited to current situation alone; customer needs change rapidly and companies must be able to respond to these needs as fast as possible. Value is delivered to customers through value stream. The goal is to make value stream consist only value-adding activities. In reality this is not possible, and processes always include waste in some form. (Sayer & Williams 2007, 28-30.)

One of the key concepts of lean is flow. This is directly linked to value stream thinking; to have perfect value stream with no wastes included (and therefore no waiting times either), you must have continunous flow. The idea is that after the first step in value stream the products never stop until they reach the end customer. (Sayer & Williams 2007, 30.)

Almost all of the concepts behind lean are based on Toyota Production System, TPS. TPS evolved at Toyota factory, Japan, in the years after the second world war. The main goals of TPS is to remove waste (muda) from the processes, while designing out overburden (muri) and inconsistency and unevenness (mura). The processes should be developed so that they are able to deliver required outputs as flexibly, smoothly and free of stress as possible, while using the least amount of resources possible. Many companies have tried to emulate Toyota's success and tried to do this by utilizing only one or few aspects of TPS. This has lead companies to create additional problems for their production. (Eaton 2013, 24-26.)

FIGURE 3. The Toyota Production System framework (Eaton 2013, 26)

In the figure above, it can be seen that overall objective of the TPS is to enable Toyota to provide the best value to their customers in the five areas: quality, cost, delivery speed, safety and morale. To make this possible, two pillars are supporting this concept: Just in time and Jidoka. Just in time is the concept of producing only what is needed and when it is needed. Jidoka in the other hand means that quality should be built into the process. Below the pillars there are several other important TPS concepts. (Eaton 2013, 26-27.)

2.7.1 Muda, mura, muri

TPS's developers identified three types of activity which were linked to poor performance, and named these muda, mura and muri. Muda is an activity which does not add value to customers. Muda is usually referred as "waste". Mura means unevenness and variations in processes due to imbalance, and muri is about unreasonable stress on people, material or equipment. Another term for muri is "overburden". (Eaton 2013, 34-35.)

In the context of lean the biggest focus is on muda, more specifically divided in to seven categories known as the seven wastes. Some lean practitioners also add eighth waste to the list, waste of human potential. Muda describes all tasks which doesn't add value to the customer. Muda tasks increase throughput times, costs and the risks for errors. In addition to the seven wastes grouping, muda can be also divided to two different categories: necessary waste which include tasks which do not directly add value to customer but are essential anyhow. Second category includes all "direct" wastes, which do not add value to customer and are not necessary even indirectly. (Eaton 2013, 35-37.)

The seven wastes (Eaton 2013, 37) are:

1. Waiting
2. Overproduction
3. Rework
4. Motion
5. Transport
6. Overprocessing
7. Inventory

2.7.2 Lean ideal production

In an ideal lean production, production needs are fulfilled immeditially, with perfect quality and without waste work. This means producing products in an ideal synchronization with the needs, while still maintaining cost-effectivity. (Slack, Brandon-Jones & Johnston 2013, 464.)

2.7.3 Traditional approach versus lean

In traditional production approach there are buffer storages between processes to eliminate downtime. However, this increases capital invested in buffer storages, and at the same time increases throughput times. Buffer storages also insulates process stages from one another and makes noticing process problems slower. Eliminating buffer storages exposes process faults faster and releases invested capital for more effective use. Traditional approach seeks process efficiency by protecting process stages from downtime and disruption, but lean promotes opposite approach by combining the efforts to make whole plants operations run smoothly. The difference between traditional approach and lean view is visualized in the picture below. (Slack, Brandon-Jones & Johnston 2013, 467.)

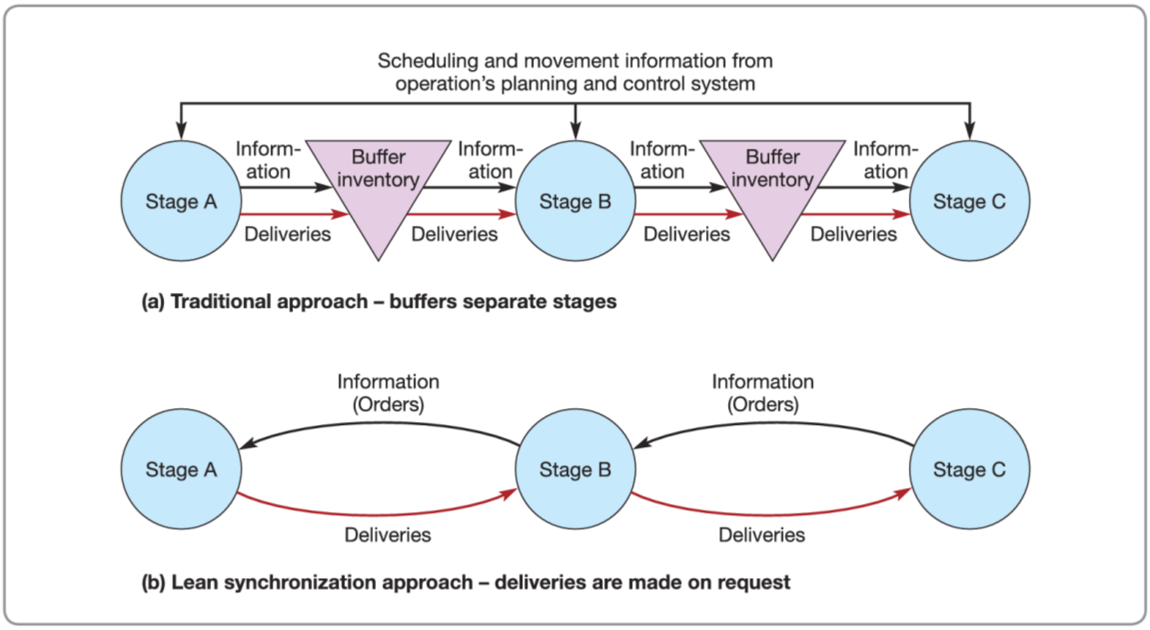

FIGURE 4. Traditional approach versus lean synchronization. (Slack, Brandon-Jones & Johnston 2013, 466.)

2.7.4 Capacity utilization

There are many benefits on lean production system, but it would be foolish to assume there would be no downsides at all. The downside which comes from lean synchronization is the big probability of decreased capacity utilization. Traditional approach includes buffer storages between process stages, which allow different stages to continue processing even if there are problems at one stage. In short, lean will definitely lead to lower capacity utilization – but possibly only in short term. Traditional approach drives for optimal utilization of capacity – but it should also be evaluated if the output is needed. There is no point of production for means of capacity utilization alone. The problem of capacity utilization and lean balance is illustrated in the picture below. (Slack, Brandon-Jones & Johnston 2013, 468.)

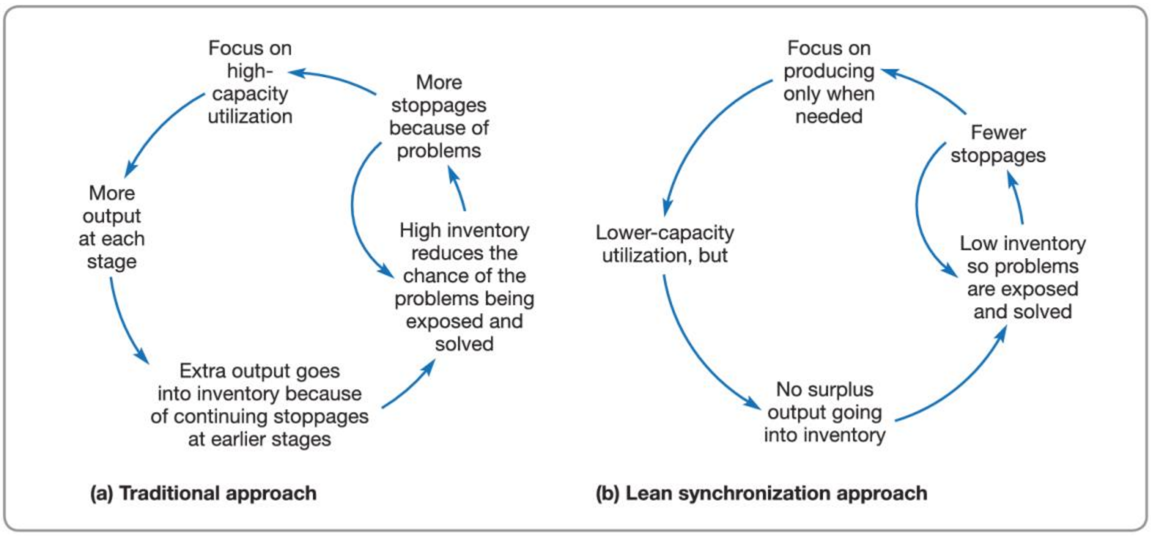

FIGURE 5. Capacity utilization – traditional approach versus lean synchronization. (Slack, Brandon-Jones & Johnston 2013, 469.)

2.7.5 Lean in job shop environment

Lean has originally been developed to increase efficiency in a mass production environment. If consepts from mass production are applied straight to a job shop style production, problems may arise. The essential difference of lean between mass production and job shop production is that in mass production the lean strategy is product based, but in job shop the focus is on speed. In other words, the essential thing to look at mass production is to avoid producing excess inventories and things you can't sell. In a job shop the situation is different: products are made for customer orders, so there is no possibility for excess inventory of non-sold products. The lean focus in a job shop environment is to cut lead time. (Bozzone 2002, 6-11.)

Job Shops	Mass Production
• Make to order/custom	• Build to stock
• No finished goods inventories	• Finished goods inventories/SKUs
• Different products	• Standard products
• Sell to other companies	• Sell to distributors or end users
• Customer order-driven	• MRP demand forecast-driven
• Bid on RFQs to get work	• No RFQs
• Estimating is critical	• Standard costing
• Customer pricing (quotes)	• Market pricing
• Lead time required	• Fill orders from finished goods inventory
• Many schedule changes	• Fewer schedule changes
• Setups/changeovers frequent	• Setups/changeovers less frequent
• Direct contact with customer	• Indirect contact with remote customer
• Smaller companies	• Larger companies
• Owner managed	• "Professionally" managed
• Variable overhead allocation	• Labor-based overhead allocation
• Variable volume	• More stable volume
• Order backlog is good	• Order backlog is bad (stock outs)
• More dynamic	• More static
• More skilled labor (variable tasks)	• Less skilled labor (repetitive tasks)
• Dynamic scheduling	• Level scheduling
• Shorter runs	• Longer runs
• Improve by reducing lead time	• Improve by reducing inventories

FIGURE 6. Differences between job shops and mass production manufacturing (Bozzone 2002, 7.)

2.7.6 Lean visual control

One of the key tools in lean manufacturing philosophy is visual control. The idea behind visualization is to bring the current and planned state of the processes for everyone to see, fast and easily. Purpose of visualization is also to show how process performance is measured, help understanding the job priorization, give instant feedback of process performance and show if something is not going as planned. (Slack, Brandon-Jones ja Johnston 2013, 475.)

Transparency eliminates the need to waste time, energy or effort to figure out problems in the processes, and therefore reduce overall waste. Visual management also enables the possibility to make conclusions from the trends in data. It is much easier to see if some measured aspects are rapidly changing if the data is visualized. (Sayer & Williams 2007, 39.)

2.8 ISO 9001:2015

Metrics are an important aspect of quality management certificate ISO 9001:2015, which is in use at Junttan Oy. The standard demands clear system for monitoring and measuring processes, and this is another reason for developing metrics in the case company. Quote from ISO 9001:2015:

"The organization shall determine:

a) what needs to be monitored and measured;
b) the methods for monitoring, measurement, analysis and evaluation needed to ensure valid results;
c) when the monitoring and measuring shall be performed;
d) when the results from monitoring and measurement shall be analysed and evaluated.

The organization shall evaluate the performance and the effectiveness of the quality management system.

The organization shall retain appropriate documented information as evidence of the results."

2.9 ERP systems

Within past decades, ERP and other software systems have been applied to virtually every organization to process business operations. These systems include loads of data about the business operations, but this data is often times unorganized. (Bose 2006, 43-44.)

The increasing amount of data makes the process of transforming data into information more and more vital. Large amounts of data increase the risk of measuring wrong things and part-optimizing process steps. Companys should empower its employees to find data from the ERP system and turn it into useful information for decision making, but also install limits to prevent information overload and overanalysis. (Bose 2006, 43-44; O'Leary 2000, 61.)

Usually ERP systems have capabilities for making data to more understandable format. Many times the systems include standard reports, which are applicable for many general-purpose needs. For more customized reports, database queries can be used. Database queries can be made on two levels: either inside the ERP system using systems own query capabilities, or within the database. (O'Leary 2000, 61-62.)

2.10 The challenges of performance measurement

It has been noted that implementing performance metrics successfully depends largely on human behavior. Differing cognitive capabilities between managers cause them to use measurement systems differently. Performance measurement systems based on critical success factors and key performance indicators are implemented in a growing number of organizations, but the user's characteristics effect on the use of metrics has not been investigated extensively. (de Waal 2003, 688-689.)

2.10.1 Part-optimization

Inappropriate metrics may suggest managers to improve areas which in reality are not important or may even cause decrease of overall performance. For example, focusing too much on a purchase price of a certain item may cause serious problem in production if the supply and delivery times can not be trusted. Often the overall financial effects of these indirect results of part-optimization are very difficult or impossible to measure using traditional methods. (Donovan 2018.)

2.10.2 Short-term versus long-term financial results

When using ROI-based measures, it becomes easy to cut costs on intangible assets when financial situation makes profit targets difficult to achieve. Positive results are achieved in short-term by cutting expenses on research & development, quality improvement, customer relations etc. These attributes are certainly essential for company's long-term performance. Cutting costs on these areas will, of course, show short-term profitability increases but may cause the company to lose its competitive position for a long time. The challenge lies in the difficulty of measuring intangible assets. (Kaplan 1984.)

3 CURRENT SITUATION

3.1 Description of the production

Part manufacturing unit produces the most complex and critical products for pile driving machines. The production has practically no automation, and it relies heavily on the workers manual fabrication skills. Most of the welding machinery consists of manual mig/mag machines, and no welding robots are used. Submerged arc welding machine is used for welding heavy, circular parts. For machining there are several manual drills, mills and lathes. In addition to manual machines, two cnc-controlled milling machines are used. Manual machine selection consists mainly rather old-fashioned machines.

3.1.1 Products

Almost all production consists of upper carriage rigs, hammer- and extension frames, drive caps, slides and ram blocks. Upper carriage frame is the most complex and slowest product to manufacture, and it can require up to one thousand hours of welding.

Large portion of the manufacturing of small and simple welded or machined parts is outsourced. The reasons for this are limited capacity, limited room, lack of suitable machines and in some parts cost-effectivity. The reasons for not outsourcing everything is the complexity of many products, the special talent needed for manufacturing them, lack of proper drawings and manufacturing instructions and last but definitely not least, flexibility. Often production schedules change with very short notices and products may need modifications even after they are ready. Doing these changes to products and production schedules with short notices would be very expensive, if not impossible, when done in outsourced facilities.

3.1.2 Shop orders

With very few exceptions, every part manufactured in the part manufacturing unit is made according to a shop order. Shop orders are opened, scheduled and released to production by production planner. Most of the shop orders contain only one part, and currently there are around 200-300 shop orders in “released” or “started” state at a time, meaning they are either waiting for the production to start or already on production. As it can be easily imagined, the shop floor management for this type of production is everything else but an easy task and requires extensive monitoring.

The shop orders are opened, scheduled, released and closed in the ERP system. The shop order tells quantity, what product id is being manufactured, what materials it consists of, what kind of routing it follows, and dates when it is supposed to be manufactured. When production planner schedules a shop order into production, a paper version of the order is also printed. These papers are handed to employees when shop orders are launched to production by production supervisor, and they include unique step-ids for every process step. These process step ids are used for employee time logging; by inputting the number into the time logging system the ERP system logs these work hours under the correct shop order. This enables the possibility to evaluate actual processing times versus routing times from the ERP system.

3.1.3 Routings

Every part manufactured in part manufacturing unit has a routing. Routings are originally crafted by investigating process structure and actual processing times, and they have been updated since to match the average of actual work times from previous shop orders. Routings are used to estimate throughput time, product finishing time, costs and workload. Realistic and up to date routings build the foundation for successful production planning.

3.2 Production planning and control

Production planning is done roughly in the scope of 2-12 weeks. Because of volatile demands, the nature of production (one-offs) and rapidly changing state of production, the rough production plan can almost never be followed strictly. This requires production supervisor to make the final decision for the production sequence. Often shop orders are released without the product having a customer, but many times this changes during the processing and requires priorization. This has to be done by the production supervisor.

The production planning is done in the ERP system using work-center specific and overall capacity graphs. The ERP system includes work center information, where the capacity is being input. Capacity is calculated by using the following formula:

(100% – avg. sick leave – avg. work time equalization holidays) * Employees working in a work center)

Production planner can evaluate the work center specific capacity graphs as well as the overall capacity. In many cases, employees can switch between work centers so final work center specific graphs do not always tell the strict truth. However, overall capacity should not be exceeded.

FIGURE 6. Capacity-workload graphs used in production planning

3.3 ERP system

Junttan uses ERP software produced by IFS Applications. Until February 2018 in use was an outdated version without practically any means for data visualization inside the program. The new version – IFS 9 – is known to include features for better production monitoring and performance measuring.

The ERP system is used for controlling the production in the part manufacturing site: the principle is that every change which happens on the shop floor should be also visible in the ERP system. The system is linked to time-clocking devices, which are used by employees to clock in to work and also to the shop order and production stage they are currently working on.

3.4 Current state of measuring

Currently the only visualization used in part manufacturing unit is capacity versus workload graphs, which are used in production planning. They are excellent for their intended use, but do not help in daily management of the production or evaluation of previous performance. It is already known that process times are logged in to the ERP system stage by stage, and this information could be used for evaluating past performance. The problem is that this information has to be dug from the system manually, one product id and one shop order at a time. This requires resources and causes the information to be wasted.

From the facts we know about work time logging, we can assume that measuring actual throughput time and actual delay of the production should be technically possible.

Junttan Oy is already using Qlik for business intelligence applications, for example comparing estimated sales to actual sales, forecasted budget versus actual etc. Qlik is not (currently) used for operational performance measurement purposes.

4 CHOOSING THE METRICS

The first thing to do was naturally choosing the metrics. Junttan Oy's overall operational goals include increasing gross profits, shortening lead time, keeping delivery reliability high (goal is 100%) and decreasing warranty costs.

For the company to achieve these goals in the whole company's level, the internal processes and synchronization with subcontractors must work accordingly. This naturally means that the part manufacturing unit's level of operation must match with organization's overall goals. With the combination of relevant theory material, company's overall goals and discussions with managers these following metrics were chosen to be the most important ones for measuring part manufacturing unit's operational performance:

- Delivery reliability

  Delivery reliability measures how many shop orders are finished on time. As mentioned before, one of the most important goals at Junttan is to get overall delivery reliability to 100%. This naturally requires that subcontractors and internal operations work accordingly. Process time variations – and therefore delivery reliability too – is one of the key components for making lean production work. Delivery reliability metric also works as a helpful resource for developing production planning; if the reliability is continuously low, production planning should be adjusted.

- Actual throughput time

  The actual throughput time measures how many working days a product's actual throughput time is in the production. Theoretical throughput times can be calculated from the routing times, but these do not show the waiting times caused by variations in the production. In addition to overall delivery reliability, lowering actual throughput times is another key goal for Junttan. The market demands faster and faster deliveries, which means that usually the manufacturing of a machine has to be done without confirmed customer. Customers change often during the production, which also changes the machines specifications and delivery times. If overall throughput time could be lowered, it would also decrease the changes and variations in production. Throughput time is also a key concept of lean production. The faster the throughput times are, the less capital is tied to the work-in-progress inventory.

- Throughput time variance

As the name of the metric tells, this is for showing the variance of the throughput times. Knowing the average of the throughput time does not tell much if there are a lot of variations in the process. Variations are a sign of non-standardized production, but they are also a sign of a huge opportunity for improving the production. Reducing variations in production is a key component for increasing operational performance and crucial for lean production and reduction of buffer storages.

- Actual processing time

Actual processing times shows how much time certain process steps take. The routing times include estimated processing times, and this metric is used for comparing routing times to actual processing times in work hours. This is closely linked to actual throughput time metric but goes into more detail by focusing on the work hours and excluding the waiting times and by showing the work hours per process step. This way it is possible to evaluate if there are restrictions and variations in certain process steps only, instead of merely looking at the throughput times or delivery reliabilities.

The chosen metrics above are mainly for evaluating past performance. It was also decided that the current situation of the production has to be seen from the ERP program easier, and the following aspects were chosen to aid in this problem:

- Current delay

Current delay metric shows the delay of the production in work hours and in real time. This metric is used for estimating future delivery delays and adjusting production planning accordingly.

5 EVALUATING THE ERP SYSTEMS POSSIBILITIES

5.1 Ad-hoc reports

Ad-hoc reports are simple reports which users can build inside the ERP system. The reports can be built either by using SQL-queries or by using built-in query builder. Ad-hoc reports can be used for building simple, often used reports which include only small amounts of data and where the data do not need processing. Ad-hoc reports are not capable of making calculations nor visualizations of the fetched data.

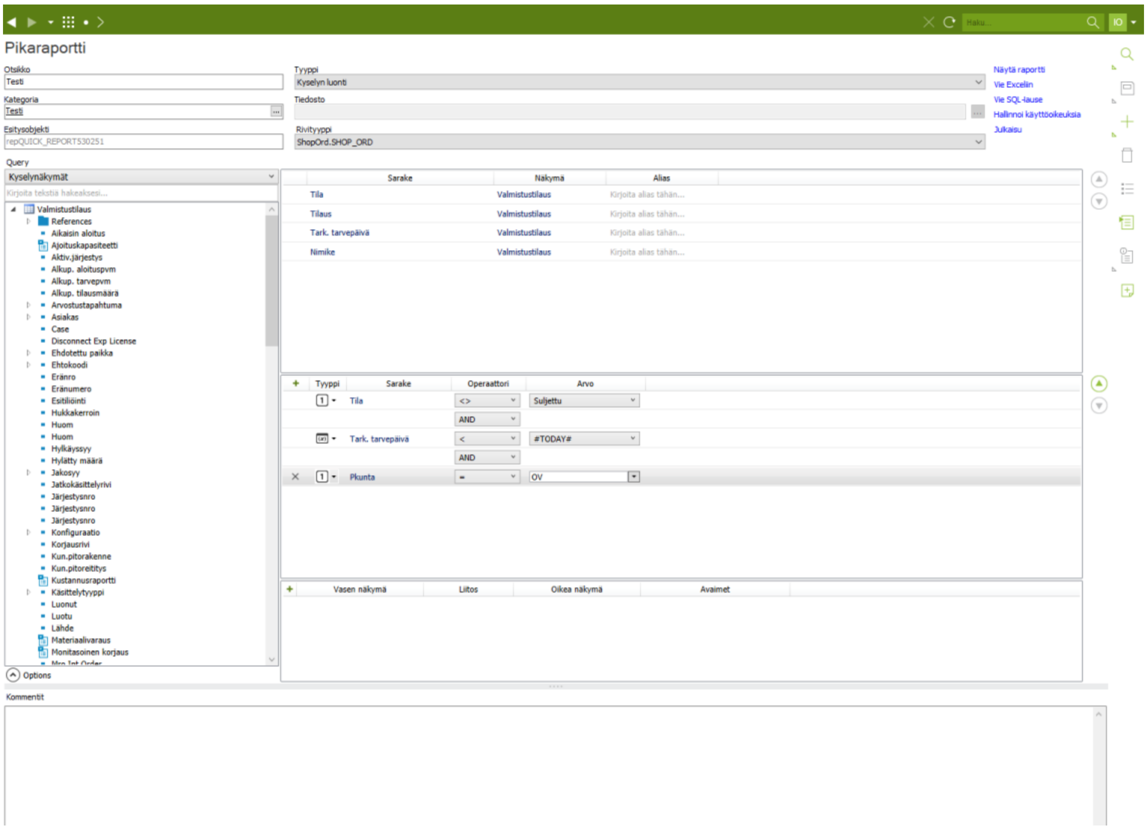

FIGURE 7. IFS 9 built-in query builder tool.

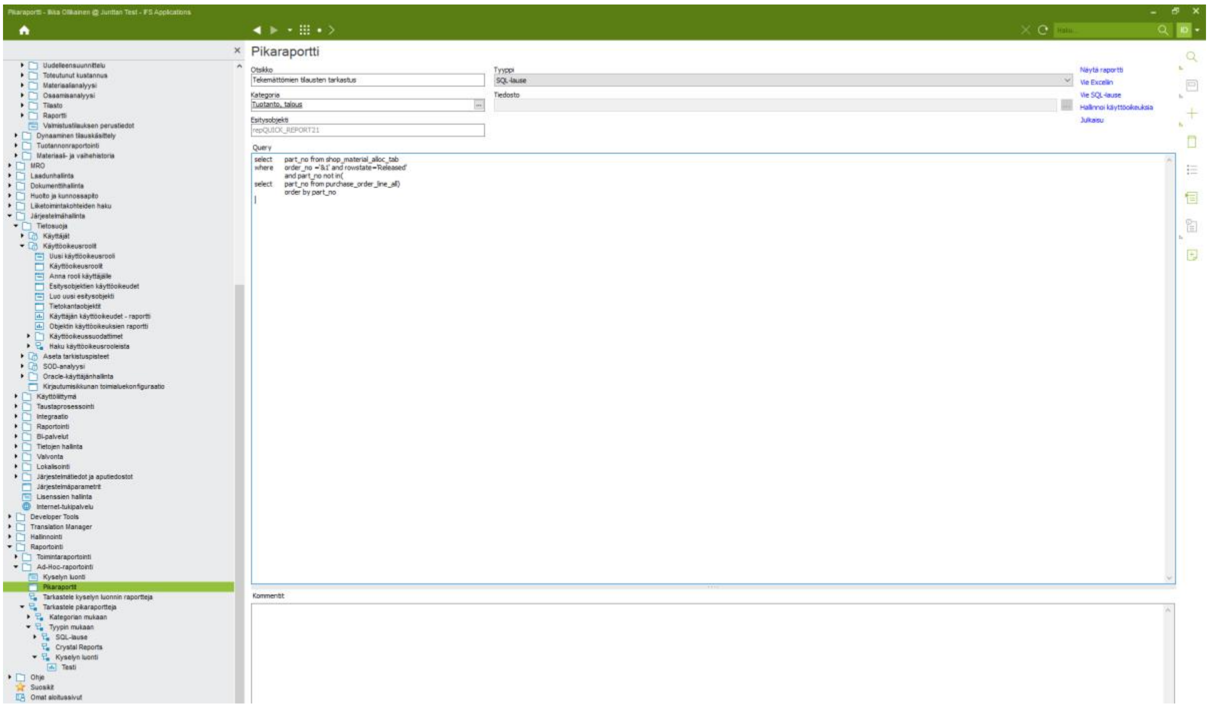

FIGURE 8. SQL based ad-hoc report.

5.2 Lobby views

IFS Lobby concept is designed for providing users information in the ERP system with simple at-a-glance view. In its intended use the software includes different individual-, role- and process-based Lobby views. Lobby makes things simple, focused and comprehendible for the end user. Lobby views are IFS Applications response to the problem of too much information scattered around the program. With Lobby views even inexperienced user can see easily what is currently going on the process and what actions should possibly be taken.

Lobby concept is completely built into IFS Applications, and there is no need for external tools for designing and configuring Lobby pages. As a default, IFS 9 has several different lobby pages available with some visualizations and links built into them. However, for modifying these views and visualizations freely, a Lobby editor package has to be bought and (currently) Junttan Oy does not have it.

Lobby views are a powerful tool for monitoring production and evaluating short-term past performance. However, it is not designed nor suitable for more complex reporting needs.

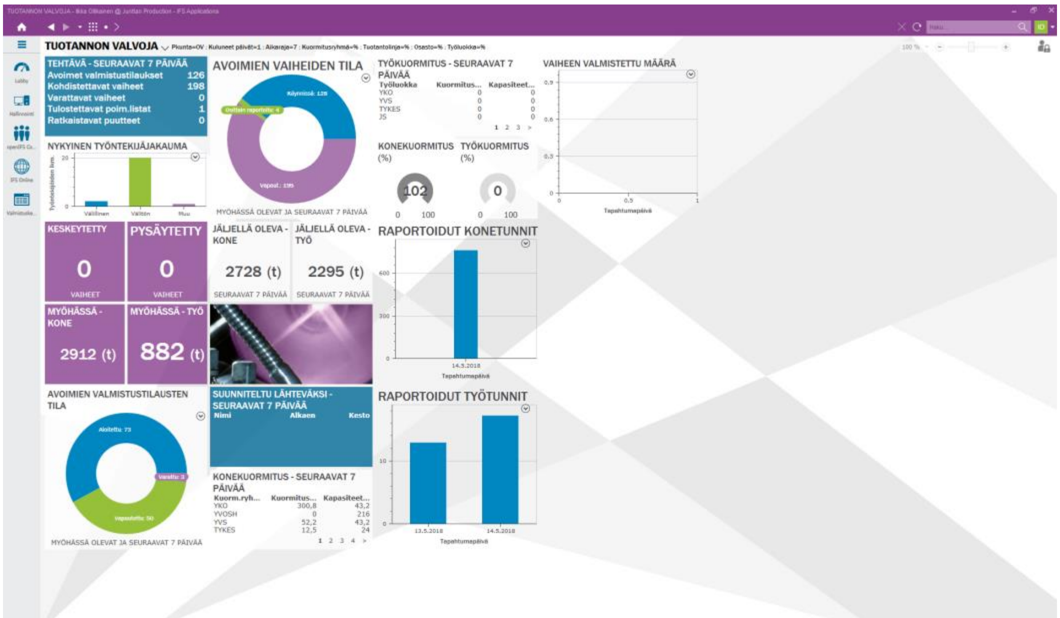

FIGURE 9. Default production supervisor lobby view.

5.3 Qlik

Qlik Sense is a data visualization software. The program is very flexible; it allows users to add data from multiple different sources and build them into same visualization. Qlik Sense includes powerful and user-friendly visualization tools, and it is intended for companies' internal use – meaning that it has been built so user-friendly, that companies should be able to install and use it without external resources. Qlik Sense can be programmed to read data from ERP systems database in regular intervals, for example every night or weekly. This way the reports will update automatically after they have initially been built.

At Junttan Qlik Sense is already in use for high-level business intelligence purposes. It reads information both from IFS ERP system and Excel sheets, and combines these into visualizations. Junttan's Qlik reports have been built by subcontractor, so knowledge for building new reports with the software is not found from company's own resources.

6 IMPLEMENTATION

6.1 Grouping products

When investigating the possibilities for building metrics, it was noted early on that products need to be divided somehow into specific categories. Products manufactured in part manufacturing unit have unique product id number, but it does not follow any rule – meaning that there is no way to recognize product type (slide, hammer block etc.) from the product id number alone. Product names can also be found from the system, but they follow the unorganized naming system (or lack of) previously mentioned in the case of product ids.

For this purpose, the ERP systems capabilities for making the product grouping was investigated. Without too much effort it was noted that a good option for the grouping would be to use "product family" and "product" -fields. This enables the possibility to group products with similar attributes under the same name, and therefore makes it possible to search information for the metrics without knowing the specific product ids.

Below is a preliminary proposal for product grouping. Part of the products change their product id number if large modifications are done (if revisions are not enough), meaning that many product ids may be under the same product name. This is usually the case in upper carriage rigs only. Most of the product names would have only one product id under them, meaning that the field would practically be used for "renaming" the product id for easier searching.

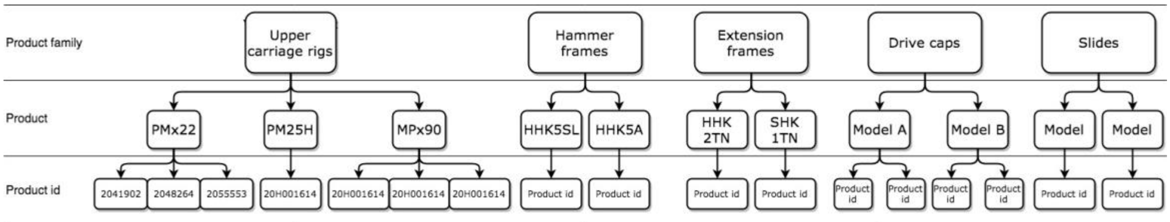

FIGURE 10. Proposal for product grouping.

6.2 Delivery reliability

Delivery reliability calculations have been previously made few times in Excel. The reports have been made by calculating the difference between planned and actual finish date on a shop order with tolerance of +-3 days. Shop orders with actual finish date under 3 working days away from the planned finish date were considered as finished on time, and rest were counted as missed. Delivery reliability percentage was then calculated from comparing "finished on time" shop orders to the total number of finished orders.

This Excel formula was used as a basis for creating delivery reliability metrics. The company's order was that Excel will not be used as a reporting tool for new reports in the future due its tendency to require a lot of manual work which also increases the risk of human error when building the reports.

Due to the need for making calculations of the data, it was known from the start that ad-hoc reports could not be used for this metric. Lobby-views were investigated, but the lack of lobby-editor and its limited capacity for making reports from past performance steered the way for using Qlik Sense instead.

While validating the reliability of data in IFS, it was noted that shop order's "finish date" information was not always correct. If any modifications are done to the shop order after closing it, IFS changes the closing date to be the date when the order was modified. These modifications are done so often that the possibility for calculating delivery reliability from these dates was discarded. This also meant that previous delivery reliability calculations done in Excel were incorrect.

Luckily there was another, more trustworthy option for calulcating delivery reliability. In this case, the comparison of planned and actual finish date would be done from shop order's last process step. By making the calculation this way, the data would be more reliable because the process steps are closed only once, and other modifications done to the shop order would not change this. The downside of this option is that the dates have to be fetched from a larger pool of data, and more accurate specifications for data visualization are needed.

The information for the metric is found from the window below.

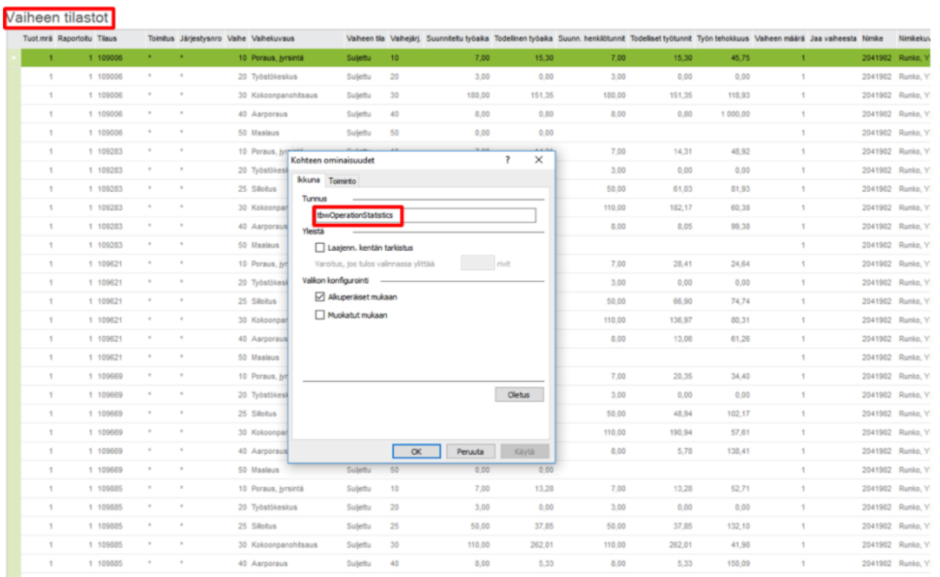

FIGURE 10. The information source in IFS for calculating delivery reliability

The delivery reliability is calculated by subtracting the last step's planned finish date from the actual finish date. The delivery reliability percentage can be then calculated by comparing the amount of successful deliveries to the total number of finished shop orders.

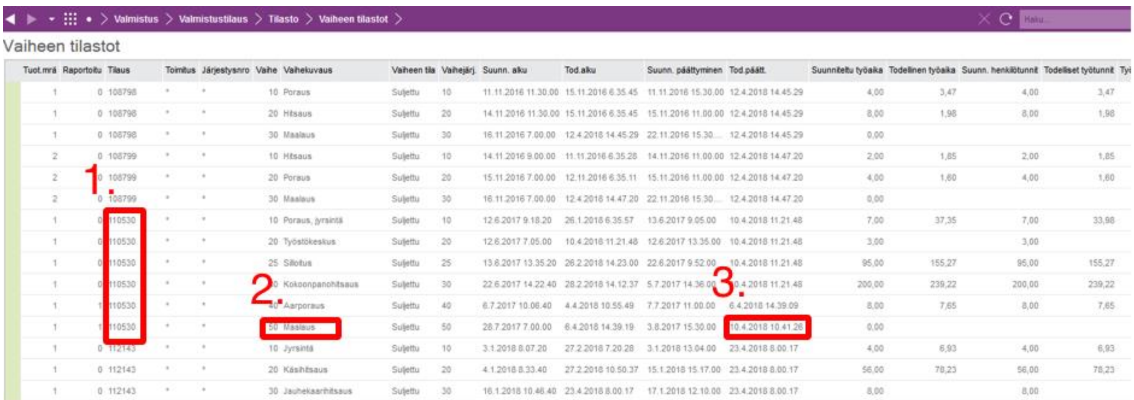

FIGURE 11. The data needed for delivery reliability

In the image above, 1. shows the shop order number – this view shows all process steps included in one shop order, but the delivery reliability has to be calculated from the last step only – marked with number 2. 3. shows actual finish date. Planned finish date is wrong in the table above, probably due to a bug in IFS software. The correct planned finish date can be found from the window seen in the picture below. Weekends and holidays need to be excluded, in Excel reports this was done by using "workdays" function.

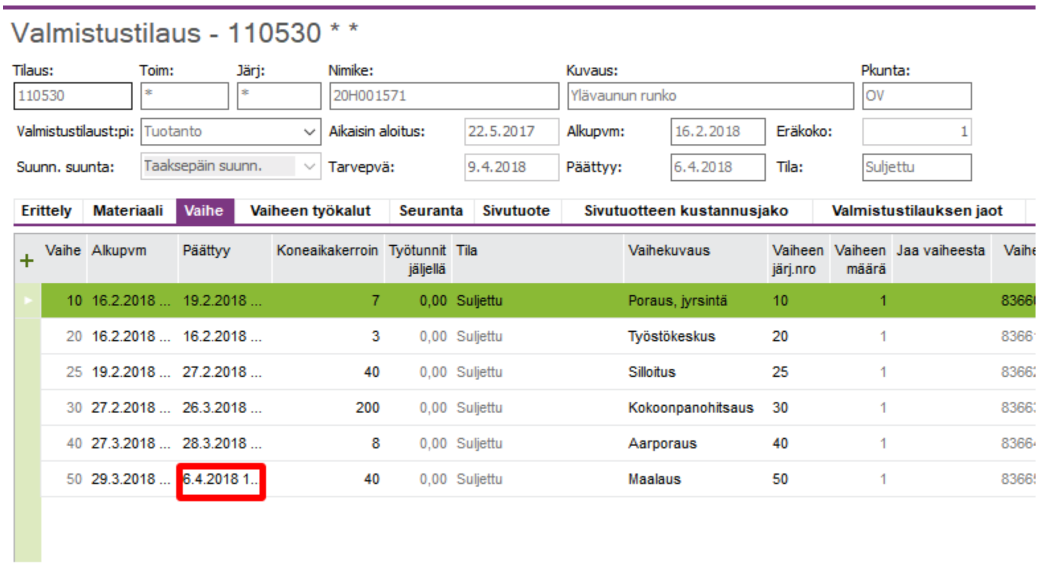

FIGURE 12. Correct planned finish date.

6.3 Throughput time

Actual throughput time calculation of a shop order is done by the following formula:

Actual start date – actual finish date – holidays & weekends = actual throughput time in work days

Since this calculation also uses the dates specified for the shop order, the information can be found from the same window as for delivery reliability. The result is calculated by using the actual start date of a shop orders first process step and actual finish date of the last process step.

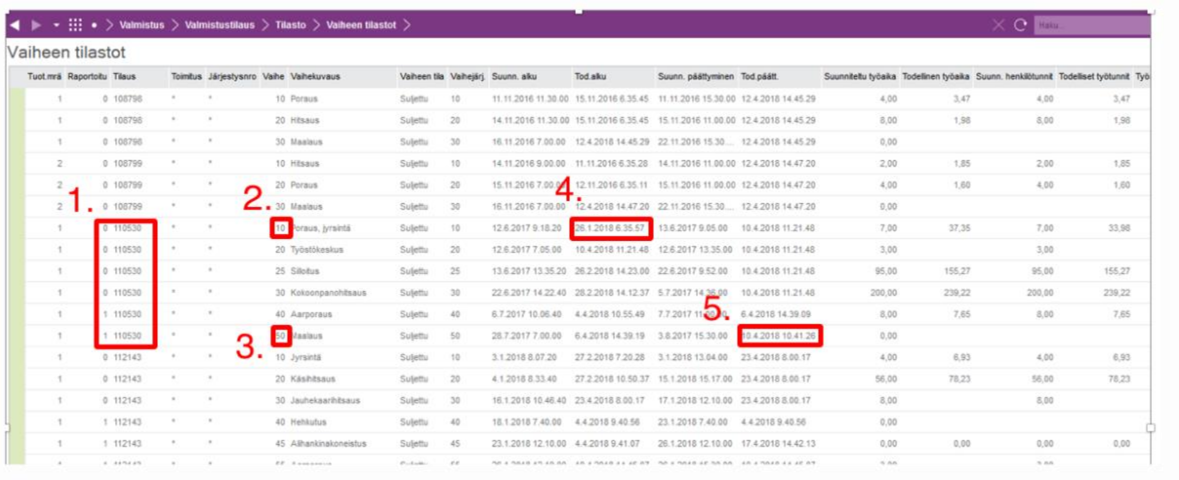

FIGURE 13. Data for actual throughput times.

In the figure above, 1. shows a shop order no, 2. and 3. show the first and last process step. Throughput time is the number of workdays between first process step's actual start date (4.) and last process step's actual finish date (5.).

6.4 Throughput time variance

For calculating throughput time variance, the restrictions for the time frame and products/product ids must be done. Throughput time variance metric will include a line chart visualization which shows the actual throughput times (as calculated for previous metric) and an average for a comparison. The visualization should also include numeric values in addition to visual line graph. The visualization shows immeditially if there are large variations in throughput times and if there are trends for either direction, increasing or decreasing times.

6.5 Actual processing times

Actual processing time metric is used for evaluating efficiency of the manufacturing process. The evaluation is done by comparing actual processing time of a shop order to routing times and to previous processing times. The efficiency of the production should always increase over time, meaning that actual processing times should be less and less at time goes by. This also means that routing times should be updated at regular intervals to keep the production planning reliable.

Actual processing times by shop order process step can be found from the same window as for the previous two metrics. This window also has a column showing the routing times, which makes comparison easy even without external softwares. No formulas are needed for evaluating this metric, and IFS internal visualization capabilities support this kind of data views. No great benefits could be acquired from exporting this data into external software, so it was decided that IFS internal capabilities are enough for now.

Final welding of upper carriage rigs is the most time consuming single process step, and it also affects directly the overall throughput time. Search parameters and visualization settings were saved inside the ERP software to make evaluation easy.

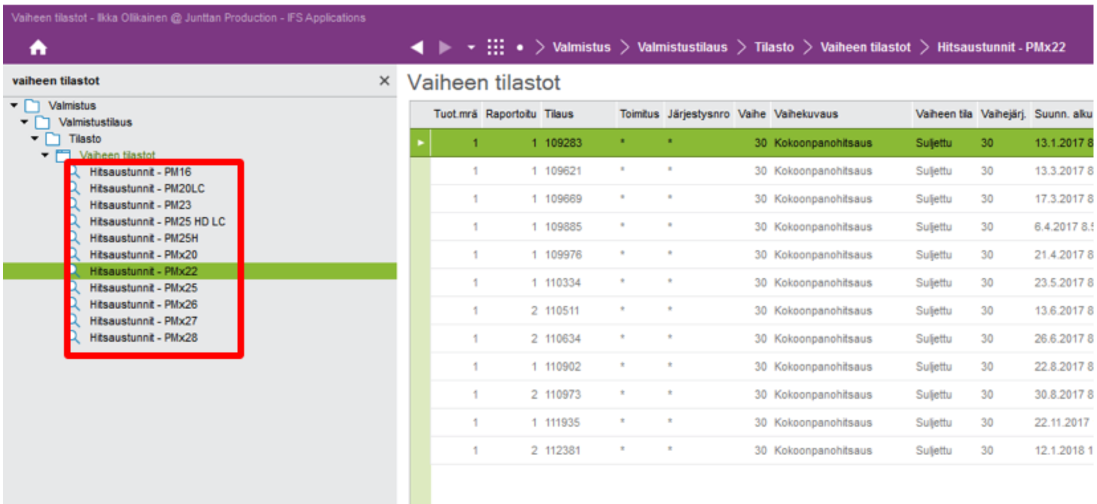

FIGURE 14. Searches for welding times saved for easy access.

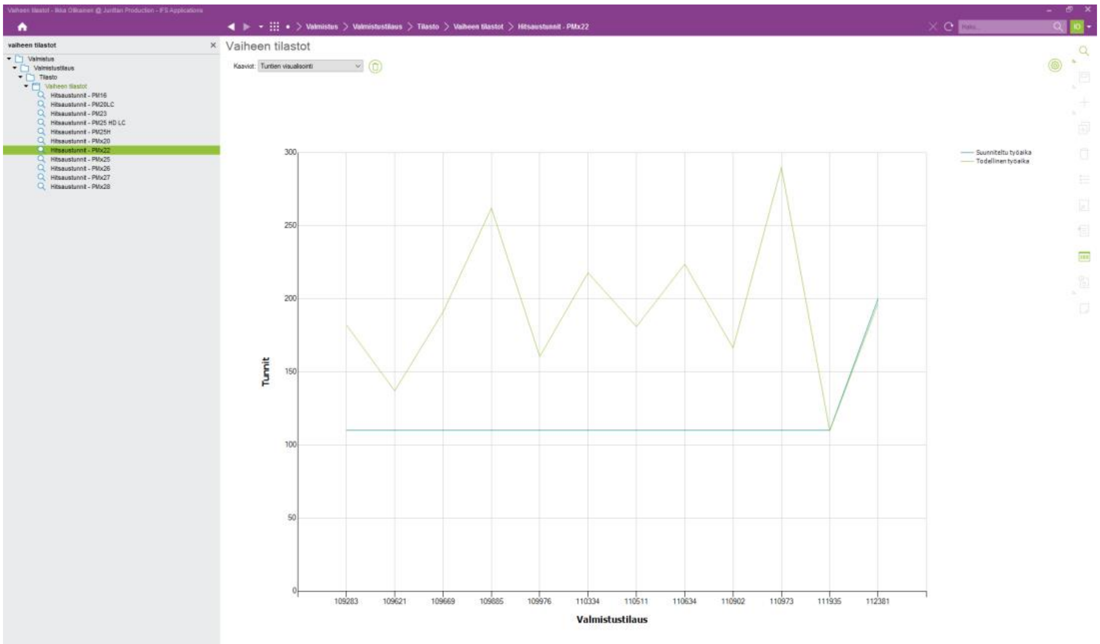

FIGURE 15. Planned welding time versus actual welding times per shop order for PMx22 upper carriage rigs.

6.6 Current delay

This measure was chosen to make the daily production control easier, and to forecast the becoming delays better. It was known that all work hours are logged into the system, and all routing times are defined. This combination enables the possibility for calculating the current delay in work hours.

This feature was found built into the new version of the ERP system, IFS 9. IFS 9 includes lobby-views, which one of them has screen for delay in work hours. However, the delay shown was way more than estimated by production supervisors, and suspects of the metrics reliability rose. When investigating the nature of this metric it was found that indeed, it was not working correctly. Investigation was done by comparing one shop orders "hours left" column to work time logs made by employees. These two were not matching, and it was obvious that something is wrong.

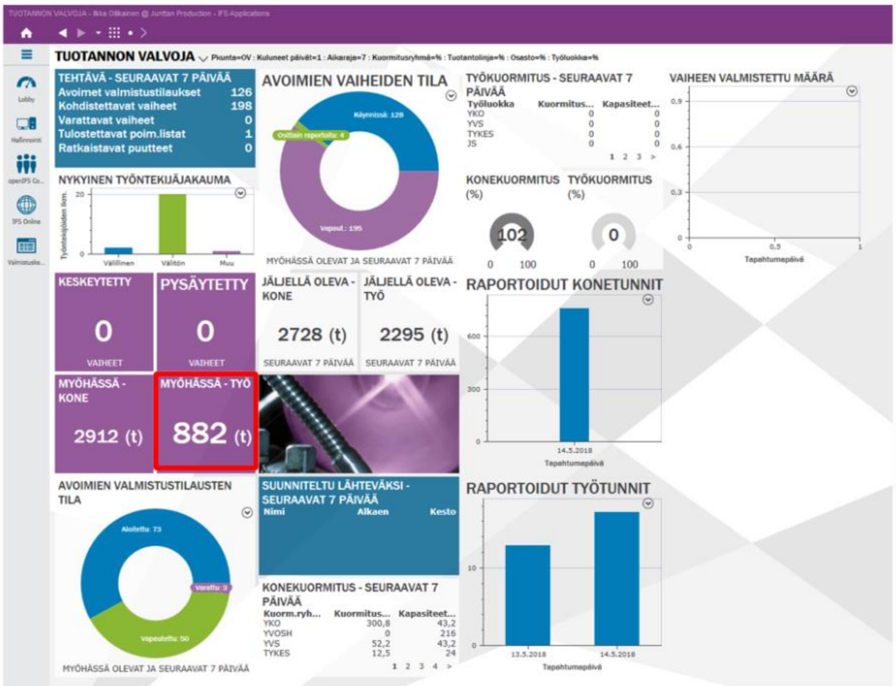

FIGURE 16. Current delay -display is found from "tuotannon valvoja" lobby view.

The instructions for this ERP system in case were not the most user-friendly, so it took a while to figure out what was incorrect. Finally, the reason was found, and it was located to be one drop-down menu in "work center" (kuormitusryhmä) window. Before, the option was chosen so that it calculates "work hours left" according to how many pieces there are left to produce in one shop order. In case company where almost every shop order contain only one piece and may include hundred of hours work, this causes massive error in delay time metric as we saw. When this option was corrected, the numbers changed to more realistic ones. The last thing to do for making this metric work flawlessly is to start closing all shop order's process steps after they have been completed. So far this option has not been in use because it causes extra work and no clear benefits have existed.

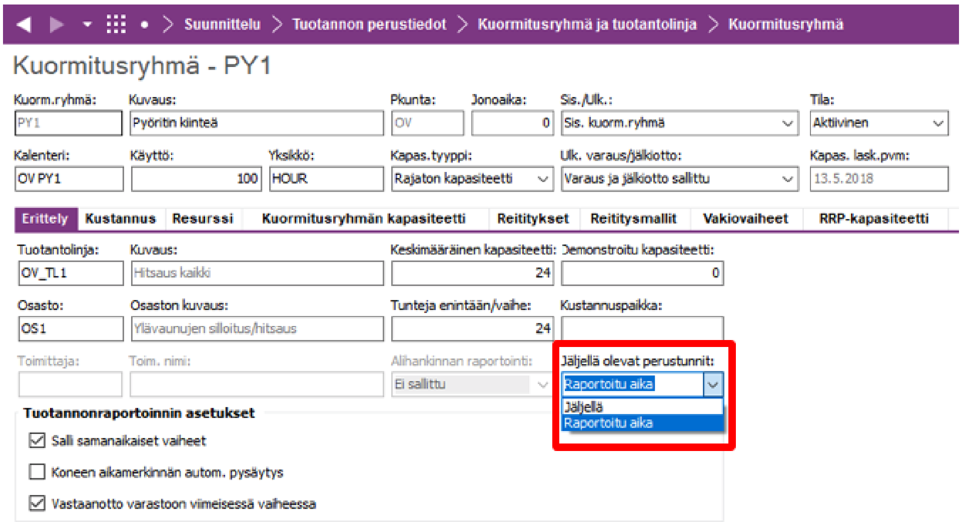

FIGURE 17. Dropdown menu which determines how process step's hours left are calculated.

From the delay-view it is also possible to see all shop orders included into the calculation. This is benefical because it allows the production supervisor to see easily what specific shop orders have delay and know early on that they will most likely not be finished on time. In the theory section of this thesis it was noted that focusing on the processes problems immeditially plays a significant role on developing the production, and this metric allows it to happen.

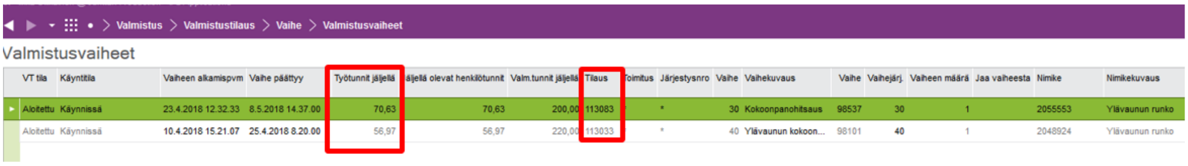

FIGURE 18. Delay hours by process step and shop order.

7 CONCLUSIONS

The company wanted to get tools for measuring how efficient their production processes are. ERP version had just been updated, and knowledge of the new versions features was not good. It was known that it's possible to make data visualizations with external software, and for this project the goal was to either find out how metrics are possible to implement in the ERP software, or to write instructions for implementing them through external software.

The importance of having accurate data is the foundation for effective performance measurement. During the process it was noted several times that even seemingly small errors in the data in ERP system – which do not affect the floor-level operations at all – may completely destroy the possibility of measuring performance in some areas. It was also rather surprising to find illogicalities caused by the nature of the ERP system – for example, change made to a shop order changes the closing day, which is not correct. For getting reliable metrics the data should always be validated as well as possible.

The results of the thesis project were not as great as I had personally expecting. The practical application of the metrics is still in progress and will be continued immeditially. The project was more time-consuming and difficult than I was initially expecting, and there were unexpected time constraints during the project. However, a lot of important information was revealed and a basis for effective metrics was made. The metrics which I was able to build will help the production control and performance measurement. I learned massive amounts of new things about the company's ERP system and about performance measurement in general.

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