LAPPEENRANTA UNIVERSITY OF TECHNOLOGY
Faculty of Technology
Department of Industrial Management

**MASTER’S THESIS**

Improved order fulfillment in paper production

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Lappeenranta, April 17, 2013
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## ABSTRACT


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| Master's thesis. Lappeenranta University of Technology. Department of Industrial Management.<br>88 Pages, 17 figures, 12 tables, and 9 appendixes.<br>Supervisor: M.Sc. Virve Räty<br>Examiners: Prof. Tuomo Kässi, and D.Sc. (Tech.) Kalle Elfvengren | |
| **Keywords**: order fulfillment, overproduction reduction, mill execution system development, performance measurement. | |

For the paper mill profitability it is crucial to minimize overproduction and underproduction. Overproduction and underproduction both generate undesired costs and profit losses in paper mill production.

This master's thesis examines paper production order fulfillment subject from paper production level point of view. Research and development approach is selected due to clarification requirements in lately implemented manufacturing execution system. Manufacturing execution systems are generally expected to offer reliable and accurate information about mill production details. However, confusions are likely to occur after implementation of new manufacturing execution system. These confusions are usually harmful and become cumulatively more influential the longer they keep occurring.

In this master's thesis is presented actions to improve order fulfillment at paper mill production level. Central points of the improvement actions are a model for successful order fulfillment in paper mill production and manufacturing execution system catalogue configuration redesign. Improvement actions are implemented in Jokilaakso paper production plant and it is examined as a case study. In the end of this master's thesis is presented performance measurements which demonstrate order fulfillment from case Jokilaakso.

## TIIVISTELMÄ


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| **Tekijä**: Jarkko Ensio Olavi Vainikka<br>**Työn nimi**: Tilausten täyteenajon tehostaminen paperin tuotannossa. |
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| **Hakusanat**: tilausten täyteenajo, ylituotannon vähentäminen, tuotannonohjausjärjestelmän kehittäminen, suorituskyvyn mittaaminen |
| Paperitehtaan kannattavuuden kannalta on äärimmäisen tärkeää minimoida sekä ylituotanto että alituotanto. Ylituotanto sekä alituotanto aiheuttavat ei-toivottuja kustannuksia ja tuottojen menetyksiä paperitehtaan tuotannossa.<br><br>Tämä diplomityö tutkii paperitehtaan tilausten täyteenajoa paperitehtaan tuotannon näkökulmasta. Valittu näkökulma tutkimus – ja kehitystoiminnalle johtuu viimeaikaisessa tuotannonohjausjärjestelmän käyttöönottoprojektissa ilmenneistä tuotantomäärien seurannan selvennystarpeista. Yleisesti tuotannonohjausjärjestelmien odotetaan tarjoavan luotettavaa ja oikeaa tietoa tuotannon prosesseista. Uuden tuotannonohjausjärjestelmän käyttöönoton jälkeen on kuitenkin todennäköistä todeta tuotannossa tapahtuvan sekaannuksia. Tuotannossa tapahtuvat sekaannukset ovat yleensä vahingollisia ja tulevat kumulatiivisesti sitä vaikuttavammiksi mitä kauemmin niitä tapahtuu.<br><br>Diplomityön esittelemät paperin tuotannon tilausten täyteenajon keskeiset tehostamistoimenpiteet ovat malli onnistuneeseen tilausten täyteenajoon sekä tuotannonohjausjärjestelmän katalogien konfigurointimalli. Tehostamistoimenpiteet otetaan käyttöön case esimerkkinä tutkittavassa Jokilaakson tuotantoyksikössä. Työn lopussa on esitetty tilausten täyteen ajoa havainnollistavia suorituskyvyn mittaustuloksia Jokilaakson tuotantoyksiköstä. |

## PREFACE

This master‘s thesis is made for UPM-Kymmene Oyj in 2013. Purpose of this research was to improve order fulfillment in paper production. This was very interesting research topic and I would like to give special thanks to UPM-Kymmene Oyj for this opportunity.

Supervisor of the master’s thesis was M.Sc. Virve Räty. Thank you, Virve, for coaching, challenging, and showing the right direction for this master’s thesis. Special thanks belong also to my colleagues at UPM-Kymmene Oyj and Global Mill Execution System -project related specialists. You gave me valuable information, support, and advices especially in the beginning of the process. I would also like to thank Jokilaakso production plant personnel. You trusted me and gave me the opportunity to carry out this research and development actions to your paper production plant.

In addition I am also grateful to my instructor, Professor Tuomo Kässi, for the guidance. I got some very good advices from Tuomo and that helped me ahead with my master’s thesis.

Finally, I would like to thank my family. Thank you for all your support during my studies in Lappeenranta University of Technology. Lot of time was taken out of the family during the studies. Without your understanding this would not have been possible.

In Lappeenranta 17.4.2013

Jarkko Vainikka

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**ABBREVIATIONS**

ERP Enterprise Resource Planning

EUR Euro, currency

GMES Global Mill Execution System

JAM Jämsänkoski paper production line

JOK Jokilaakso paper production plant

KAI Kaipola paper production line

LWC Light Weight Coated. Paper sort.

MES Manufacturing Execution System

MIS Management Information System

MRD Mill Ready Date

PMS Performance Measurement System

PTD Package Transfer Database

ROCE Return On Capital Employed

SAP Systeme, Anwendungen und Produkte - ERP system

SKU Stock Keeping Unit

SPOC Single Point of Contact

UPM United Paper Mills

# 1 INTRODUCTION

## 1.1 Background

Crucial step from the paper mill profitability point of view is to minimize underproduction as well as overproduction. Overproduction and underproduction are illustrated in figure 1. Minor confusion between the order balance data and the run balance data at the mill production level can lead to a seriously inaccurate quantity of paper at the mill warehouse or even at the dispatching point at the harbor warehouse. To achieve the best result and to avoid misunderstandings at the production and the production planning, all users should be monitoring the same balance data with the same definitions and basis.

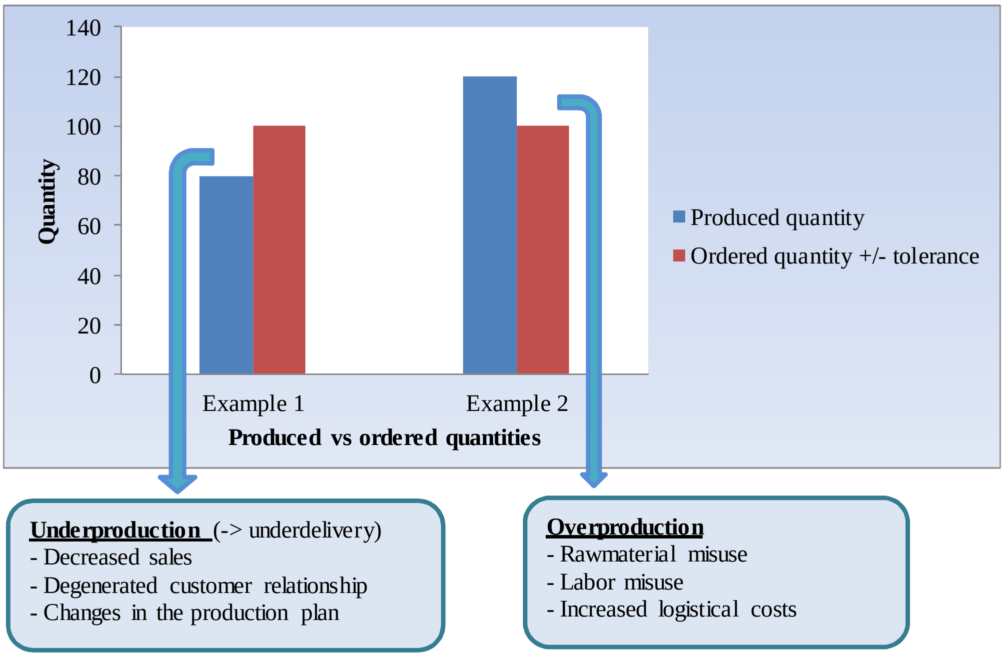



Figure 1. Overproduction and underproduction.

Underproduction results not only as decreased sales, but also as degenerated relationships with the customers. In addition underproduction generates changes in the production plans due to the customer order filling needs. Overproduction is misuse of the raw material and labor. Overproduction realizes usually as increased logistical costs accumulating from warehousing, loading and transportation and as additional material processing like pulping, rolls sawing and unintentional rewinding and wrapping. These are the main reasons for UPM-Kymmene Oyj to have clear definitions for production balance data monitoring at the production level and production planning.

## 1.2 Targets and scope

Targets of this master's thesis are divided to two entities:

- First target is to clarify paper mill operational level production balance monitoring to achieve improved order fulfillment. The main focus is on produced paper quantities since it is totally controllable by the paper mill production.

- Second target is to measure realized order fulfillment to prove improved order fulfillment performance. The measured performance statistics are used to benchmark coherent paper production lines with each other.

### 1.2.1 Paper mill production balance monitoring

The first target of this master's thesis contains:

- the explanations and clarifications for used terms in the paper mill production,
- a production guide for successful order fulfillment in the paper mill production,
- redesigning of the paper mill production operation screen catalogues, and
- the operation screen catalogue configurations.

The actions mentioned above are executed to prevent overproduction from occurring. However, if overproduction is for some reason being produced from the paper machine, this master's thesis explains how to proceed with the exceeding paper quantity.

Terminology understanding, together with its connection to the vendible product, is considered to be fundamental knowledge for end user in order to achieve successful order fulfillment in the paper production. At first this report defines few fundamental definitions for order fulfillment. The difference and relationship between an order and a run should be acknowledged by all Global Mill Execution System, GMES, end users. This report also includes a GMES catalogue column explanation table which content should be understood by all end users in order to recognize commonly pursued production targets. This subject finishes with the winder operation screen catalogue model configurations.

### 1.2.2 Performance measurement and benchmarking

Second target of this master's thesis is to measure realized order fulfillment before and after the development actions to prove improved order fulfillment performance. Data from the paper mill production, warehousing, and dispatching is used as base of the order fulfillment performance measurements. Measured performance statistics are used to benchmark coherent paper production lines with each other.

Performance measurement in this master's thesis is realized by examining realized overproduction quantities, realized under delivery quantities and the mill warehouse overproduction stock levels. The purpose of the performance measurement in this occasion is to prove improved order fulfillment after the development and redesign actions in the GMES and production processes.

### 1.2.3 Scope

The purpose of this work is to focus on the paper mill production line procedures in order to clarify and develop the functions of recently implemented global mill execution system. Another matter that has influence on the order fulfillment is the paper mill production planning. The paper mill production planning is however so wide research subject that it would take another master's thesis to investigate it thoroughly.

The order fulfillment performance measurement is realized in a way that only the order fulfillment related factors are measured. After all, the target is to prove the improved order fulfillment from the taken development and redesign actions.

## 1.3 Research realization

The following sections describe the actions, which have been left for lower level of attention, but still have affected on this master's thesis.

Other GMES live paper mills were investigated, as the best possible practices were searched to build up the most effective and clear GMES catalogue configuration model for Jokilaakso. The paper mill production end user and the GMES project colleagues had significant influence in developing the most practical solution for problems to be solved. The developing suggestions were taken account and realized within the possibilities. This part of work also required from master's thesis worker to learn and step to an earlier totally unknown area of the GMES catalogue configuring.

The performance measurements required the order item data detail gathering from April 2012 to February 2013. This timespan include total of 17 000 individual order rows from only Jokilaakso paper production plant. A base for performance measurements was built as follows:

1. The requirement analysis was done, for collected order row data.
2. The system supplier experts collected the order row data into a Microsoft Office Excel add on application in the GMES.
3. Order fulfillment related data was gathered from the add-on application in the GMES.
4. Order fulfillment related data was analyzed and verified to be reliable.
5. Order fulfillment data was modified to a reader friendly mode.

## 1.4 Structure of work

In the beginning of this master's thesis is presented overall view of UPM-Kymmene Oyj with more detailed insight to the UPM-Kymmene Oyj paper division. Financial ratios are presented on both the corporation and the paper division level.

The UPM-Kymmene Oyj presentation is followed by overview to the paper mill production. In this chapter is presented the generally used paper production machinery and the commonly used terminology in the paper mill production.

The master's thesis topic related theory is presented in the following chapter. The theory part presents a process performance improvement model which is applied generally to the whole order fulfillment improvement process. Theory chapter presents also the manufacturing system characteristics and requirements. Finally in theory chapter is presented views on effectual performance measurement in manufacturing.

The next chapter considers UPM-Kymmene Oyj's manufacturing execution system implementation. The main topics of this chapter are:

- the situation before the GMES,
- the GMES development and implementation,
- the GMES program targets, and

- the situation after implementation of the GMES.

In the following chapter is described general order fulfillment related issues focusing on paper mill production. The paper mill production planning related issues and the dispatching related issues are presented also.

After the general order fulfillment related issues are presented, the order fulfillment monitoring issues are defined. This chapter determines all the influential factors that have to be assimilated in order to achieve successful order fulfillment.

In the last two chapters is presented case Jokilaakso which includes order fulfillment improvement actions and order fulfillment improvement actions.

# 2 UPM-KYMMENE OYJ

UPM-Kymmene Oyj officially started its operations on 1 May 1996 after Kymmene Corporation and Repola Ltd and its subsidiary United Paper Mills Ltd announced their merger in autumn 1995. (UPM-Kymmene Oyj, 2010)

The UPM group's roots in the forest industry reach all the way to the 1870s when the first saw mills started its operation. The mechanical pulp production began in the 1880s, the paper production in the 1920s and the plywood production in the 1930s. (UPM-Kymmene Oyj, 2010)

At the present UPM-Kymmene Oyj's business areas are paper, pulp, energy, biofuels, label, plywood, forest and timber. Nowadays the present corporation comprises about hundred production facilities from all around its business areas. (UPM-Kymmene Oyj, 2010)

### 2.1.1 Strategy and key figures

UPM Kymmene Oyj's businesses are in the long run supported by the majority of the change drivers. According to UPM-Kymmene Oyj (2013) these change drivers can consider being:

- the global demand for oil, food, water and energy
- the shifting of economic power from West to East
- the climate change
- the integration of digital technologies into peoples everyday life

Strategically UPM-Kymmene Oyj focuses its growth efforts on the regions and markets with the most promising future forecasts. Because of this strategic decision, UPM-Kymmene Oyj has divided its business portfolio into two groups; mature businesses and growth businesses. The business portfolio groups are illustrated in figure 2. (UPM-Kymmene Oyj, 2013)

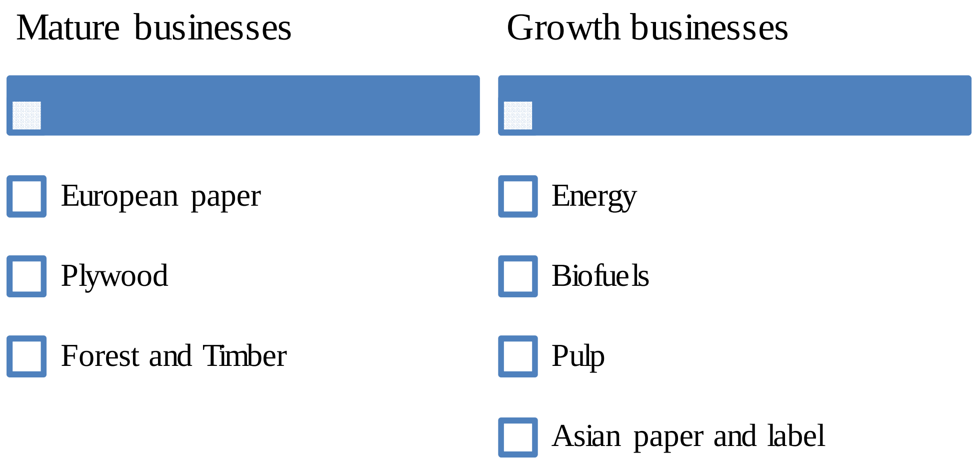



Figure 2. UPM-Kymmene Oyj's business portfolio groups

The mature businesses' target is to increase the efficiency on operating businesses whereas growth businesses are expected to have very likely future growth and profitability prospects. In addition UPM Kymmene Oyj is constantly developing biochemical related businesses with expected high added value. (UPM-Kymmene Oyj, 2013)

UPM-Kymmene Oyj's vision is to be a forerunner in the integration of bio and forest industries. According to UPM-Kymmene Oyj (2013) UPM-Kymmene Oyj's competitive position is based on following factors:

- cost competitiveness,
- material and energy efficiency,
- high quality products, and
- the ability to quickly adapt to changing circumstances.

Key figures from last three years are presented in table 1.

Table 1. UPM Kymmene Oyj's total key figures from year 2010 to 2012. (UPM-Kymmene Oyj, 2013)

| | *Scale* | **2012** | **2011** | **2010** |
|---|---|---|---|---|
| **Sales** | *EUR million* | 10,438 | 10,068 | 8,924 |
| **Operating profit *** | *EUR million* | 530 | 682 | 731 |
| **Earnings per share *** | *EUR million* | 0,7 | 0,93 | 0,99 |
| **Operating cash flow per share** | *EUR* | 1,93 | 1,99 | 1,89 |
| **Dividend per share** | *EUR* | 0,6 | 0,6 | 0,55 |

* *excluding special items*

## 2.2 Paper business area

UPM-Kymmene Oyj's 21 modern paper production plants are located in Finland, Germany, the United Kingdom, France, Austria, China and the United States of America. The combined annual paper production capacity is 12,2 million tons. (UPM-Kymmene Oyj, 2013)

UPM-Kymmene Oyj reaches its customers with its global paper sales network and an efficient logistics system. UPM-Kymmene Oyj's main customers are publishers, retailers, printers, distributors and paper converters. (UPM-Kymmene Oyj, 2013)

### 2.2.1 Strategy and key figures

UPM Kymmene Oyj paper business areas main focuses are on the cost leadership and European profitability to secure strong cash flow. At the present this is the only way to consolidate its position in the European markets. (UPM-Kymmene Oyj, 2013)

Despite the improved key figures in the last three years, profitability needs focusing. Even though the paper business area's sales were 68,4 % from UPM- Kymmene Oyj's total sales, paper business areas operating profit was only 0,37 % of

UPM Kymmene Oyj’s total operating profit. UPM Kymmene Oyj paper business areas total key figures from year 2010 to 2012 are shown in table 2. (UPM-Kymmene Oyj, 2013)

Among others, minimization of overproduction and underproduction is one way to improve profitability since it reduces costs and increases profitability.

Table 2. UPM Kymmene Oyj paper business areas total key figures from year 2010 to 2012. (UPM-Kymmene Oyj, 2013)

| | *Scale* | **2012** | **2011** | **2010** |
|---|---|---|---|---|
| **Sales** | *EUR million* | 7,150 | 7,184 | 6,269 |
| **Operating profit *** | *EUR million* | 2 | -16 | -254 |
| **Capital employed (average)** | *EUR million* | 5,470 | 5,437 | 5,465 |
| **ROCE *** | | 0,0 | -0,3 | -4,6 |
| **Personnel on 31 December** | | 12,627 | 13,877 | 11,901 |
| **Deliveries** | | | | |
| Publication papers | *1000 tons* | 7,230 | 7,071 | 6,123 |
| Fine and speciality papers | *1000 tons* | 3,481 | 3,544 | 3,791 |

** excluding special items*

At the moment the Asian paper business area markets are favorable for seeking growth. Therefore, UPM Kymmene Oyj strengthened its position in Asia by investing on the wood-free specialty paper machine in Changsu, China. (UPM-Kymmene Oyj, 2013)

# 3 PAPER MILL PRODUCTION OVERVIEW

In this chapter is described a normal paper mill production line. After production line insight, some common terminology concerning paper mill production is explained.

## 3.1 Paper mill production line

The paper mill production line overview is presented in figure 3. A paper mill production line process is following:

1. Paper reels are produced from the paper machine.
2. Paper is refined at the paper re-reeling machine, paper coating machine or paper calendar. Refining methods depend on the customer's requirements and the production line assembly.
3. The paper reels are then produced at the winder to customer rolls according to customer's requirements.
4. The customer rolls are wrapped at the wrapping machine.

The next steps are logistical functions followed by the paper mill production line:

5. Wrapped customer rolls are transported to the mill warehouse or delivered directly to the customer.
6. The mill warehouse personnel organize rolls to the warehouse stock lots according to the scheduled delivery date.
7. The customer rolls are delivered to the customer or to the external warehouse via the train cargo, truck or vessel.

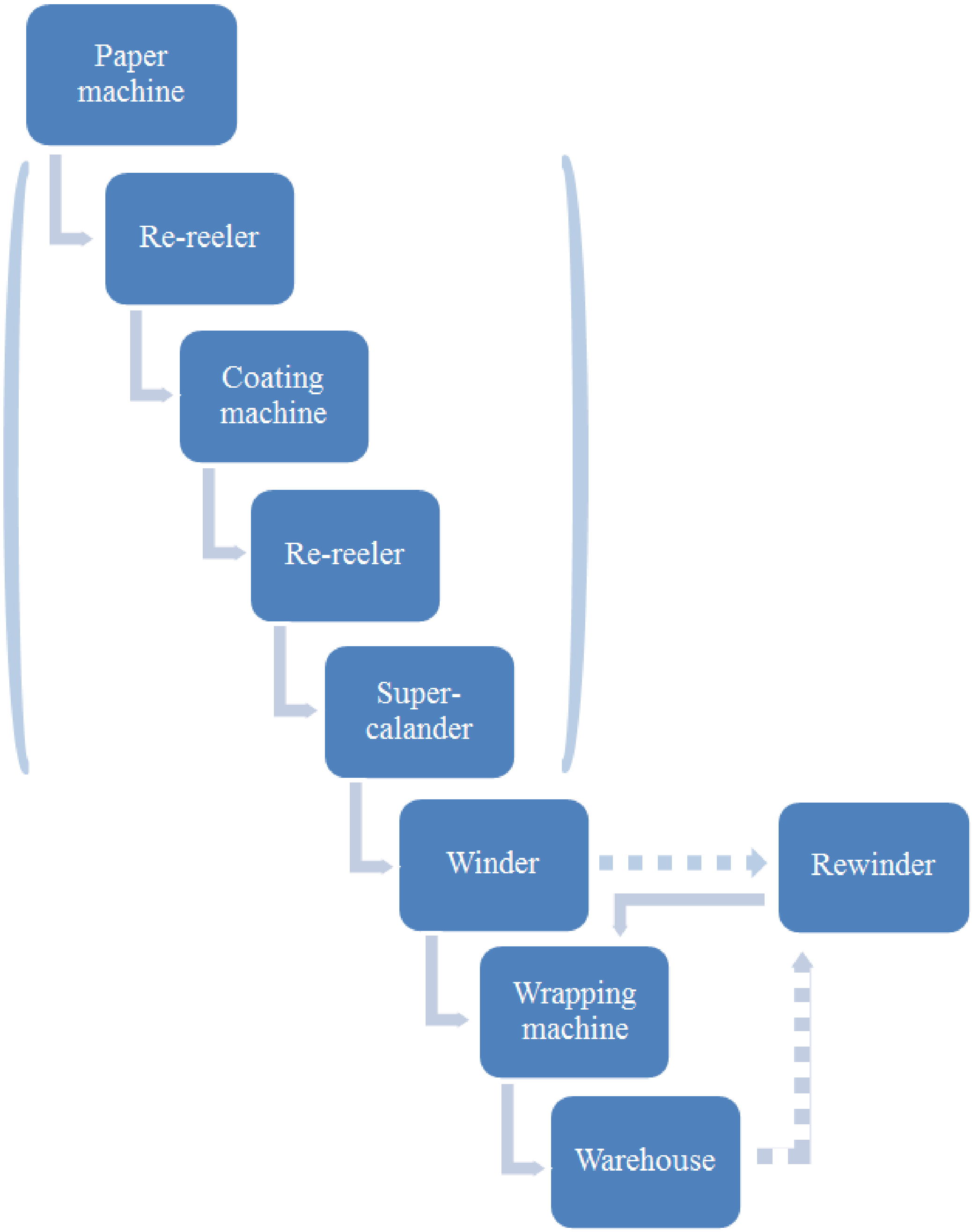



Figure 3. The paper mill production line overview. All production activities inside the parenthesis are independently alternative. The rewinder processes paper rolls, which are directed to it from winder and warehouse.

## 3.2 Common terminology in paper production and planning

Order

The orders are normally placed against the customer requirement. Common variables for the roll order are paper grade and basis weight, order quantity and basis, roll diameter/length and width, core model and tolerance of delivered quantity.

Order item / Order row

The order can be partitioned in order items. This occurs due to the different variables and specifications in one order.

Schedule line

The order item can be partitioned in schedule lines. This occurs due to the different delivery dates. The order item schedule lines are usually produced in the different runs. GMES receives order item schedule line level data.

Production lot

One schedule line can produced in one or more production lots. This occurs due to production and production planning reasons.

Run

One run consists of planned quantity of paper for one or more production lots. Usually the planned quantity for one order item schedule line is exceeding the ordered quantity by the customer. One run is normally produced continuously from the paper machine.

Planned quantity for order item schedule line

Planned paper quantity for one order item schedule line. Planning is executed by the production planner in association with the production planning algorithm.

Paper machine reel

A paper unit which is produced from the paper machine. A paper reel weight varies from 20 to 25 tons.

Paper roll

A paper roll is produced at the winder or rewinder and it usually weights from 450 to 8 000 kilograms.

Mill ready date

Mill ready date represents the point in time when the prime quality paper roll is supposed to be in mill warehouse at the latest to reach the planned delivery to customer. This is also the date when the further transferring is planned to take place.

# 4 THEORY

## 4.1 Process performance improvement

Processes hold the people and procedures together, even if people and procedures change from time to time. Organizations typically focus on people, procedures, tools, and technology but performance can be improved more effectively by focusing on the process. (Chrissis, Konrad, & Shrum, 2005) According to Martin (2008, p. 30) “People and technology cannot produce the best of products unless the processes are effective”.

The main idea of the process performance improvement is to measure performance of a particular process and process modifications in stages to increase the output performance. (Martin, 2008) Martin (2008, p.31) states that “The concept of performance improvement can be applied to individual or organizational performance.”

The company uses performance measures called metrics or indicators in the processes to measure the characteristics of the products, services, and operations. These metrics and indicators are then used to track and improve performance. Process improvement is always possible if the process can be measured by identifying the metrics. (Martin, 2008)

## 4.2 A process performance improvement model

Martin (2008) presents an outline of a simple process model for a performance technologist as an operations consultant or process analyst (figure 4). Process model presented by Martin (2008) is meant to help clients to improve the production or service processes. Production or service process improvement is possible via developing operations strategies and identifying interventions. (Martin, 2008) An alignment between strategy and process dimensions is brought about by an effective operations consultant. This alignment enhances the business performance of the client. (Chase et al. 2006)

Performance improvement model has been designed as a five-stage framework where each stage has been further subdivided. The model has been designed so that the improvement model steps can be conveniently followed to improve process performance. (Martin, 2008)

Detailed understanding of how a process can be designed and redesigned to improve the performance is provided by process performance management. It starts with identifying an opportunity for improvement and ends with an opportunity for continuous improvement, which can be determined as relatively light on the analysis front but it focuses more on identifying performance outcome measures. (Martin, 2008)

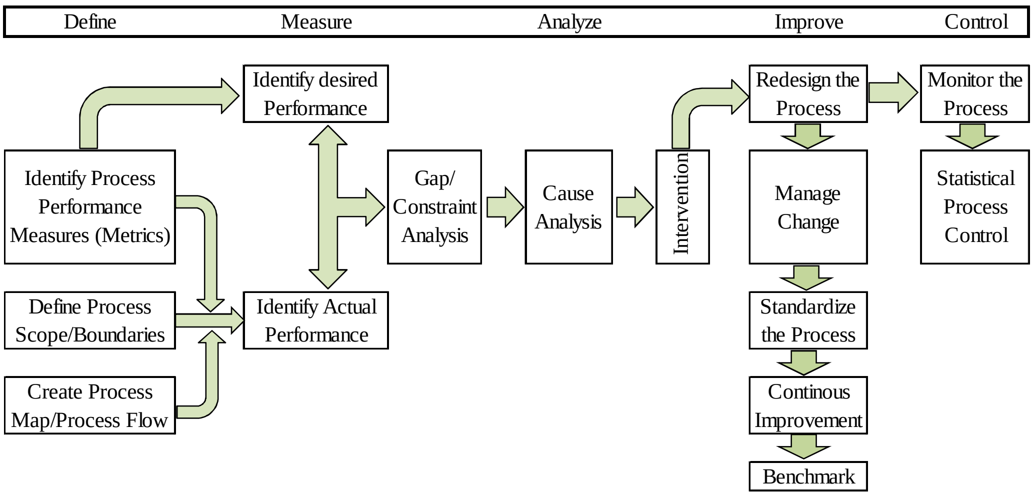



Figure 4. Process performance model. (Martin, 2008)

### 4.2.1 Step 1: Define the Process

A. Identify Performance Measures (Metrics and Indicators).

The process owners have in most cases identified the process outcome measures that provide the best indication of their process health and efficiency. Performance technologist will have to work with the leadership to identify the outcome measures or metrics, if they have not been identified. (Martin, 2008) Theory of constraints originator Goldratt states that goal of any economic enterprise is to make money. (Goldratt & Cox, 1992) This goal of making money is contributed towards by every organizations set of process outcome measures. (Martin, 2008)

Metrics are a system of parameters or ways of quantitative assessment of a process that is to be measured, along with the processes to carry out such measurement. The measurement of the right thing is very important, and metrics define what is to be measured. If the right things are not measured the ability to improve performance will be impossible. Metrics also help to assess the ability to meet customers' needs and business objectives. (Martin, 2008)

Martin (2008) presents a list of performance measures or metrics that help determine the efficiency of the process:

- Profitability and productivity: Business success can be measured through comparing profit made with the amount sold or invested. It is a relation between the value of the goods and services produced and the value of the factors of production used.

- Service quality: Delivering the promised product at the promised time and ensuring reliability. This step includes more than just delivery time; it is the interface step with the customers and how happy they are with the provided service.

- Capacity or quantity of output: The amount of output a system is capable of achieving over a specific period of time. It is normally measured in tons or units or using relative key figures. Martin (2008, p. 32) states that

"When a new process is in place, the first priority is to get functional. At start-up, capacity is one of the main process outcomes."

- Manufacturing time: The total time taken for a product to be manufactured. It is the time period during which the raw material input is converted into the output in a manufacturing process.

- Quantity of rejects: The number of products that do not meet the customer's requirements. It is the measure of the products that require any amount of rework before they meet the customer's expectations.

- Quantity of waste: Unwanted or undesired material left over after completion of a process. (Martin, 2008)

B. Define the Scope or Boundaries of the Process.

Process boundaries' setting becomes necessary since processes can be at the organizational level, the department level, or even the employee level. The process boundary is formed by the entry points of the process inputs and the exit points of the process outputs. (Martin, 2008)

C. Process Mapping and Process Flowcharting.

According to Martin (2008, p. 33) "Process mapping refers to a picture of activities in the process". In process maps the processes are broken down into simple, manageable, and easily understandable units. Inputs, outputs, controls, and resources for all the processes are defined in process maps. Interactions between independent units are represented in a logical and objective way. (Martin, 2008) In literature process mapping is also known as system task analysis, process task analysis, process diagramming, and work mapping. (Langdon, 2000; Marrelli, 1998; Siever, 1993; Swanson, 1994)

### 4.2.2 Step 2: Measure Performance

The next step is to measure the desired and the actual performance. At this point, data have been collected about the process and the targeted outcome measures. Martin (2008, p. 34) states that "Desired performance measures are set as business goals in an organization. However, actual performance is measured at every stage where there is a transformation of the input."

A. Identify Desired Performance.

Stakeholders' statements and business input are used to identify desired performance goals. Organization's performance is significantly impacted by five types of stakeholders. These stakeholders are customers, stockholders, employees, suppliers, and community (Chase et al. 2006). Access to the business goals will help identify the desired performance. (Martin, 2008)

Process goals are usually used to identify the desired performance. At the process design point is set goals for the cost of process, the quantity, and quality of the output, manufacturing, and delivery time. (Martin, 2008)

B. Identify Actual Performance.

When specific outcome measures are identified for each level of desired performance, we are ready to measure the actual process performance (figure 5). (Martin, 2008)

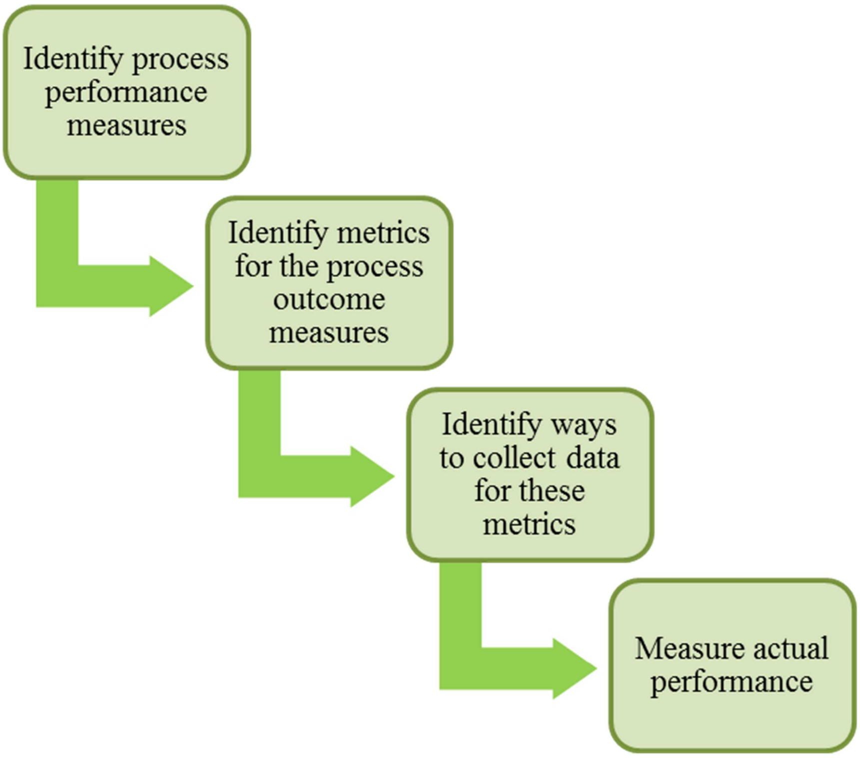



Figure 5. Measuring actual performance. (Martin, 2008)

C. Data Analysis Tools and Techniques.

At the point when the desired and actual metrics have been established, a process improver needs a data collection method for analyzing each of these performances indicators. Measuring ways of this information can be numerous, from collecting data to interviewing people to observing the process. Martin (2008) presents sample data collection and analysis tools such as checklist, bar charts, histograms, pareto chart, scatter diagram, cause-and-effect diagrams, line and pie charts, matrix analysis, dot plot chart, tally chart, control charts, force field analysis, and simulations.

### 4.2.3 Step 3: Analyze the Process

A. Gap Analysis and Constraint Analysis.

Gap analysis is used to compare the company's performance to the expectations of its stakeholders and customers. Likewise, company's performance can be compared to the performance of their competitors. (Chase et al. 2006). Thus, it is utilized to identify gaps between examined subjects. Measuring the gap (figure 6.) is relatively simple when there are metrics data for the desired performance and actual performance (Martin, 2008).

Gap = Desired performance − Actual performance

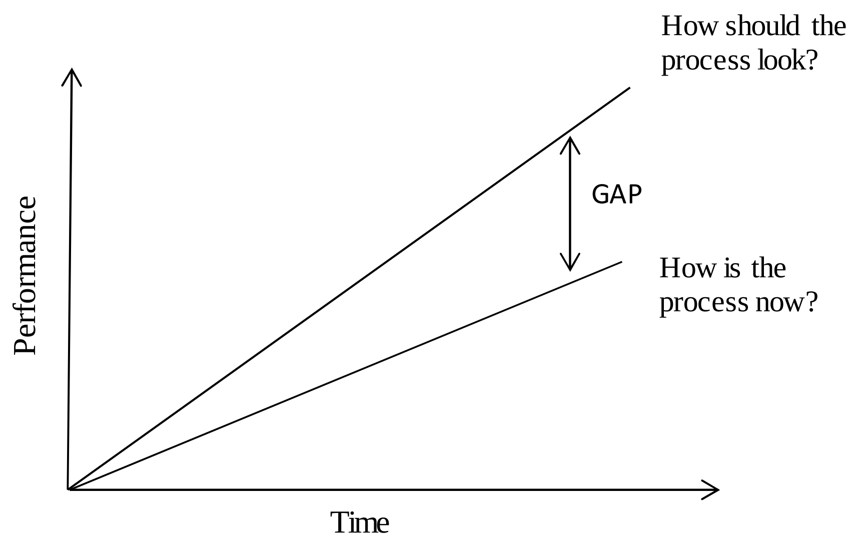



Figure 6. Identifying the gap. (Martin, 2008)

At this step is identified any existing gap. Process constraint identifying is also important for the process analyst. Martin (2008, p. 36) states that "Constraints are factors that limit the performance of a system and restrict its output." Every organization has one key constraint that limits the system's performance relative to its goal. (Goldratt & Cox, 1992) A bottleneck is a special type of constraint that relates to capacity shortage in a process. Bottlenecks are identified by measuring capacity and utilization of a process. Bottlenecks and other constraints that decrease the process performance are also identified in this step. (Martin, 2008)

B. Causes for the Gaps and Constraints (Cause Analysis).

Identifying of the causes and root causes for the gaps and constraints takes place in this step. Missing process steps or illogical arrangement of process steps or other factors can realize as gaps and constraints. Gap causes can be analyzed with causal factor charting. Root causes are those for which effective recommendations can be generated. Organization has control over underlying causes like root causes. (Martin, 2008) It is all about identifying the causes for the mistakes such as unclear labeling or a confusing procedure, not about identifying minor mistakes made in the process. (Rooney & Heuvel, 2004)

C. Identify Intervention for the Causes.

Solution recommendations are made in this step. Solution recommendations are used as a way to address root causes, close gaps, and achieve desired performance measures. Automation is not always the best or only solution even though many process performance problems look to automation as a performance improvement solution. (Martin, 2008)

### 4.2.4 Step 4: Improve the Process

In addition to planning or redesigning process, improving includes also implementing the new process with an implementation plan for redesign. (Martin, 2008)

A. Reengineering/Redesign.

The process typically has to be redesigned based on the cause identified and interventions recommended. The employees will have to be trained, if the root cause is discovered to be a training issue. If the cause is a missing step, the missing step must be included in the reengineering of a process. (Martin, 2008) Michael Hammer initiated the reengineering movement, which is defined as the fundamental rethinking and radical redesign of processes to improve performance dramatically in terms of cost, quality, service, and speed. (Krajewski et al., 2007)

B. Manage the Change.

Redesign process typically contains changes. According to Martin (2008, p. 38) "Based on the extent of changes that have occurred, either there has been incremental improvement where a process is enhanced in one or two departments, or perhaps there has been a redesign of a variety of processes where the change has to be managed.". Some type of change management program is recommended in the implementation phase, even though incremental improvements may not require much change. Martin (2008, p. 38) also states that "Change management is a structured approach to change in individuals, teams, organizations, and societies that enables the transition from a current state to a desired future state". Job content is likely to be changed, and training should be considered during implementation of any redesign. (Curtice, 2007)

C. Standardize and Document the Process.

A new process must be standardized if the purpose is that it will be accepted and followed by the entire organization. This phase involves documentation and usually training. (Martin, 2008)

D. Continuous Process Improvement.

Continuous process improvement is based on the Japanese concept of kaizen, a philosophy of constantly seeking ways to improve the process. Benchmark identifying and implementing the improvements is included in continuous process improvement. (Martin, 2008)

E. Benchmarking.

Benchmarking is systematic procedure that is utilized to measure a firm's processes, services, and products and compared with those of the leaders of its industry. (Martin, 2008) The different types of benchmarking are competitive benchmarking, functional benchmarking, internal benchmarking, and generic benchmarking. (Anderson & Peterson, 1996)

In this context the most relevant benchmarking type is internal benchmarking. Martin (2008, p. 39) describes internal benchmarking as follows: "Internal benchmarking is comparing similar operations between departments units, subsidiaries, or countries within the same organization."

### 4.2.5 Step 5. Control the Process

Essential thing is to maintain the improvement once the performance of the process has been improved. (Martin, 2008)

A. Monitoring the Process.

In order to maintain the performance rate, the process has to be monitored continuously. Process control can be supported by data analysis tools. (Martin, 2008)

B. Statistical Process Control.

Statistical process control uses statistical tools to observe the performance of the production line to predict significant deviations that may result in rejected products or other undesired outcome. (Martin, 2008) Martin (2008, p. 39) describes that "statistical process control indicates when an action should be taken in a process, but it also indicates when no action should be taken."

### 4.2.6 Summary of process performance improvement model

Process performance management starts with identifying an opportunity for improvement and ends with an opportunity for continuous improvement. Process performance improvement model provides detailed understanding of how a process can be designed or redesigned to improve organizational performance. (Martin, 2008)

## 4.3 Manufacturing execution system, MES

At first this chapter presents Manufacturing Execution System, MES, basis and background. From this point of view can be stated:

- what information MES should be providing, and
- which questions MES should be able to answer to?

Fundamental idea of this chapter is to describe how a MES should be working and what features it should include.

### 4.3.1 Background

Today's trend in manufacturing businesses is the increasing needs for flexibility, reactivity and efficiency. These needs result in a growing complexity of manufacturing systems and a necessity of integration of their control. (Blanc et al. 2008)

Rolón & Martinez (2012, p. 54) describes that "In highly competitive global markets characterized by make-to-order production manufacturing and volatile demand production systems must meet individual requirements and comply with stringent deadlines while guaranteeing superior quality at low prices." This can be achieved when production planning work and execution control are tightly integrated. (Rolón & Martinez, 2012)

A demanding and fast changing environment challenges today's manufacturing systems. In order to maximize their productivity, industrial firms have to implement control policies and adapt their manufacturing systems. As a main issue, industrial firms have to consider the manufacturing–customer responsiveness. As a part of fitting to an ever-changing environment, manufacturing systems have to undergo small changes on-the-fly. Similarly it has to have the ability to co-evolve with continuously changing necessities, by way of significant transformations. (Blanc et al. 2008)

Paper production process lacks effective unity and communication of model and information between the production planning management of upper layer and the process control of bottom layer. This causes unsuccessful performance of specific business functions in the control layer in time, bad visibility of production information such as supplies, equipment, product quality and order information as well as difficulties of information communication. In response to this question, MES emerged. (Xu et al. 2009)

### 4.3.2 MES

A MES usually consist of a control execution system and a production planning. However, production planning is in some cases integrated together with enterprise resource planning system, ERP.

A MES is defined as a system, acquired by an enterprise, to ensure the control of the processes. It is a main actor of the enterprise integration, as it interfaces the physical subsystem and the high-level decisional subsystem. (Blanc et al. 2008)

The MES is generally a specific system for each different manufacture. The MES is defined as an interface between business and manufacturing. It materializes the frontier between provisional plans and actual realizations. (Blanc et al. 2008) Blanc et al. (2008, p. 317) describes that "The MES is in charge of the detailed scheduling of activities in the manufacturing system, the launching of the orders, the response to random events, the adjustments of plans and the following-up of activities”.

A MES is defined to be a real-time information system and a production management technology, which lies between the enterprise upper layer (ERP) and the shop floor layer. (Xu et al. 2009) MES’s are control systems which attempt to follow a given schedule as closely as possible. A MES is trying to fill the gap between the planning level and shop-floor execution. (Kletti, 2007)

Rolón & Martinez (2012, p. 54) describes that “Manufacturing execution systems (MESs) are the main production management tools to integrate production planning – at the company management level – with control/automation systems at the shop-floor level”. Typically, an Enterprise Resource Planning, ERP, system trickles data for planned orders down to an MES for schedule generation and execution control. Data for planned orders includes sizes, product mixes, and due dates. Thus, all MESs must include a shop-floor planning and scheduling tool for transforming planned orders into detailed, executable schedules for verification and tracking purposes of production orders. (Rolón & Martinez, 2012) A MES should also be able to reschedule in real-time the execution of tasks as contingencies and disruptions occur. (Meyer et al. 2009)

In figure 7, is shown how the information and decisions are exchanged up and down between a control execution system (MES) with shop-floor sensors/actuators and with a production planning system. In this view of the management hierarchy, an MES has the key role of translating production goals, also described as planned orders, decided at the company management level into a detailed scheduled to be executed at the shop-floor. The state of the shop-floor is abstracted using data gathered in the control/automation level and fed into the MES for execution control and rescheduling. Statuses of orders are then being processed and reported to the company management level which may affect the release of future planned orders. (Rolón & Martinez, 2012)

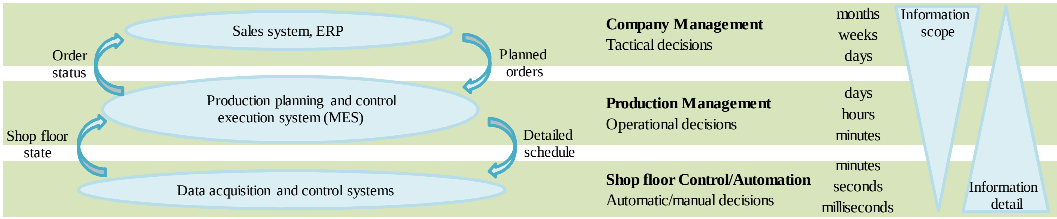



Figure 7. The information and management systems for planning and control. (Rolón & Martinez, 2012)

Blanc et al. (2008, p. 315) states that "besides well-identified characteristics such as reactivity, flexibility and productivity, new requirements such as re-configurability and evolvability lead to drastically increase the complexity of the (re)design of manufacturing execution systems, MES".

## 4.4 Effectual Performance Measures in Manufacturing

One of the most important aspects in manufacturing has always been productivity performance measurement. This comprises a long-term or progressing measure. When it comes to benchmarking and improving a company performance, this measurement is essential. Human and system behavior can be steered by measurement. Changes in productivity levels can be monitored via the measurement results. The measurement results can also provide the direction for improvement. (Wazed & Ahmed, 2008)

Overall productivity improvement strategy is desired by most manufacturing plants. However, manufacturing plants that are searching for improvement strategies are still likely to find out, that they are unable to take full advantage of the modern methodologies and techniques. Part of this can be attributed by fear of changes, complexity in working culture, lack of management commitment and shortfall of personnel competency on appreciation and understanding of productivity. (Wazed & Ahmed, 2008)

Many definitions of productivity seem to have the same basic concept. However, Wazed & Ahmed (2008, p. 988) defines that there are three broad categorizations within the similar definitions:

A. the technological concept: the relationship between ratios of output to the inputs used in its production;
B. the engineering concept: the relationship between the actual and the potential output of a process; and
C. the economist concept: the efficiency of resource allocation.

This master's thesis implements an application of the engineering concept which focuses on the relationship between the actual and the potential output of a process.

### 4.4.1 Performance measurement systems

Performance measurement aims to provide decision makers with information that enables them to take effective actions and evaluate whether a company is progressing in line with its strategy. (Grosswiele & Röglinger, 2013) Performance measurement is defined to be the process of quantifying the efficiency and effectiveness of action. (Neely et al. 1995)

With respect to what characterizes a performance measurement system, PMS, existing definitions are classified into different groups. Furthermore it is concluded that two major features make up a PMS: measures and supporting infrastructure. (Franco-Santos et al. 2007)

A. From an operations perspective, a PMS is a set of interdependent performance measures, also known as metrics, figures, or indicators. (Neely et al. 2000) A PMS also includes the reporting process that gives feedback to employees on the outcome of the actions. (Bititci, 1997)

B. From a strategic control perspective, PMS include the procedures to translate strategies into measures as well as the system that provide the necessary information to challenge the content and validity of strategies. (Grosswiele & Röglinger, 2013)

C. From a management accounting perspective, PMS correspond to traditional management planning and budgeting. (Grosswiele & Röglinger, 2013)

Each measure encloses in a PMS quantifies the efficiency and/or effectiveness of the entity under investigation from a distinct perspective and serves as indicator of overall performance. (Kennerley & Neely, 2002) It is common to distinguish between different, though not necessarily disjoint types of measure, such as financial and non-financial measures, leading and lagging measures, measures relating to different perspectives (e.g. financials, customer, business processes, or learning and growth), measures relating to different levels of abstraction (e.g. department-wide, company-wide, or industry-wide), or measures relating to phenomena from inside or outside the company. (Kaplan & Norton, 1996) It is important to note that measures in general do not exhaustively cover decision makers' information requirements. They typically have to be complemented by qualitative information such as rumors, press releases, or external reports of competitors. (Grosswiele & Röglinger, 2013)

# 5 MES AT UPM-KYMMENE OYJ

## 5.1 Situation before GMES

Before the year 2010, all of UPM Kymmene Oyj paper production plants have had individual control systems for the production planning, mill product manufacturing and product balance monitoring as well as the warehouse stock monitoring. These individual manufacturing execution systems, MES, have usually been developed by a local system supplier or own personnel of the paper mill. Even though the system developing purpose has been the same at every paper mill, it is clear that the MES's have been quite different in every paper mill, The biggest differences between the paper mills MESs mainly occur because of the different policies, production lines, system suppliers.

Individual manufacturing execution systems, MES, have been developed by the paper mills distinctive needs. Individual MES's are usually functional for a paper mill's needs, but are often too rigid for development. Nowadays development is crucial for individual paper mills to survive in the tough competition situation at the current markets.

Due to the diverse nature of individual MES's, UPM-Kymmene Oyj's coherent reporting system has been challenging to gather together. As a strategic level decision making tool, a global paper mill reporting system is essential. This global paper mill reporting tool has been difficult to deliver reliably and comprehensively.

## 5.2 GMES development and implementation

In 2008 UPM-Kymmene Oyj made business decision to develop and implement one globally common manufacturing execution system, MES, for all paper production plants (figure 8). The continual development and implementation process has been proceeding step by step in cooperation with the system supplier. The

MES, which is supposed to be implemented in every UPM-Kymmene Oyj´s paper mill by the year 2014, is called Global Mill Execution System, GMES.

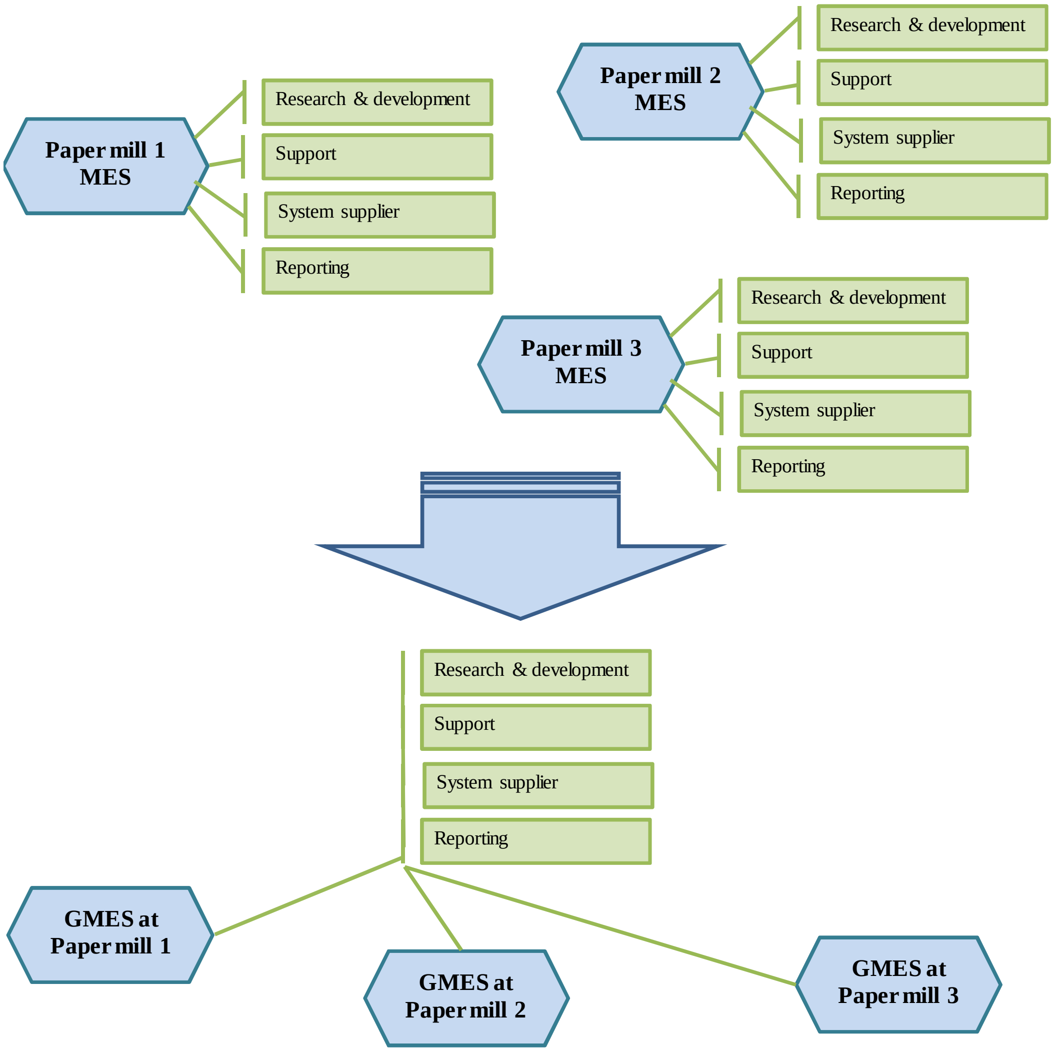



Figure 8. Proceeding to a globally common manufacturing execution system.

### 5.2.1 Structure

The GMES is a MES which consists of the production planning, production and mill warehouse. In table 3 is presented an example of system consists. The GMES is planned and developed to be compatible with all different kind of paper production forms which UPM-Kymmene Oyj is operating with. Because of the large amount of paper production forms and activities, the GMES demands a complex structure to be functional.

Table 3. An example of a system structure.

| | |
|---|---|
| Finance and controlling | ERP |
| Sales and distribution | ERP |
| Production planning | MES |
| Production execution | MES |
| Transport planning | MES |
| Transport execution | MES |
| Material management and purchasing | ERP |

The GMES implementation has, and will have, effects on processes concerning the mill order handling, production planning, reel and sheet production, warehousing and dispatching, quality management, mill reporting and product costing. These effects are planned to occur as improved ways of working, reporting, and end user knowledge and understanding.

The fundamental idea of the GMES infrastructure is that it includes a basic model and additional features. The basic model includes all the essential functionalities and information, which are known to be necessary for every paper mill. The additional features consist of information and functionalities, which are known to be essential for an individual paper mills due to the production environment or some other deviant feature. Based on their needs, an individual paper mill selects which information and functionalities are used in their production environment. This is procedure ensures that the GMES can match for every mills individual needs.

### 5.2.2 Implementation process (Rollouts)

At this point of time the GMES has been successfully implemented to the paper mills at France, United Kingdom, Germany, China and Finland. The implementation process is ongoing at one paper mill in United States of America, and at one paper mill in Germany.

After the GMES system implementation and go-live point, the GMES related matters and issues are communicated via the paper mill contact persons. This contact person is called Single Point of Contact, SPOC. Furthermore, supply chain control personnel and every paper mills every working shift includes qualified persons who are named and trained as the GMES key users. These GMES key users support the paper mill production level end users in issues concerning the GMES. For the best possible outcome for all paper mills, the development process of GMES is continuing and new versions and updates are installed frequently.

## 5.3 GMES Program targets

The GMES Program's main target is to enable the paper production process harmonization by implementing a common Information Technology, IT, solution for manufacturing execution.

Objectives of the GMES program are as follows:

- support implementation of the strategy for UPM Kymmene Oyj Paper Business Group,
- harmonize and continuously optimize the mill business processes,
- implement a standard GMES according to approved rollout plan, and
- reduce the overall costs with a global template.

### 5.3.1 Expected benefits

Compared to the local manufacturing execution systems, the improved and more efficient GMES solution is expected to realize benefits as follows:

- business process harmonization,
- streamlined rollout,
- improved application support, and
- cost efficiency.

### 5.3.2 Business process harmonization

The most important business process harmonization targets are globally standardized production planning, implementation of harmonized mill execution and warehouse functionality and standard interfaces with other global systems, such as Sell It (SAP), PTD, MIS and Move It. The data communication between these global systems is presented in figure 9.

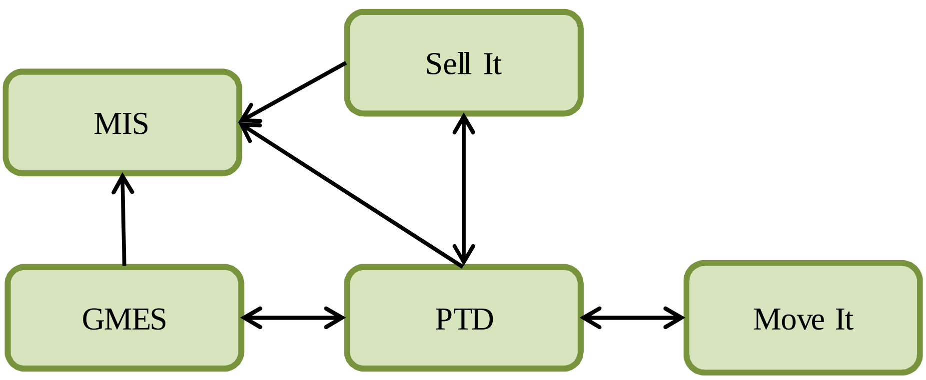



Figure 9. The data communications between the global systems.

In this occasion business process harmonization means uniform business processes throughout all UPM-Kymmene Oyj paper mills and production planning. For the most beneficial outcome the GMES program participants have to analyze all the different procedures and find the best procedure practice for every process. In a point when the best practice for every business process is found, the best practices will be

- gathered together,
- evaluated, and
- implemented if possible

to every paper mill or production planning, as harmonized business process.

### 5.3.3 Streamlined rollout

Streamlined rollout contains industrialized rollout activities at the paper mills, and coordinated replacement of the legacy MES systems throughout all paper mills. Industrialized rollout activities are used due to accelerated implementation process at individual paper mill level. Clear template orientation for local rollouts allows shorter rollout times, which means shorter and more efficient implementation process.

### 5.3.4 Improved application support

The improved application support includes two main points which are clarified in the next chapters. These two main points are:

- globally improved capabilities for the GMES governance and support, and
- improved upgradeability and release management.

UPM-Kymmene Oyj’s every paper mills manufacturing execution system can be administrated and supported by one selected group of administrators. The governance can make decisions which affect all MES’s at the same time. The governance also makes decisions with the knowledge of how these decisions affect to the production environment at all paper mills and paper production planning.

Due to the global MES, all upgrades can be done at the same time, or at the different points of time. However, all paper mills can achieve the same advantages through the globally common system upgrades.

### 5.3.5 Cost efficiency

In this chapter the cost efficiency advantages are considered from the global system development and implementation point of view.

First of all the cost efficiencies and advantages can be reached through the global mill template development. The template development is now centralized for responsibility of the GMES program development team. The GMES program development team cooperates closely with the local paper mill development personnel.

From the global functions point of view the overall paper mill procedure development can be achieved through the benchmarking. The individual paper mill procedure templates are benchmarked to find the best processes. When the best processes are found and pointed out, they are also implemented to the other UPM-Kymmene Oyj paper mills if possible.

The cost efficiency can also be reached from the system acquiring point of view. The GMES has only one system supplier. The legacy local MES's had couple providers and multiple different versions of MES's. One provider means one cost factor for the development instead of multiple cost factors to the paper mill's local MES providers.

## 5.4 Situation after implementation of GMES

The GMES implementation generates significant benefits and advantages to UPM-Kymmene Oyj. In addition, the GMES implementation also causes some negative side effects. The most negative side effects are change resistance and new system learning phase. This chapter describes these negative side effects and problems from the issue solution point of view.

The negative matters and problems are described because those are the most important things to be improved and fixed in order develop the existing system and procedures into the right direction for even better outcome.

### 5.4.1 Change management

As it could be imagined, change resistance can be noticed in a change operation of this large scale. In this case change resistance appears as indifferent behavior, rejecting attitude for the information and highlighted self-defense. From the production and profitability point of view the change resistance results as decreased production quantity and deteriorated order delivery rate.

At this point the change management is extremely important. The most common procedures to deal with the change resistance are shared commitment to change, leadership and support in challenging situations. All these procedures are generally well managed in the GMES program.

### 5.4.2 Training

A new mill execution system implementation requires efficient end user training. It could be stated that within reasonable limits it is impossible to offer so comprehensive training that every end user learn everything about the GMES. This leads to a situation where several confusions and questions occur at the beginning of use of new system. This also results as a short term decreased production quantity and deteriorated order delivery rate. That is why the paper mills every shift has a key user who has been trained to have more extensive know-how about the

GMES. The end users are then guided to invoke key users when problematic situations occur.

# 6 ORDER FULFILLMENT ISSUES

This chapter describes the most common and the most problematic occasions concerning the order fulfillment in the paper production. These situations are totally normal and occur daily at the paper mill production level.

## 6.1 Paper quantity for ongoing run

How much paper should be produced from the paper machine for the ongoing run? The produced paper quantity for the ongoing run has to be decided during every run. The idealistic paper production situation is where a production chain consists of three machines:

1. a paper machine,
2. a winder, and
3. a wrapping machine,

The idealistic paper production situation features fault-free paper, the trouble-free production chain, and the winder patterns with no trimming waste. The described situation is unrealistic with the current production line processes. However, the solution for above situation would be the difference between the scheduled quantity for run and the produced quantity for run from the paper machine. This solution is presented in the figure 10.

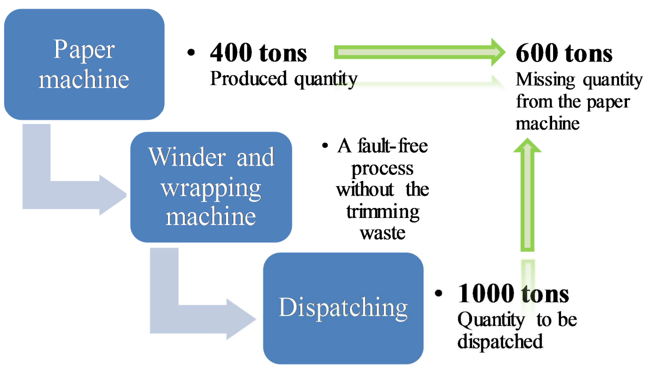



Figure 10. An example of an idealistic paper production situation.

In figure 11 is illustrated that the solution gets trickier when more machines are added into the production line and the paper faults and humane errors are included into the every process step.

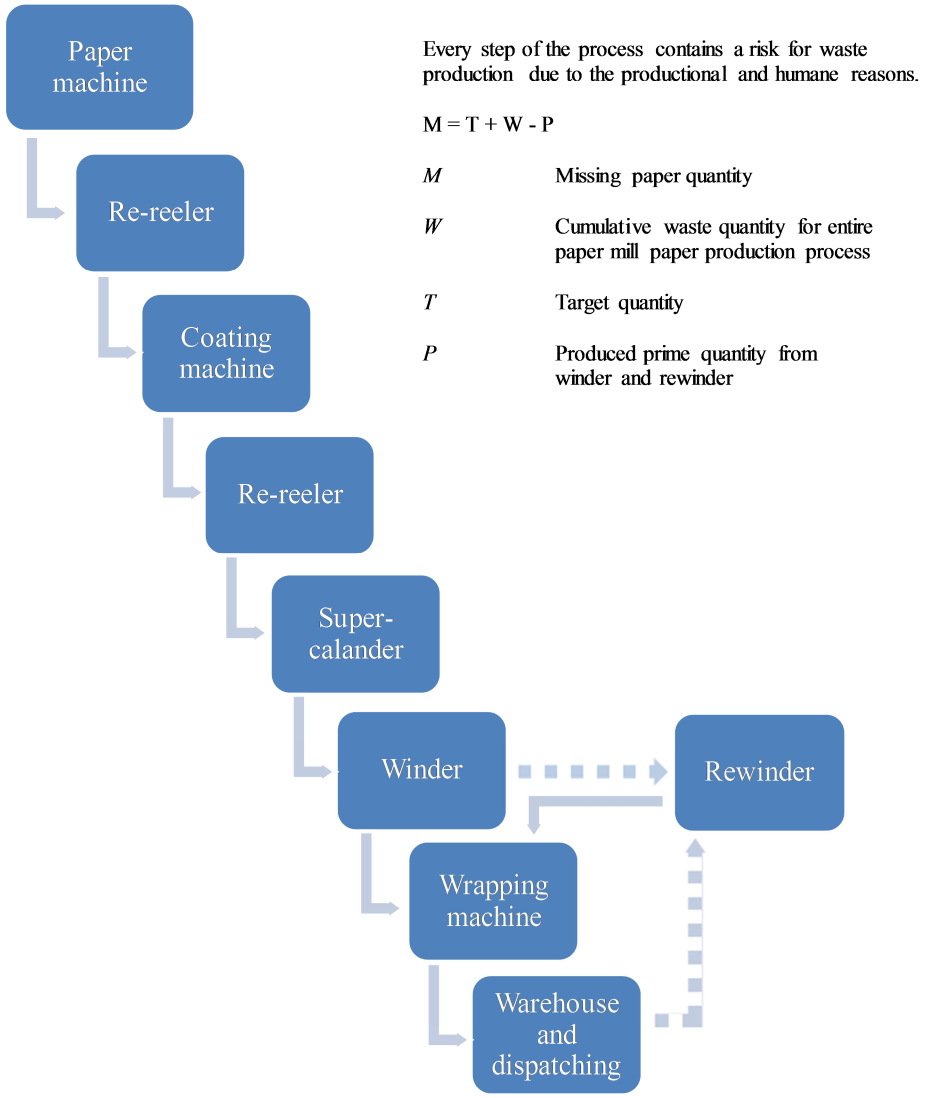



Figure 11. A normal offline paper production line situation.

Usually the paper grade change at the paper machine must be known at least few hours before the actual grade change takes place. The preparation time varies depending on the nature of paper machine and the produced paper grade. Usually the preparation time occurs due to the mechanical pulp preparation and production, the paper machine production speed change and the paper grade weight change. This preparation time complicates the evaluation of still to be produced paper quantity to fulfill the run. The complication is mostly because of the unknown paper faults in future and breakdowns at the machines in the production chain.

The normal policy at the paper machines is that the produced paper quantity exceeds the missing quantity for the run by one or two sets. (One production batch from the winder is called set.) Usually this kind of overproduction situation should be easily handled at the winder. But as the production chain gets longer, the estimation for missing paper quantity gets trickier. Reasons for this complication are described in previous section. At this point, the accountable person, who usually is shift supervisor, has two options. The first option is to produce paper just enough to fulfill the target tons of run. The second option is to produce exceeding paper which ensures that the run will be fulfilled. From the paper mills profitability point of view is there is two options:

1. Produce a little bit extra paper from paper machine and then produce the possibly exceeding paper for the open orders.
2. Produce too small quantity of paper and possibly miss a delivery date and late from the dispatching point.

From the paper mills profitability point of view, the first option is more profitable, since the exceeding paper can be produced to other open orders.

## 6.2 Run is fulfilled, exceeding paper occurs

The situation which is presented in the heading is usually dealt with every run. Exceeding paper occurs at the winders due to intended overproduction from the paper machine. Reasons for the paper machine overproduction are describe in previous chapter.

The winder patterns for one run are generated by scheduling algorithm. The patterns of the run are then inspected by the production planner. Normally the production planner schedules the patterns for one run as follows:

1. the urgent orders will be fulfilled first, and
2. the other orders are added in to provide the optimal pattern widths for the production.

When all planned patterns for one run are produced, the paper mill production has a situation where exceeding paper occurs at the winders. At this point, the production level process has to have a procedure to produce the exceeding paper quantity as profitably as possible.

## 6.3 The run is partially produced, paper is missing

The situation which is presented in the heading occurs normally because of three different reasons. These reasons are:

1. Too small quantity of paper is produced from the paper machine.
2. Troubles occur at the production line which results as breakdowns, faults and waste. Produced paper grade is changed at the paper machine.
3. The winder personnel has not monitored production quantity balances, which occurs as under- and overproduction for some order item schedule lines.

A normal situation in the paper production is that when the winder produces last patterns of the current run, the paper grade has already changed at the paper machine due to the production plan progression.

The described chain of events leads to a situation where at least parts of the planned quantities for the orders in current run are not fulfilled at the winder. At this point the paper mill personnel have to inspect if runs missing quantities are going to be late from the dispatching point of time. If the delivery need for missing paper quantity is not urgent it will be produced from the paper machine in a suitable moment. If the missing paper quantity is urgent, the paper mill personnel have to decide when it is possible to change the paper grade at the paper machine and if it is possible for the customer rolls to be ready at the dispatching time.

## 6.4 Run/order is partially produced at rewinder

A rewinder is a paper production machine which can process one paper roll into one or more paper rolls. The effect of the rewinder production is illustrated in figure 12. The rewinders are normally used in three different occasions:

1. The planned quantity for the order item schedule line is produced intentionally at the rewinder because of the winder pattern trimming reasons.
2. The order item schedule line is for some reason produced under the ordered quantity at the winder and it needs to be fulfilled to meet the customer requirements and the sales agreement. The paper rolls, which are not directed to any specific order item schedule line, are used as rewinder raw material.
3. The paper roll which is directed to the order item schedule line is reprocessed at the rewinder because of a detected production fault at the winder production. In these occasions the rewinder product can be directed to the original or alternative order item schedule depending on the quality of detected fault.

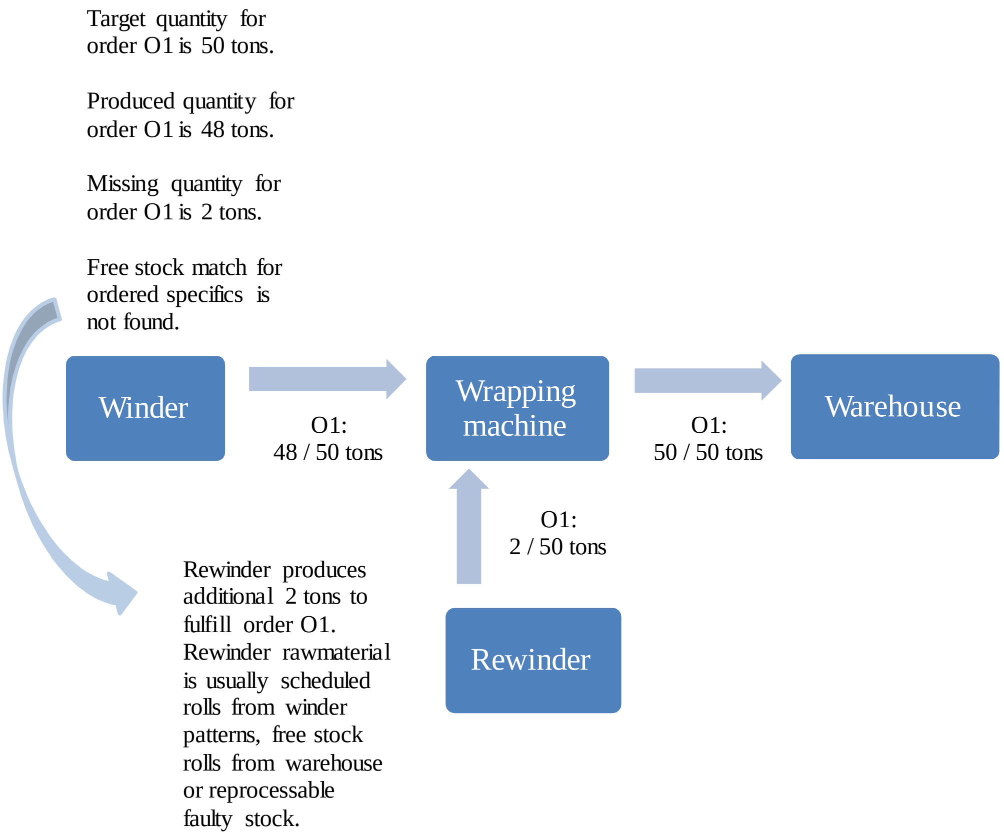



Figure 12. The rewinder production influence on order fulfillment.

From the order fulfillment point of view problems usually occur in the situations described at the occasion number one. The following chain of events may cause confusions in the production balance monitoring, and result as overproduction at the paper machine:

1. The production planner has decided that a part of planned quantity for order item schedule line will be produced at the rewinder. In other words, a part of the planned quantity is scheduled to be produced at the rewinder.

2. Intended rewinder raw material is produced at the winder.

3. The rewinder raw material is defined to be ‘Waste’ in GMES classification due to the logistical and data communicational reasons. Paper quantities which are classified as ‘Waste’ in GMES will not have an effect on the monitored production balances.

4. The winder production which is directed to the rewinder, in other words classified as ‘Waste’, will not have an effect on the run production balances: ‘Produced quantity for run’ and ‘Missing quantity for run’.

5. Since the produced quantity for run is not increasing and on the other hand the missing quantity for run is not decreasing, even though paper is not actually rejected, the paper machine personnel may be unaware of this chain of events and produce surplus paper.

This chain of events is the more adverse the bigger quantity is scheduled to be produced at the rewinder. Minor confusions are undesired but they are not considered as major issues if winder personnel are properly instructed to proceed with exceeding paper quantities. A major issue occurs if confusions befall in the situation where the rewinder is intended to produce a large paper quantity for the run.

## 6.5 The order is partially fulfilled as order transfer(s)

The order can be (partially) fulfilled with the order transfers. The order transfer process is illustrated in figure 13. The order transfers are usually executed as a wrapped paper roll relabeling at the mill warehouse or at the external warehouse. The relabeled paper rolls are usually earlier overproduced for the original order item schedule line, and then classified as free stock.

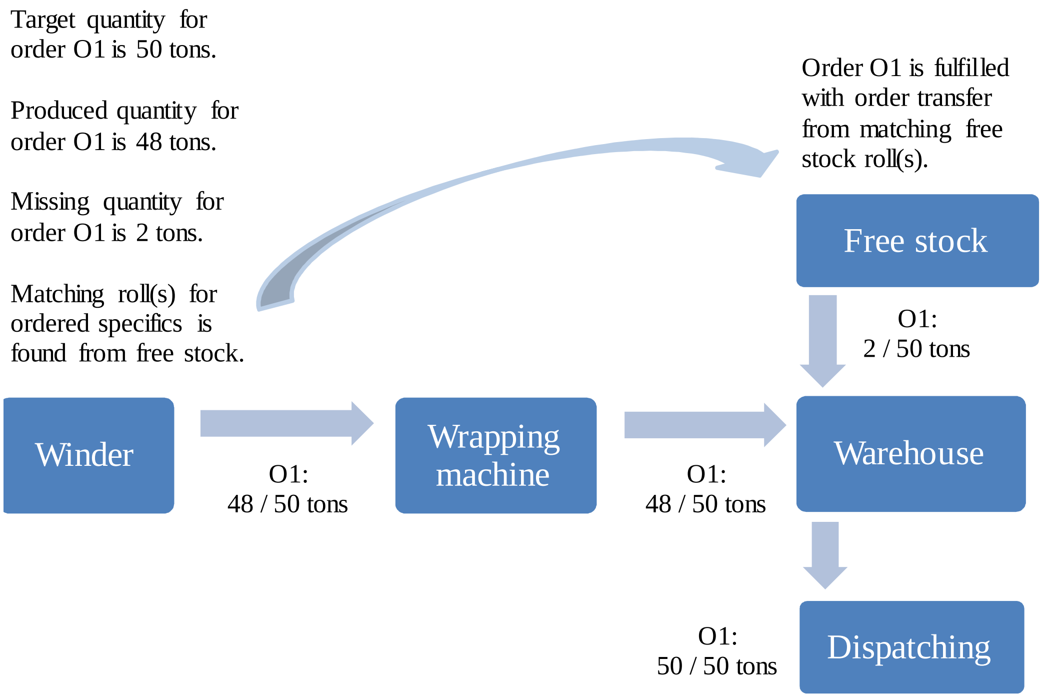



Figure 13. The order transfer process example.

When the order transfer is done at the winder or at the mill warehouse, problems should not occur since the production balances are automatically updated in the GMES.

When the order transfer is done at an external warehouse, for example harbor, problems can occur if the order transfers are not reported to the GMES. The GMES is currently not in use in the external warehouses. The PTD is basically the only telecommunication interface between the GMES and the external warehouse processes.

# 7 ORDER FULFILLMENT MONITORING ISSUES

## 7.1 Paper mill production level issues

Minor confusion between the paper mill balance data at the mill production level can lead to a inaccurate quantity of paper at the mill warehouse and/or dispatching point at the harbor warehouse. To achieve the best result and to avoid misunderstandings at the production and production planning, all end users should be monitoring the same balance data with the same definitions and basis.

In the paper mill production level, especially at the winders and rewinders, the issues concerning the order fulfillment needs to be taken into account. These issues are discussed in the next sections. Next sections also describe the most usual confusions which have occurred at the production level at the paper mills.

### 7.1.1 Order split

One order can be delivered in multiple delivery lots depending on the customers' wishes, the sales contract, the order type and the delivery dates. So one order can contain several order item lines and order item lines can contain several schedule lines. The GMES receives the schedule line level data. The order in the GMES (i.e. normally schedule line) is normally produced in one production lot, but it can be divided to two or more production lots to be produced in the different runs. Small orders are usually produced in one production lot, but as order size grows, possibility for orders separate production lots increases. In figure 14 is described a relationship between an order item line and a schedule lines, contained by order item line.

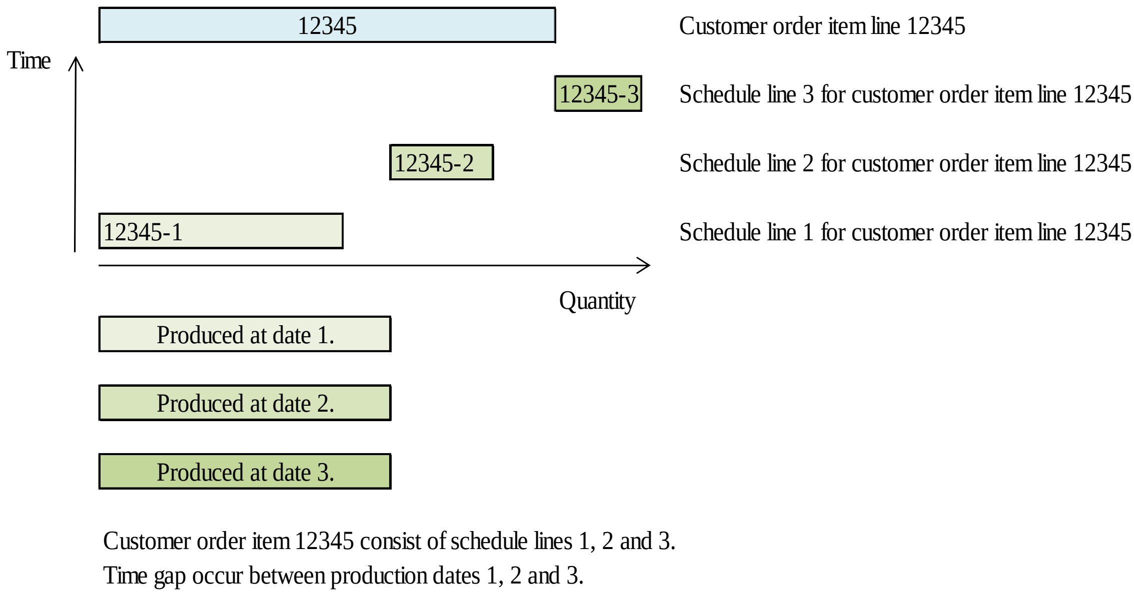



Figure 14. The relationship between a fictional order item line and schedule lines contained by the order item line.

From the order fulfillment point of view it is crucial to identify if the order is fulfilled during the ongoing run or in some other instance. In this case the other instance can mean other production lot, the rewinder production or the order transfer at the mill warehouse or at the harbor warehouse. The winder personnel as well as the other production level personnel have to be aware of the orders separate production lots. This awareness prevents from unnecessary confusions about the paper quantity which should be produced. In the end is eliminated one major reason for the underproduction and the overproduction.

A part of paper mill production personnel monitor only the ordered quantities as significant production balance. This monitoring procedure leads into a situation where all the orders of ongoing production lot are fulfilled regardless whether the order is split or not. Another consequence of described procedure is a situation where the production lot schedules are mixed up in the both production planning level and paper mill production level. This result as an additional work at the production planning level, and as a possibly mixed up production scheme. In the end the consequence is erroneous dispatching bookings. In this paper is presented a solution to identify the production lot in which the order fulfillment should be occurring.

### 7.1.2 Planned vs. ordered amount

A run is aggregated by the production planner. The run always consists of

- same (or alternative) grade paper, and
- a scheduled quantity of paper for the order, a part of order or group of orders.

The production planner plans certain amount of paper for each order. The planned quantity for one order depends on the ordered quantity, order basis, order tolerance and order roll width compatibleness with the other roll widths in the same run. The patterns for run are generated with the calculation algorithm used by the production planner.

One run consists of the planned quantity of paper for one or more orders. If the order is produced in more than one production lot the scheduled quantity is naturally less than the ordered amount. Usually the total planned quantity for one order is exceeding the ordered tons by the customer as shown in figure 15. This happens because of following reasons:

- the physical restrictions for trimming,
- the paper mills want to secure order fulfillment, and
- the production planners personal decision due to the prevalent situation.

These occurrences lead the paper mill production to a situation where surplus paper reels or rolls occur at the end of production line or at the warehouse.

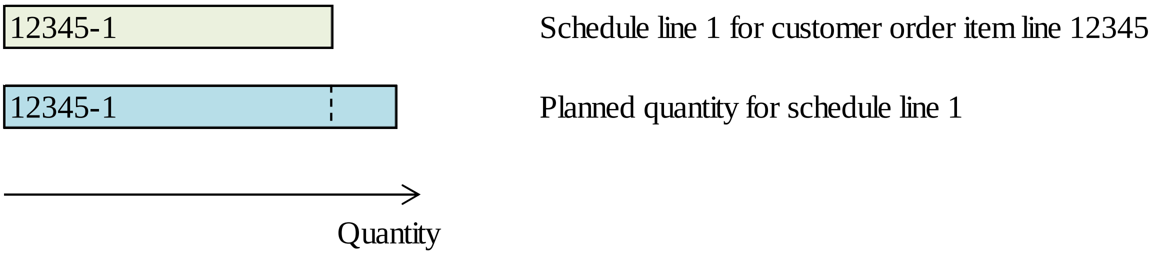



Figure 15. The relationship between the ordered quantity and the planned quantity.

Issues, which are presented in the previous sections, are highly connected to ‘the split order’ –problem which is previously presented in the problem/issue list. The production level personnel in addition with the production supervisors and the production planners have to understand the difference and the relationship between the planned and ordered quantity in order to avoid underproduction and overproduction.

In table 4 is presented a fictional and simplified example of the relationship between three runs and four orders. ‘Fullflag’ states that order has to be fulfilled during said run.

Table 4. The relationship between run and order.

| | **Order 1** | **Order 2** | **Order 3** | **Order 4** | |
|---|---|---|---|---|---|
| Tolerance key | MIN | MIX | EXACT | MAX | |
| Order basis | ROLL | KG | ROLL | KG | |
| Calculated average gross weight of roll (tons) | 3,5 | 1,5 | 3 | 1,4 | |
| Ordered quantity | 100 rolls (350 tons) | 60 tons | 90 rolls (270 tons) | 180 tons | |
| | | | | | Planned quantity (tons) for run: |
| **Run 1 target weight** | 119 | 61,5 | 69 | | 249,5 |
| **Run 3 target weight** | 112 | | 201 | 79,8 | 392,8 |
| **Run 3 target weight** | 122,5 | | | 99,4 | 221,9 |
| Planned quantity (tons) for order: | 353,5 | 61,5 | 270 | 179,2 | 864,2 |

Fullflag

Some paper mill production level monitoring systems have been configured so that it is very hard to detect the real definitions behind terms. This configuration has taken place either in the original catalogue configuration point or later when the paper mill personnel for some reason have wanted to change the configurations. In some cases it is very hard to identify which figures are presenting the scheduled quantities and which are presenting the ordered quantities. In fact, in many cases it is very hard to even identify if one figure is presenting overall target quantity, already produced quantity or missing quantity.

In some paper mills only other quantity, planned or ordered, is monitored even if it would be preferable to monitor both depending on the ongoing situation. The production balance monitoring policies can vary between the paper mills, between the production lines in the same mill or even between the shifts in the same production line. These erroneous process models and non-harmonized production balance data monitoring's results mostly in the same ways than last chapters' problems and confusions. These undesirable results are overproduction, underproduction, additional work, mixed up production lots, mixed up production scheme and mixed up dispatching bookings.

Possible confusions have to be avoided in order to eliminate the underproduction as well as the overproduction. In this paper is presented model to designate operational level catalogues with the understandable and suitable column names. The catalogue column names are in association with the appropriate production balance figure or other information.

### 7.1.3 The order basis

The orders are normally placed against the customer requirements. In addition to the original sales agreements separate order confirmations are sent to the customer to approve the specification. The customer normally places the order quantity based on the weight or count. In some special occasions the customer places the order based on weight but still expects to receive some specific roll count.

The order basis is easily assumed to be simple to understand. Still, when effects of the other significant factors are added in, the influence to the total production balance can be confused by the production level end users. The order basis is highly connected to the order tolerance rules in context of the production balances and the delivered quantities of goods. The main problems and confusions of the tolerance rule are explained in the next chapter.

It has been recognized that in some cases the production level end users did not clearly know the meaning of the order basis. Confusions were detected at the latest when the order basis indicated figures like ‘LB’, ‘1000KG’ and ‘KG’. At the same time in some cases the order basis information was not clearly visible at the production level operation screen. At these points it is unsurprising that mistakes could happen when it comes to the produced quantities.

### 7.1.4 Order tolerance and order tolerance key

A relatively small amount of customer orders are bulk products which are reasonable enough to keep in the stock as the Stock Keeping Units, SKU, to be ready to dispatch whenever needed by the customer. These orders are easy to fulfill quite precisely as demanded. A larger share of order rows is customer orders which have to be produced directly to the specific customer order. This is one reason to agree about the tolerances with the customer. Another reason is to ease the production planning and order fulfillment at the paper mill production and dispatching. Due to the tolerances the paper mill has specific allowance within which it is supposed to deliver the ordered goods.

Investigation on the paper mill’s GMES interfaces seemed so that the tolerances were not an influential attribute in some paper mill production. Further investigation during case Jokilaakso confirmed earlier assumptions. For example in some cases the paper mill production level procedure model was to produce at least the ordered amount by the customer. This procedure is incorrect for example in the case where the ordered quantity is required to be the maximum delivered quantity. Another case occurs when the order is fulfilled during some other instance, e.g. the order transfer in the mill warehouse.

The tolerance rules should be made clear at every paper mill to all end users who have anything to do with the customer order fulfillment. Especially the tolerance rules have to be assimilated by the supervisors, the winder personnel, the rewinder personnel, the wrapping machine personnel, the warehouse personnel and the paper machine personnel. Because of the tolerance rule effect, the production level end user are highly required to understand differences between ordered and scheduled quantity, in addition with the effect of the order basis.

In the next sections are described the basic, and at the same time the most common tolerance keys

According to the business rules and for the good of common harmonization of UPM-Kymmene Oyj production processes, the customer order tolerances will be implemented as they are stated. The tolerance acceptance benefits are numerous but the most notable can be stated to be the clarification on production balance monitoring and the dispatching booking reservations. The common customer order tolerances clarify the production balance monitoring as well as the reporting and the benchmarking between the production lines and the paper mills.

The orders are normally placed against the customer requirement. At the sales agreement approve point, the customer chooses between the order delivery tolerances based on its individual needs. Usually there are three different tolerance options to choose. The different tolerance options are as follows:

- MIN tolerance: The minimum tolerance. The customer needs at least certain quantity of paper tons or rolls. The delivered products over ordered quantity is dependable on how large the total customer order is.

- MAX tolerance: The maximum tolerance. The customer needs at most certain quantity of paper tons or rolls. The delivered products under ordered quantity is dependable on how large the total customer order is.

- MIX tolerance: The mixed tolerance. The customer needs certain quantity of paper tons or rolls, but the delivered quantity can vary under or over the ordered quantity by the customer. The delivered products under or over the ordered quantity is dependable on how large the total customer order is.

In order to be able to operate profitably within these tolerance rules, the paper mill production level personnel have to understand and assimilate the meaning and definition behind tolerance key. In addition to get all the available advantage from the tolerance rules, the paper mill production should be producing maximum amount of products which customer is willing to receive in limits of the tolerance rules.

### 7.1.5 Other factors that has to be considered

In addition with the production quantities, the order basis and the tolerances the production operators have to master following list of factors concerning the order fulfillment:

- the paper grade,
- the roll width, diameter and core,
- possible compound of rolls in the same wrapping,
- the mill ready, and
- the customer specified requirements (paper machine wire side, maximum roll weight, splice count per roll and winder edge roll denial).

The GMES prevents the mistakes and confusion from happening in occasions concerning the paper grade and the roll compounds. Even though above described features are attached in the GMES, the process operator has to be aware of all order fulfillment related factors.

### 7.1.6 The order fulfillment priority

The trim group is a group of order item schedule lines which have a mutual paper mill production details e.g. grade, width, diameter (or length) and core. Further, one trim group has an internal fulfillment priority sequence for the order item schedule lines. This fulfillment priority sequence is normally based on mill ready date. However, the production planner can also modify trim group priorities as desired.

The customer order schedule lines which have alike details concerning the paper mill production are usually placed in the same trim group. Because of the automation, the trim group order schedule lines switch from one to another when the order item schedule line is fulfilled. The trim group prioritization should not be mixed up by the production end users.

## 7.2 The paper production planning level issues

The paper mill production planning related issues are mainly originating from the distances between planning and production plants and production planners' widened responsibility areas.

From production planning point of view the most influential matters concerning order fulfillment are

- inaccurate target quantities for the scheduled run,
- the communication between the paper mill production and the paper mill production planning, and
- a defective training and ignorance of the production line characteristics.

## 7.3 The warehousing and dispatching issues

The paper mill overproduction normally ends up filling the warehouse resources. This happens because it is more profitable for the paper mill to find an alternative purchaser for the product or use it as a raw material at the rewinder or roll saw than recycling it and using it as a raw material at the paper machine. This procedure generates a deteriorate mill warehouse stock turnover and increased bound capital in the mill warehouse. It also causes an additional labor reservation in the mill warehouse and in the future reprocess location.

# 8 CASE JOKILAAKSO

## 8.1 JOK paper mills introduction

Jokilaakso paper production plant consists of two paper mills; Jämsänkoski paper mill and Kaipola paper mill. As it noted earlier in this paper, Jokilaakso paper production plant includes total of seven paper production lines; four paper production lines in Jämsänkoski paper mill and three paper production lines in Kaipola paper mill. In this instance these two paper mills are investigated as one paper production plant.

Jämsänkoski paper mill consist of four paper production lines. Later in this chapter Jämsänkoski paper mill production lines are called as noted in the brackets;

- Jämsänkoski paper production line 3 (JAM 03)
- Jämsänkoski paper production line 4 (JAM 04)
- Jämsänkoski paper production line 5 (JAM 05)
- Jämsänkoski paper production line 6 (JAM 06)

Kaipola paper mill consist of three paper production lines. Later in this chapter Kaipola paper mill production lines are called as noted in the brackets;

- Kaipola paper production line 4 (KAI04)
- Kaipola paper production line 6 (KAI06)
- Kaipola paper production line 7 (KAI07)

Jokilaakso paper mills production lines’ assemblies and products are described in table 5. Jokilaakso paper mills production lines’ characteristics are presented in table 6.

Table 5. Jokilaakso paper mills production lines' assemblies and products.

| Mill | Paper production line | Paper machine | Rereeler | Calender | Winder | Rewinder | Roll saw | Wrapping machine | Product |
|---|---|---|---|---|---|---|---|---|---|
| | | Production line machine count | | | | | | | |
| Jämsänkoski paper mill | JAM 03 | 1 | | 1 | 1 | 1 (shared) | | 1 (shared) | Special papers such as label paper |
| | JAM 04 | 1 | | | 1 | | | | Special papers such as sticker facing paper |
| | JAM 05 | 1 | | 3 | 2 | 1 (shared) | 1 | 1 (shared) | Uncoated magazine paper |
| | JAM 06 | 1 | | 3 | 2 | | | | Uncoated magazine paper |
| Kaipola paper mill | KAI 04 | 1 | | | 2 | 1 | | 1 | Catalogue and newspaper |
| | KAI 06 | 1 | 1 | 2 | 2 | 1 | | 1 | LWC -paper |
| | KAI 07 | 1 | | | 2 | 1 | | 1 | Newspaper |

Table 6. Jokilaakso paper mills production lines' detailed characteristics.

| | | Grades | Production | | Run characteristics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Paper grade are densities | Packed gross production per year ( 1000 tons) | Number of order rows per year | Number of runs per year | Number of orders per run | Number of patterns per run | Number of sets per pattern | Number of positions per set |
| Jämsänkoski paper mill | JAM 03 | 50 - 85 grams per square metre | 110 | 3000 | 750 | 3 - 10 | 3 - 15 | 5 - 130 | 2 - 12 |
| | JAM 04 | 60 - 135 grams per square metre | 115 | 4500 | 570 | 3 - 25 | 3 - 15 | 5 - 130 | 2 - 12 |
| | JAM 05 | 39 - 60 grams per square metre | 170 | 3200 | 700 | 1 - 30 | 1 - 15 | 1 - 60 | 2 - 12 |
| | JAM 06 | 39 - 56 grams per square metre | 230 | 1500 | 650 | 1 - 30 | 1 - 15 | 1 - 60 | 3 - 12 |
| Kaipola paper mill | KAI 04 | 29 - 40 grams per square metre | 120 | 1800 | 470 | 1 - 20 | 1 - 10 | 1 - 100 | 2 - 13 |
| | KAI 06 | 42 - 65 grams per square metre | 230 | 1600 | 450 | 1 - 20 | 1 - 10 | 1 - 100 | 2 - 13 |
| | KAI 07 | 34 - 52 grams per square metre | 200 | 2300 | 530 | 1 - 20 | 1 - 10 | 1 - 100 | 2 - 13 |

## 8.2 Situation before fall 2012

The GMES was implemented in Jokilaakso paper production plant in February 2012. The GMES rollout project was active at Jokilaakso paper production plant since July 2011.

Since the fall 2012 was noticed multiple malfunctions and erroneous procedures which had direct or indirect effect on the order fulfillment. Below is listed and described the most influential procedures:

- Jämsänkoski paper mill production follows only the run balances.
- Kaipola paper mill production follows only the order balances.
- The tolerance is unknown construct.
- The tolerance key is unknown factor.
- The order basis is always considered to be weight, in some cases roll based order with ‘EXACT’ tolerance key was taken into account.
- The order transfers which were done in the harbor warehouse did not have effect on the production levels in GMES.
- The winder production which was intentionally directed to the rewinder did not have an effect on the run balance.
- The production operators had confusions about the gross, net and net-net value differences.

The first development action concerning order fulfillment in Jokilaakso was implemented to the wrapping machines in July 2012. This development action modified the wrapping machine logic so that the overproduction for the individual order item was automatically turned into a “free stock” classification with no reservation for any delivery lot.

## 8.3 The development actions

The following topics are reviewed in this chapter:

- The GMES catalogue column explanations for the production.
- A basic action model and guide for the winder to complete a run.
- An operation screen catalogue model and catalogue configurations for the successful production monitoring.

### 8.3.1 The GMES catalogue column explanations for the production

The GMES operation screen catalogues provide all essential information for the production. In order for that information to be functional, it has to be understandable. In the table 7 is described the most important information provided by the GMES operation screen catalogue columns. Some examples are included to support the actual purpose.

Essential information for the order fulfillment includes:

- The order basis, which indicates whether the customer has ordered paper quantity based on weight or roll count.
- The order diameter or length, which indicates whether the customer wants its rolls based on the roll diameter or track length.
- The tolerance key, which indicates what kind of quantity margins the customer permits.
- ‘Fullflag’ indicates whether the order is scheduled to be fulfilled in the current run or in the future production.
- The production balances for the order includes the ordered target quantity, the produced quantity and the missing quantity.
- The production balances for run includes the run target quantity, the produced quantity and the missing quantity.

Following table 7 should be understood and then used as a supportive material for the successful order fulfillment at the winders, the rewinders and the production planning. The information provided by table 7 can also be useful for the personnel through the production chain.

Table 7. The GMES catalogue column explanations for the production.

**GMES column explanations for production**

| **Column name**<br>**(Column name at GMES)** | **Explanation** |
|---|---|

**Order data**

| | |
|---|---|
| Order basis<br>(Basis) | Customer order basis<br>If basis is weight (KG/1000KG/LB) order will be fulfilled according to produced tons.<br>If basis is count (ROLL) order will be fulfilled according to produced number of rolls. |
| Diameter or lenght<br>(DiamLength) | e.g. 1: D/1250/29200<br>Roll will be cut to 1250 mm according to diameter ( + / - tolerance)<br>e.g. 2: L/1250/29200<br>Roll will be cut to 29200 m according to lenght ( + / - tolerance) |
| Tolerance | Order fulfillment tolerances |

| Quantity Tolerances | | | | Diameter Tolerances | Running Meter Tolerances |
|---|---|---|---|---|---|
| | Primary Tolerances | | Customer specific | | |
| MIX | Under 1 ton<br>1 ton but under 5 tons<br>5 tons but under 10 tons<br>10 tons but under 100 tons<br>100 tons and over | +/- 15%<br>+/- 10%<br>+/- 7,5%<br>+/- 5%<br>+/- 3% | -1/+1 package | TARGET specified:<br>-50/+20 mm | +/- 50 m |
| MIN | Under 1 ton<br>1 ton but under 5 tons<br>5 tons but under 10 tons<br>10 tons but under 100 tons<br>100 tons and over | + 15%<br>+ 10%<br>+ 7,5%<br>+ 5%<br>+ 3% | -0/+1 package | MIN specified:<br>-0/+20 mm | |
| MAX | Under 1 ton<br>1 ton but under 5 tons<br>5 tons but under 10 tons<br>10 tons but under 100 tons<br>100 tons and over | - 15%<br>- 10%<br>- 7,5%<br>- 5%<br>- 3% | -1/+0 package | MAX specified:<br>-50/+0 mm | |
| EXACT | NOT applicable | | Applicable for package based orders only | NOT applicable | NOT applicable |

| e.g. 50 t, order is based on weight (KG): | e.g. 60 rolls, order is based on roll count (ROLL): |
|---|---|
| MIX: 47,5 t - 52,5 t, primarily over 50 t | MIX: 59 - 61 rolls |
| MIN: 50 t - 52,5 t | MIN: 60 - 61 rolls |
| MAX: 47,5 t - 50 t | MAX: 59 - 60 rolls |
| | EXACT: 60 rolls |

| | |
|---|---|
| Order Fullflag (Fullflag) | If there **IS an ASTERISK** in the column, **ORDER** will be fulfilled.<br>If there **IS NOT an ASTERISK** in the column, **RUN** will be fulfilled. |

**Details for run defined by production planner:**

| | |
|---|---|
| Run, target weight/count (Run trg w/c) | Target weight and count of run. |
| Run, produced weight/count (Run prod w/c) | Produced weight and count for run. |
| Run, to do weight/count (Run missing w/c) | Weight and count which are still to be done for this run.<br>Calculation: ('Run target weight/count') - ('Run produced weight/count')<br>You have to monitor this columns data if there **IS NOT an ASTERISK** in the **fullflag** column |

**Details for order:**

| | |
|---|---|
| Order, to do weight/count (Ord missing w/c) | Weight and count which are still to be done for this order<br>Calculation: ('Ordered weight/count') - ('Order produced weight/count')<br>You have to monitor this columns data if there **IS an ASTERISK** in the **fullflag** column |
| | Missing amount of rolls for order<br>Calculation: ('Order To Do weight') / ('Order produced avg weight') |
| Order, produced avg weight (Ord avg w) | Average weight of produced roll for order |
| Ordered weight/count (Ord trg w/c) | Target weight and count for order |
| Order, produced weight/count (Ord prod w/c) | Produced weight and count for order |
| Order, wrapped weight/count (Ord wr w/c) | Wrapped weight and count for order |
| Maximum weight for roll (Ord max w) | Maximum weight of a roll (If 0, then not specified) |

### 8.3.2 A basic action model for the winder to complete a run and order

1. The patterns of ongoing run should be produced according to the production planner’s instructions.

2. When all of the patterns of ongoing run are produced, the ’Run status’ tab should be checked for the incomplete orders. The fulfilling pattern(s) should be created and produced for the incomplete orders.

3. If the surplus paper is still available and all orders of ongoing run are fulfilled, the paper will be produced to the ’Reserve orders’ offered by the production planner (OR the winder personnel in cooperation with the supervisor search for the orders which are NOT yet scheduled for any run.)

### 8.3.3 Operation screen catalogue model and configurations

The operation screen catalogue is organized so that the essential information is available in a logical order for the end user to monitor. The operation catalogue should be monitored as instructed in table 7 and the production end users should be operating as guided in the previous chapter named ‘The basic action model/guide for the winder to complete a run and order’.

In the appendix 1/9 is presented a basic model for ‘Tracks’ –tab at the winder operation screen. The visible columns can be added or removed depending on the production plant needs and the configurable tab. The tab content and the configuration can vary depending on its function in the production and needed information by the end users. The column names which are vulnerable for confusions are clarified in table 7.

In appendix 2/9 is presented the catalogue configurations for ‘Tracks’ –tab at the winder operation screen. The catalogue configurations define which columns and information are visible at the operation catalogues. The catalogue configurations should be modified by the competent users only. The content of column numbers 26 to 31 are set to be invisible, but can be set visible if desired. The additional information can be added to the configurations from the databases like production lot, mill order, balances and active pattern.

# 9 ORDER FULFILLMENT PERFORMANCE MEASUREMENT

Overproduction and underproduction are in main scope of the performance measurement since the target of this work is to improve the order fulfillment in the paper production and the focus is on produced quantities. Therefore, in order to perform a successful performance measurement, overproduction and underproduction in the paper production have to be defined.

Overproduction can be investigated from two points of view; the paper production quantities for certain orders and the warehouse stock quantity levels.

The data for the paper production quantities for certain orders can be acquired from the data communications between the shop floor control/automation and the GMES. In other words, the paper production quantities are available in the roll history event logs by sorting them by order items and order rows.

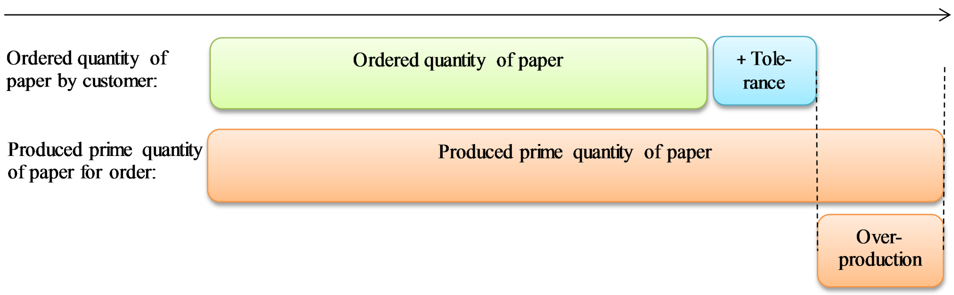



Figure 16. A visual approach for to describe overproduction.

After the visual approach is presented in figure 16, overproduction can be defined simplest by the following formula:

*Overproduction =*
*Produced prime quantity for order*
*- Ordered quantity of paper*
*+ / - Tolerance*

Overproduction can also be investigated from the warehouse stock levels point of view. This aspect is has to be considered because if the process works as determined, overproduction piles up in the free stock lots in the warehouse. Overproduction which is located in the mill warehouse can be tracked with the GMES and PTD classifications.

Following statements has to fulfill that the warehouse stock can be stated as overproduction:

- the paper roll is classified as prime
- the paper roll is not reserved for any order
- the paper roll is classified as obsolete
- the paper roll is originally produced against customer order

Underproduction can be investigated from the delivered quantities point of view. If the delivered quantity is lower than what is agreed in the sales contract (within tolerances), the missing quantity can be defined to be underproduction as illustrated in figure 17.

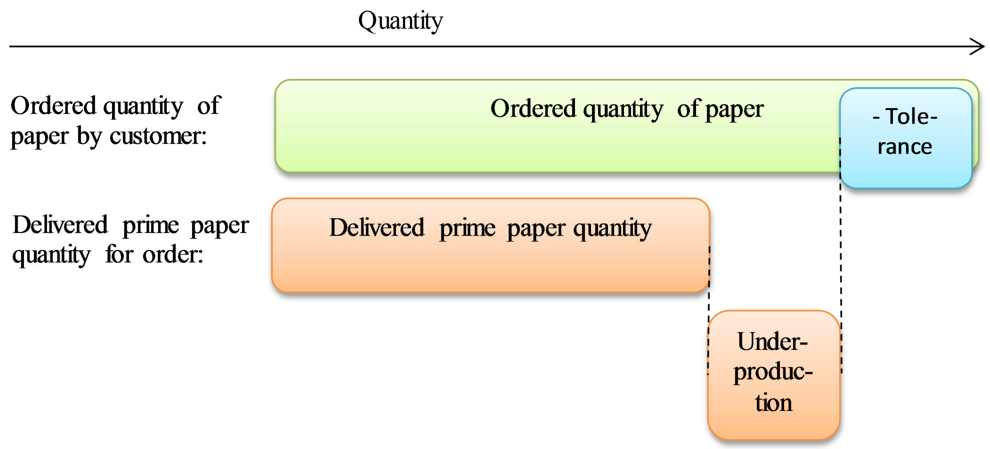



Figure 17. A visual approach for to describe underproduction.

After a visual approach is presented in figure 17, underproduction can be defined simplest by the following formula:

*Underproduction =*
*Delivered prime paper quantity*
*- Ordered quantity of paper*
*+ / - Tolerance*

## 9.1 Jokilaakso

The overall order fulfillment improvement in Jokilaakso paper production plant is presented in this chapter. Main focus of the performance measurement is in over-production and underproduction measurement. Overproduction is examined from two separate viewpoints:

- the produced quantities viewpoint, and
- the warehouse stock level viewpoint.

Underproduction is examined from the delivered quantities point of view.

Individual paper production lines are also examined by their overproduction tons and underproduction tons. Each of these paper production lines are presented in table 5 and table 6 by their individual characteristics.

The development actions and GMES redesign were implemented 17.12.2012. This should be noted when following performance measurement tables are examined.

The following figures are based on the order item data which was gathered by system supplier experts. The table indexes are not coherent between the different production lines.

In table 8 can be seen the overall overproduction at the paper production lines in Jokilaakso paper production plant. The monthly overall overproduction quantity has a decreasing trend. The decreasing trend in overproduction quantity development began in May, 2012, and has been mainly continuous since then. In table 9 can be seen decreasing trend in overproduction quantities in Jokilaakso by quarter. The quarter data chart (table 9) includes a forecast of the overproduction data from March 2013. The forecast is based on the trend from April 2012 to February 2013.

Table 8. Overproduction by mill ready date (MRD) month in Jokilaakso paper production plant.

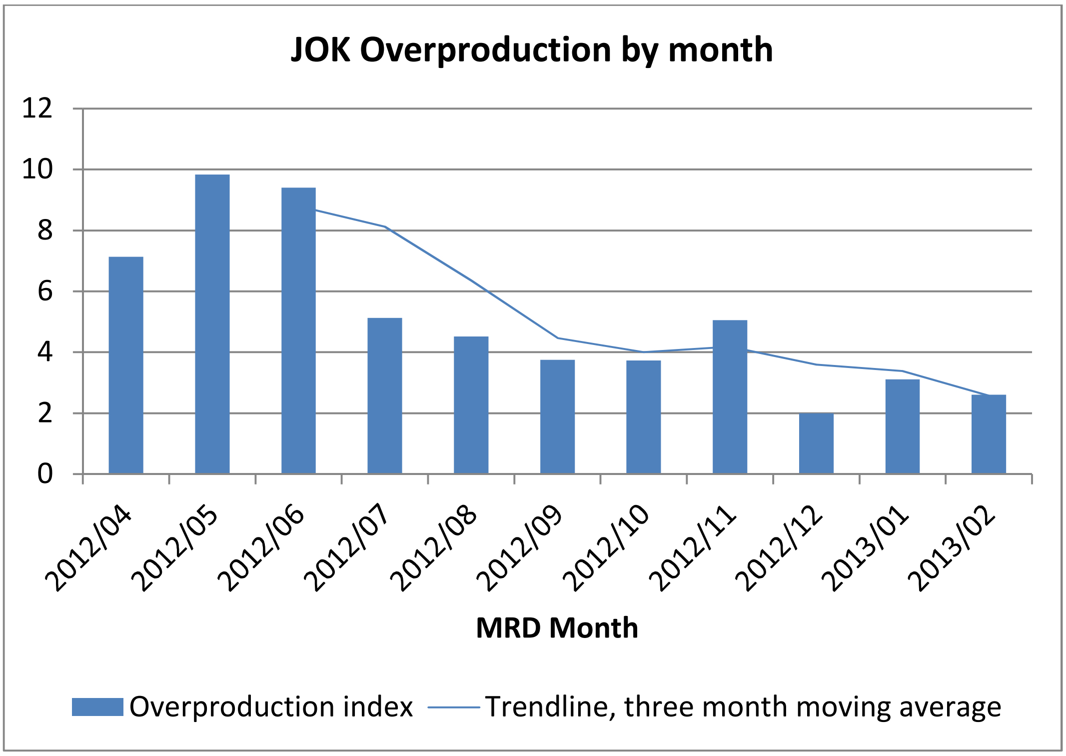



Table 9. Overproduction by quarter in Jokilaakso paper production plant.

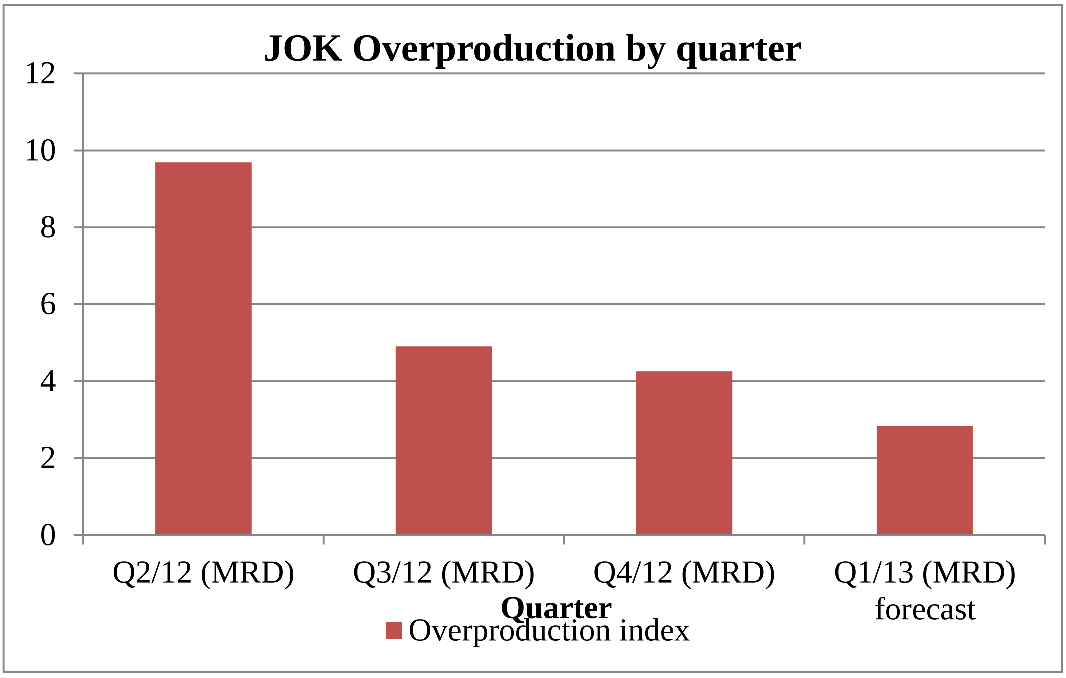
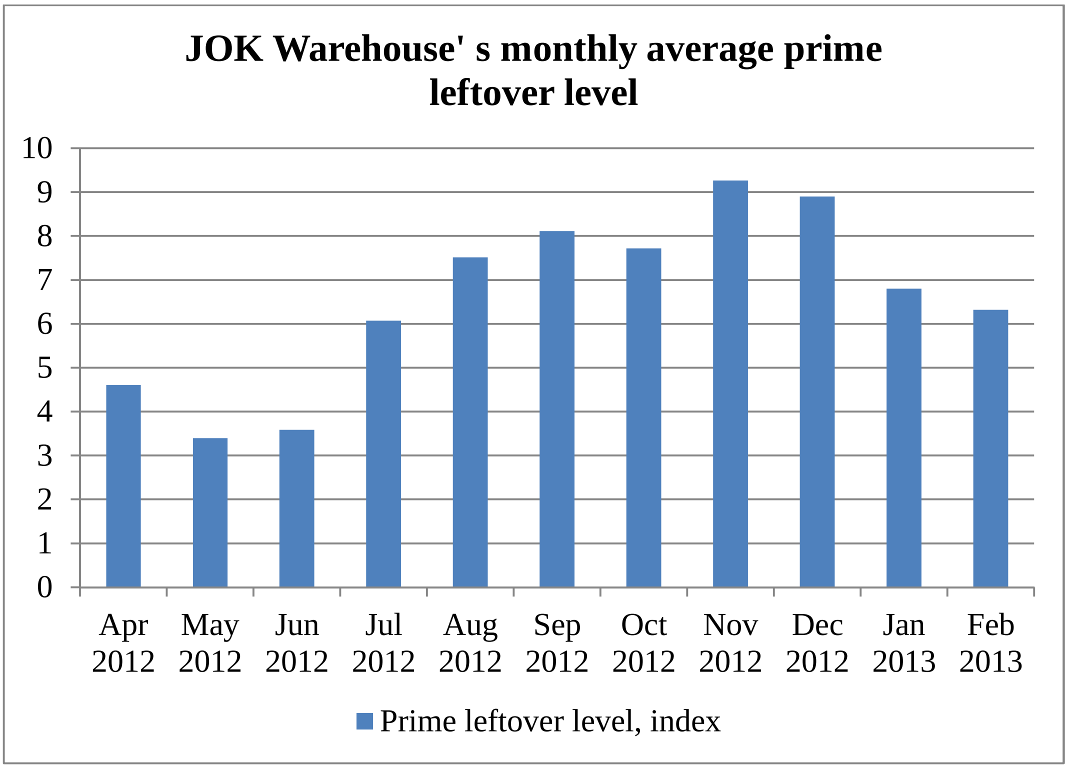


Table 10 presents Jokilaakso warehouse’s monthly average prime leftover level. Jokilaakso warehouse’s monthly average prime leftover level also indicates the order fulfillment success since the overproduction has a tendency to pile up in the mill warehouse’s free stock. In table 10 can be detected significant positive development since December, 2012.

Table 10. The monthly average leftover level in JOK mill warehouse’s.




Order fulfillment can also be investigated from the underproduction viewpoint. In table 11 can be seen the monthly overall underproduction at the paper production lines in Jokilaakso paper production plant. The monthly overall underproduction quantity has a decreasing trend. The decreasing trend in underproduction quantity development began in May, 2012, and has been mainly continuous since then. In table 12 can be seen decreasing trend in underproduction quantities in Jokilaakso by quarter. The quarter data chart (table 12) includes a forecast of the underproduction data from March 2013. The forecast is based on the trend from April 2012 to February 2013.

Table 11. Underproduction by MRD month in Jokilaakso paper production plant.

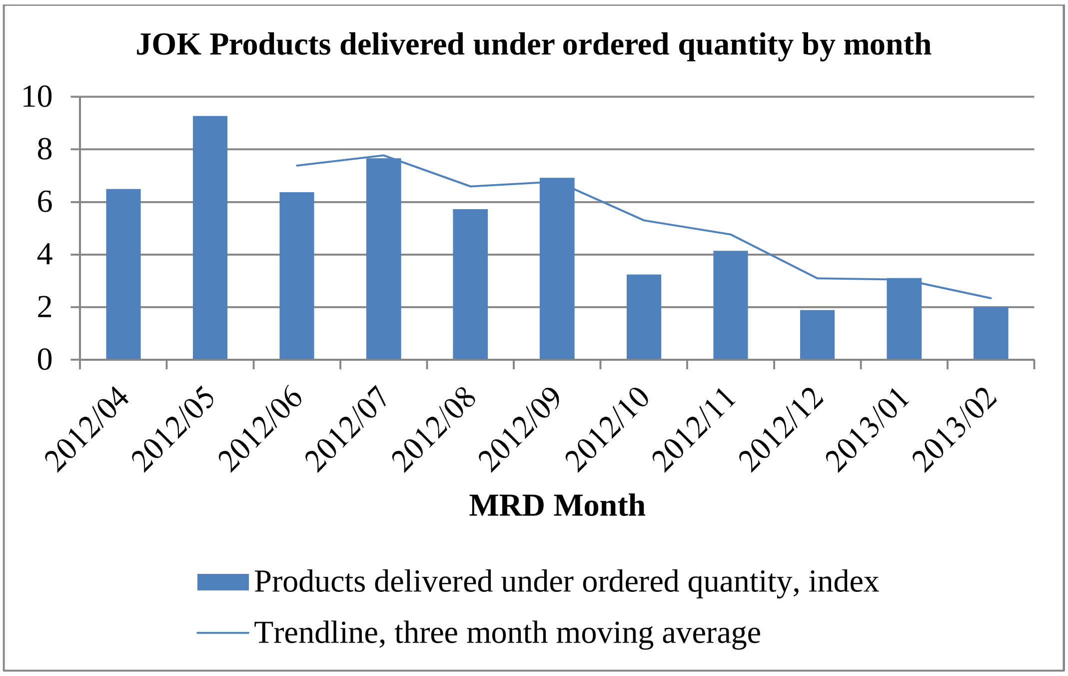
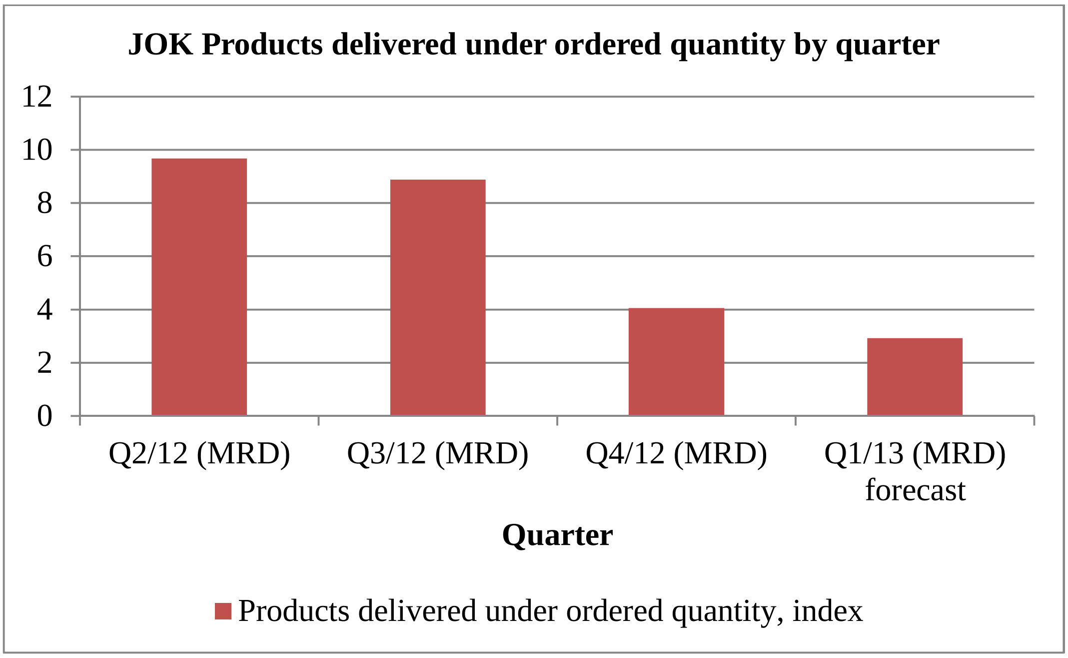



Table 12. Underproduction by quarter in Jokilaakso paper production plant.



The most important aspect of this performance measurement is the overall order fulfillment in Jokilaakso paper production plant. As it can be seen in previous sections, overall order fulfillment has been improved in Jokilaakso paper production plant. However, the order fulfillment can also be discussed at the individual paper production line level.

In appendixes 3/9 to 9/9 can be seen each Jokilaakso paper production line investigated by its overproduction and underproduction quantity indexes. In appendixes 3/9 to 9/9, seven Jokilaakso paper production lines are called JOK 1/7 – JOK 7/7.

At individual paper production line level the order fulfillment success can be seen at the long term trend since the order backlog has significant impact on the trimming results and the run consists. Furthermore, one humane mistake, telecommunications error or system malfunction can result as a relatively large order fulfillment distraction in the statistics. Examples from this kind of behavior can be seen in overproduction in appendix 3/9 and in underproduction in appendix 6/9.

# 10 CONCLUSIONS

The GMES program has achieved the given targets to provide one common mill execution system to each mill and harmonize main concepts and processes. During the rollout projects, the paper mills have had a chance to configure balance monitoring catalogues but they have been lacking good templates and discussion between the different modules. The definitions of vendible product and reasons why something is done must be clear to every end user. The program installation and personnel training is not enough at the system implementation point. Furthermore, the personnel training focus is misleading in system usage although the main focus should be pointed out to the understanding of global processes. Employee has to know the purpose and the target of the job, before he/she can think about how to do it. Everyone on the production line should know which production factors have an effect on the order fulfillment.

Only the meaningful and relevant production balance data with understandable definitions should be visible at the GMES operation screen. This is the way to get rid of the confusion causes. And if confusions are occurring, at least production supervisor should have the knowledge what should be done next.

It is surprising to realize how many different procedures and assumptions about the process there is inside the corporation. Unfortunately most of the erroneous procedures and assumptions are extremely harmful especially when it comes to the subject of order fulfillment.

The GMES production balance catalogues were reconfigured and explained in order to clarify the monitoring of the production balance details. In addition, the guide for the successful order fulfillment was gathered together and instructed to end-users. When the product definitions are made clear and every production end user is aware of the factors effecting on the order fulfillment, the amount of occurring confusions decreases. In this case, the quantities of overproduction and underproduction decreased. From the warehouse viewpoint the stored quantity of prime leftover decreased. All this indicates to the procedure development concerning the exceeding paper quantities handling at the winders. Decreased underproduction levels indicate that there have not been major problems with the actual paper production and the produced paper quantities are produced to the originally scheduled orders.

The development actions related feedback from the Jokilaakso production plant end users was mainly positive. The general opinion at Jokilaakso was that the production balances are now easier to monitor and the relevant production information was easily available. Some end-users expressed their satisfaction for the catalogue column explanations since they can now do their job according to globally harmonized production procedures.

Performance measurements indicated that overall overproduction in Jokilaakso paper production plant has a decreasing trend. The influential factors for the decreasing trend of overproduction and underproduction are as follows:

- personnel has learned to use new mill execution system,
- new configuration model and order fulfillment guide,
- customer roll reservation release method at wrapping machine, and
- order backlog situation has significant impact.

It is extremely challenging to point out exactly how much each individual factor influenced on the order fulfillment improvement. However, from April 2012 to February 2013 the average monthly overproduction quantity in Jokilaakso has decreased 63, 5 %. Overproduction has to be decreased to minimum as it is misuse of the raw material and labor.

At the same time, from April 2012 to February 2013, overall underproduction in Jokilaakso has decreased 69, 0 %. Underproduction has to be eliminated from the process outcomes since it results not only as decreased sales, but also as degenerated relationships with the customers.

The redesign and development actions such as

- the GMES catalogue column explanations for the production,
- a basic model for the winder to complete a run or order, and
- the winder operation screen catalogue redesign and catalogue configurations

are currently implemented only in Jokilaakso paper production plant. In order to obtain all the order fulfillment improvement related benefits, the same harmonization exercise should be executed also in UPM-Kymmene Oyj's other paper production plants.

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**APPENDIX 1/9:** The winder catalogue for ’Run status’, ’Tracks/Positions’ and ‘Search order’ -tabs

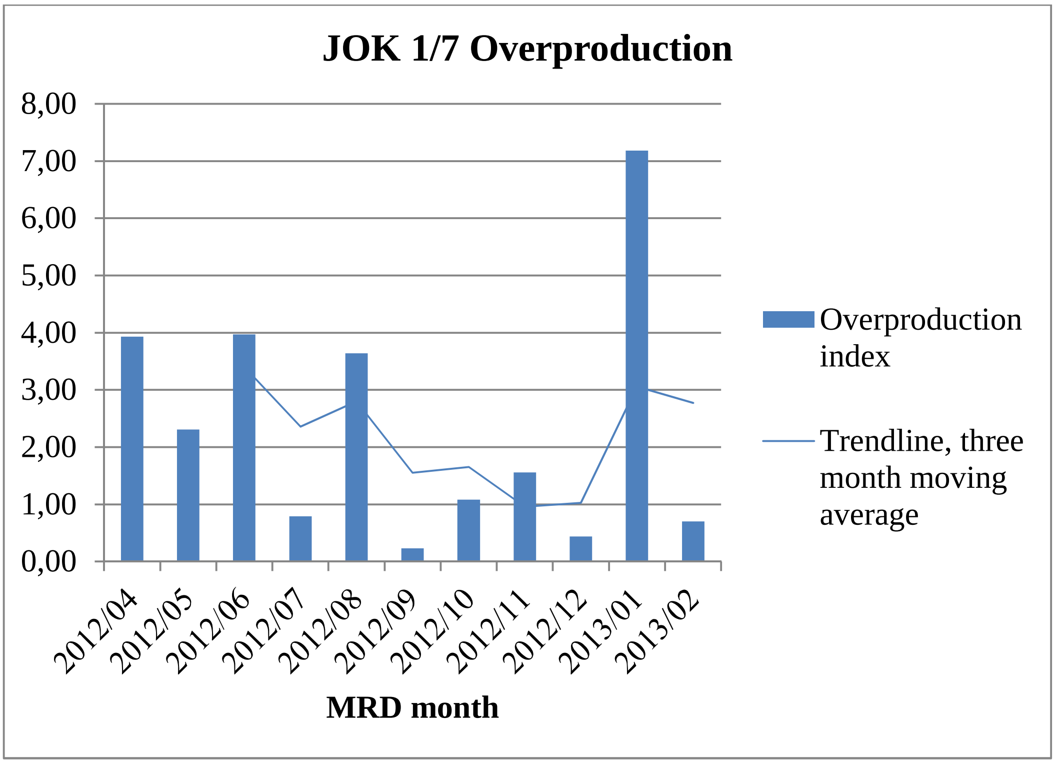
Tracks | Set log

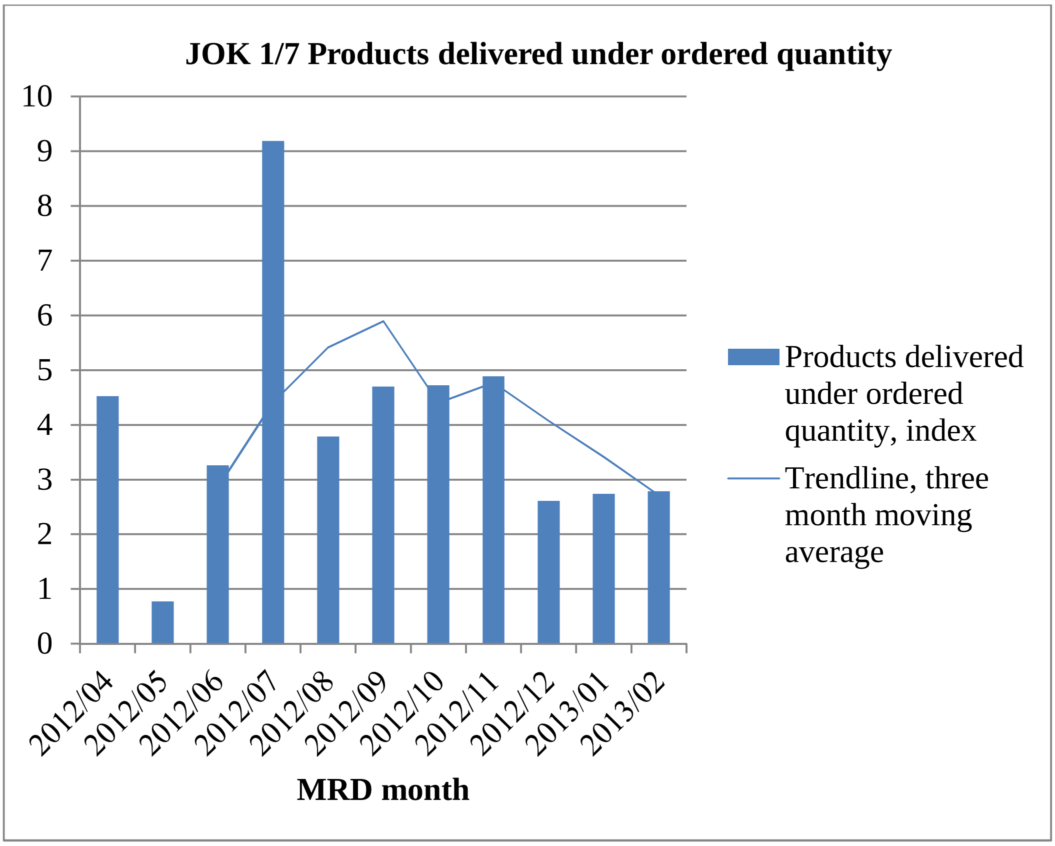
| Position | Grade | OrderString | ShortCode | Width | DiamLenght | Core | Fullflag | Basis | Tolerance | Ord trg w/c | Ord prod w/c | Ord wr w/c | Ord missing w/c | Run missing w/c | Run trg w/c | Run prod w/c | Run wr w/c | Ord avg w | Ord max w | Ord Cnt/Pkg | Run RejToRW | Ord ExMill | Customer | Classification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | RSM557 | 4288050-01-1-1 | U4EB | 1000 | D/1000/16417 | ECO-8/76/15 | * | 1000KG | MIX | 10,0/11 | 13,2/14 | 11,3/12 | -3,2/-3 | -2,9/-3 | 10,4/11 | 13,2/14 | 11,3/12 | 945 | 0 | 1 | 0,0/0 | 05.12.2012 | HELPRINT OY | A WR 0000 |
| 2 | RSM557 | 4288050-01-1-1 | U4EB | 1000 | D/1000/16417 | ECO-8/76/15 | * | 1000KG | MIX | 10,0/11 | 13,2/14 | 11,3/12 | -3,2/-3 | -2,9/-3 | 10,4/11 | 13,2/14 | 11,3/12 | 945 | 0 | 1 | 0,0/0 | 05.12.2012 | HELPRINT OY | A WR 0000 |
| 3 | RSM557 | 4288050-01-1-1 | U4EB | 1000 | D/1000/16417 | ECO-8/76/15 | * | 1000KG | MIX | 10,0/11 | 13,2/14 | 11,3/12 | -3,2/-3 | -2,9/-3 | 10,4/11 | 13,2/14 | 11,3/12 | 945 | 0 | 1 | 0,0/0 | 05.12.2012 | HELPRINT OY | A WR 0000 |
| 4 | RSM557 | 4288050-01-1-1 | U4EB | 1000 | D/1000/16417 | ECO-8/76/15 | * | 1000KG | MIX | 10,0/11 | 13,2/14 | 11,3/12 | -3,2/-3 | -2,9/-3 | 10,4/11 | 13,2/14 | 11,3/12 | 945 | 0 | 1 | 0,0/0 | 05.12.2012 | HELPRINT OY | A WR 0000 |
| 5 | RSM557 | 4288050-01-1-1 | U4EB | 1000 | D/1000/16417 | ECO-8/76/15 | * | 1000KG | MIX | 10,0/11 | 13,2/14 | 11,3/12 | -3,2/-3 | -2,9/-3 | 10,4/11 | 13,2/14 | 11,3/12 | 945 | 0 | 1 | 0,0/0 | 05.12.2012 | HELPRINT OY | A WR 0000 |
| 6 | RSM557 | 4288050-01-1-1 | U4EB | 1000 | D/1000/16417 | ECO-8/76/15 | * | 1000KG | MIX | 10,0/11 | 13,2/14 | 11,3/12 | -3,2/-3 | -2,9/-3 | 10,4/11 | 13,2/14 | 11,3/12 | 945 | 0 | 1 | 0,0/0 | 05.12.2012 | HELPRINT OY | A WR 0000 |
| 7 | RSM557 | 4288050-01-1-1 | U4EB | 1000 | D/1000/16417 | ECO-8/76/15 | * | 1000KG | MIX | 10,0/11 | 13,2/14 | 11,3/12 | -3,2/-3 | -2,9/-3 | 10,4/11 | 13,2/14 | 11,3/12 | 945 | 0 | 1 | 0,0/0 | 05.12.2012 | HELPRINT OY | A WR 0000 |
| 8 | RSM557 | 4288050-01-1-1 | U4EB | 1000 | D/1000/16417 | ECO-8/76/15 | * | 1000KG | MIX | 10,0/11 | 13,2/14 | 11,3/12 | -3,2/-3 | -2,9/-3 | 10,4/11 | 13,2/14 | 11,3/12 | 945 | 0 | 1 | 0,0/0 | 05.12.2012 | HELPRINT OY | A WR 0000 |

**APPENDIX 2/9:** The winder catalogue configuration for ’Run status’, ’Tracks/Positions’ and ‘Search order’ –tabs

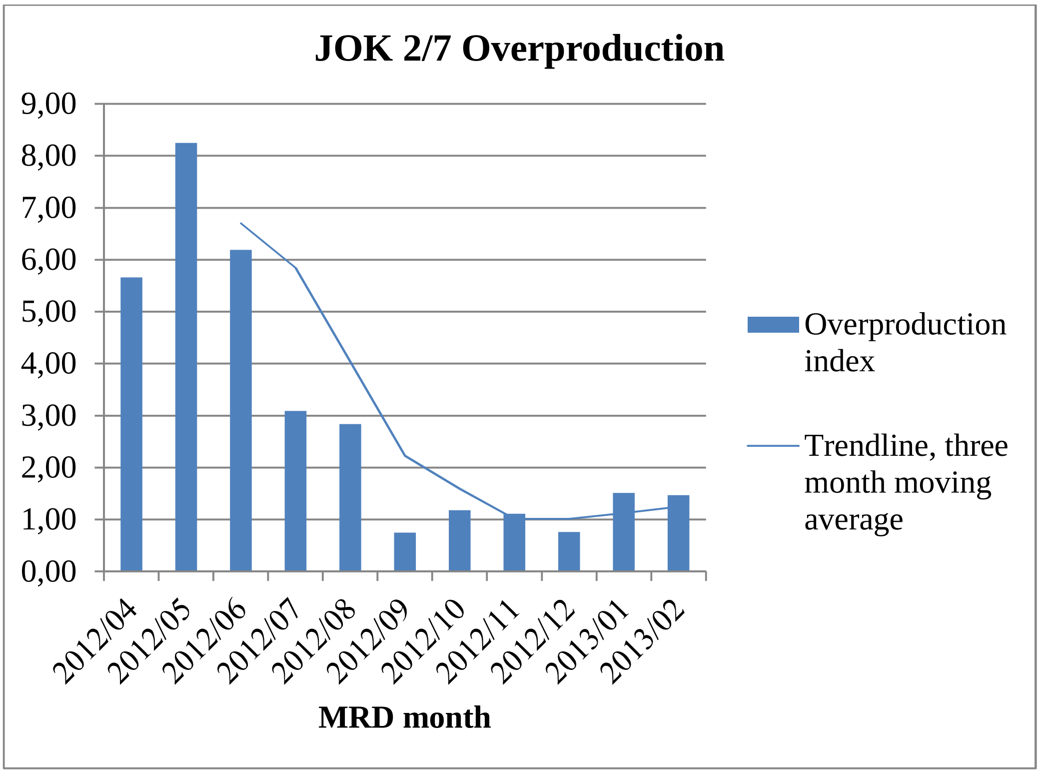
| Pos... | Sarake | Määrite | M... | Sa... | Koko | Väripohja | I | Hdr san. koodi | Tyyppi | I |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | PosiNbr | PosiNbr | 0 | 55 | | | | Position | int | |
| 2 | GradCode | $MillOrder.GradCode | 0 | 60 | | | | Grade | CRuString | |
| 3 | OrderString | M_TextMillOrder | 0 | 90 | | ORDETYPE | | OrderString | CRuString | |
| 4 | OShortCode | $MillOrder.ShortCode | 0 | 65 | | | | ShortCode | CRuString | |
| 5 | PosiWidt | PosiWidt | 0 | 45 | WIDT | | | Width | CRuDouble | |
| 6 | OLengDiam | $MillOrder.LengDiam \|V\| $MillOrder.OrdeDiam \|V\| $MillOrder.OrdeLeng | 0 | 90 | | | | DiamLenght | CRuDouble | |
| 7 | OCoreCode | $MillOrder.CoreCode | 0 | 80 | | | | Core | CRuString | |
| 8 | RFullFlag | $ProdLot.M_TextFullFlag | 0 | 50 | | FIXORDEFLAG | | FullFlag | int | |
| 9 | OrdeBasi | $MillOrder.OrdeBasi | 0 | 55 | | | | Basis | CRuString | |
| 10 | OMinOrMax | $MillOrder.MinOrMax | 0 | 70 | | | | Tolerance | CRuString | |
| 11 | OTrgWgtCnt | $MillOrder.M_TargetGrossWeight \|V\|$MillOrder.M_TargetCount | 0 | 70 | PRODAMNT\|\|CNT | | | Ord trg w/c | CRuDouble | |
| 12 | OProdWgtCnt | $MillOrder.$BalanceObject.M_ProducedGrossWeight \|V\| $MillOrder.$BalanceObject.M_ProducedCount | 0 | 80 | PRODAMNT\|\|CNT | | | Ord prod w/c | CRuDouble | |
| 13 | OWrapWgtCnt | $MillOrder.$BalanceObject.M_WrappedGrossWeight\|V\| $MillOrder.$BalanceObject.M_WrappedCount | 0 | 70 | PRODAMNT\|\|CNT | | | Ord wr w/c | CRuDouble | |
| 14 | OToDoWgtCnt | $MillOrder.$BalanceObject.M_MissingGrossWeight\|V\|$MillOrder.$BalanceObject.M_MissingGrossWeight*$MillOrder.$Balanc... | 0 | 95 | PRODAMNT\|\|CNT | MISSINGAMOUNT | | Ord missing w/c | CRuDouble | |
| 15 | RToDoWgtCnt | $ProdLot.$BalanceObject.M_MissingGrossWeight \|V\| $ProdLot.$BalanceObject.M_MissingNormCount | 0 | 95 | PRODAMNT\|\|CNT | MISSINGAMOUNT | | Run missing w/c | CRuDOu... | |
| 16 | RTrgWgtCnt | $ProdLot.$BalanceObject.M_PlannedGrossWeight \|V\| $ProdLot.$BalanceObject.PlanCnt | 0 | 75 | PRODAMNT\|\|CNT | | | Run trg w/c | CRuDouble | |
| 17 | RProdWgtCnt | $ProdLot.$BalanceObject.M_ProducedGrossWeight \|V\| $ProdLot.$BalanceObject.M_ProducedCount | 0 | 85 | PRODAMNT\|\|CNT | | | Run prod w/c | CRuDou... | |
| 18 | RWrapWgtCnt | $ProdLot.$BalanceObject.M_WrappedGrossWeight \|V\| $ProdLot.$BalanceObject.M_WrappedCount | 0 | 75 | PRODAMNT\|\|CNT | | | Run wr w/c | CRuDouble | |
| 19 | OAvg | $MillOrder.$BalanceObject.M_ProducedGrossWeight/$MillOrder.$BalanceObject.M_ProducedCount | 0 | 70 | WEIG | | | Ord avg w | CRuDouble | |
| 20 | OUnitWeigMax | $MillOrder.UnitWeigMax | 0 | 75 | | | | Ord max w | CRuDouble | |
| 21 | OCntPerUnit | $MillOrder.CntPerUnit | 0 | 75 | | | | Ord Cnt/Pkg | int | |
| 22 | RRWRejWgtCnt | $ProdLot.$BalanceObject.M_RewinderGrossWeight \|V\| $ProdLot.$BalanceObject.M_RewinderCount | 0 | 90 | PRODAMNT\|\|CNT | | | Run RejToRW | CRuDouble | |
| 23 | OExMillDate | $MillOrder.ExMillDate | 0 | 70 | FormatDateLong | | | Ord ExMill | CRuTime | |
| 24 | OCustName | $MillOrder.CustName | 0 | 80 | | | | Customer | CRuString | |
| 25 | GetTextClassificati... | M_TextClassification | 0 | 80 | | | | Classification | CRuString | |
| 26 | OWireSide | $MillOrder.WireSide | 0 | 0 | | | | WI/WO | CRuString | |
| 27 | InOut | InOut | 0 | 0 | | | | InOut | CRuString | |
| 28 | StationCode | StationCode | 0 | 0 | | | | Station | CRuString | |
| 29 | SpliceCount | $ActivePattern.$ActiveTrackColl(0).$ActiveUnitItem.M_TextSpliceCount | 0 | 0 | | | | SpliceCount | CRuString | |
| 30 | HoleCnt | HoleCnt | 0 | 0 | | | | PatchCnt | int | |
| 31 | Remark | M_TextRemaFlag | 0 | 0 | REMAFLAG | | | Remark | CRuString | |

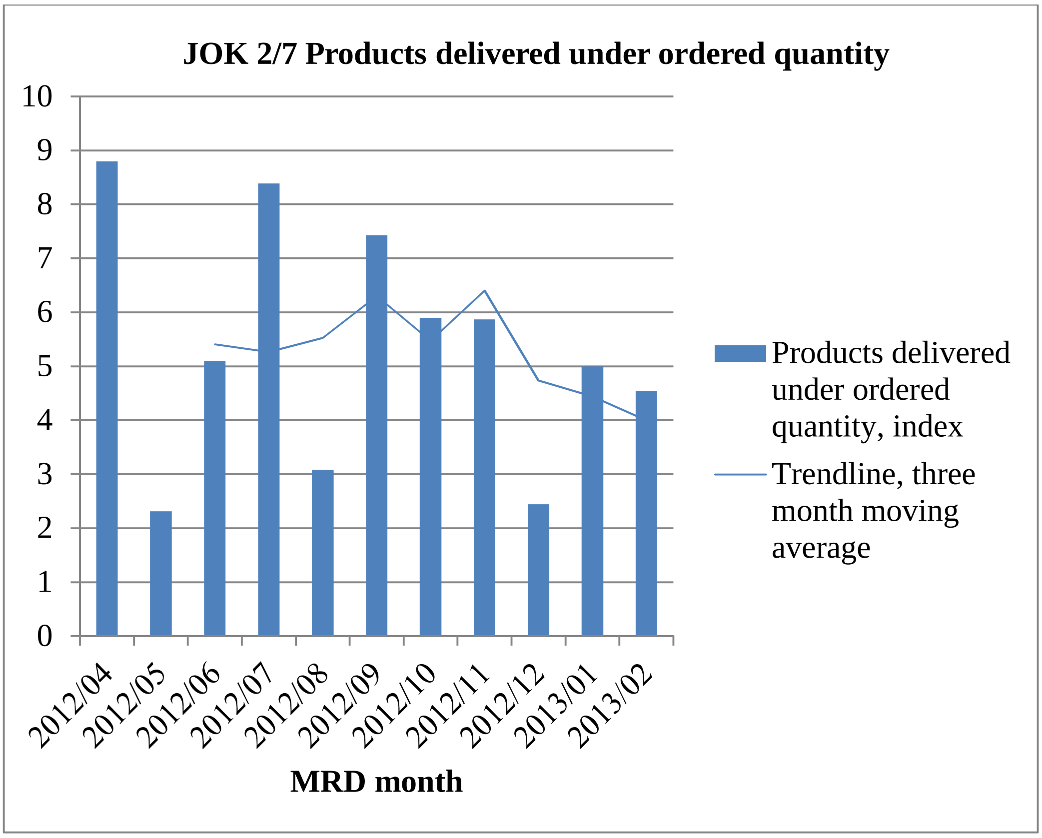
**APPENDIX 3/9:** Monthly overproduction and underproduction in JOK 1/7.



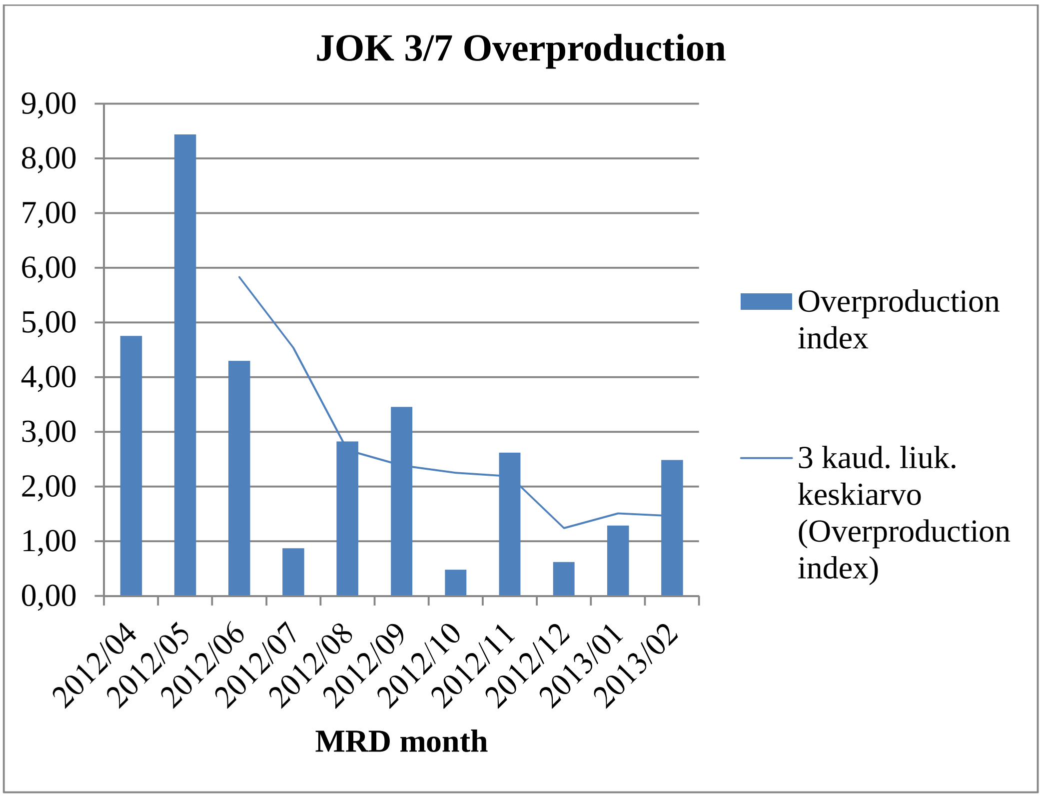



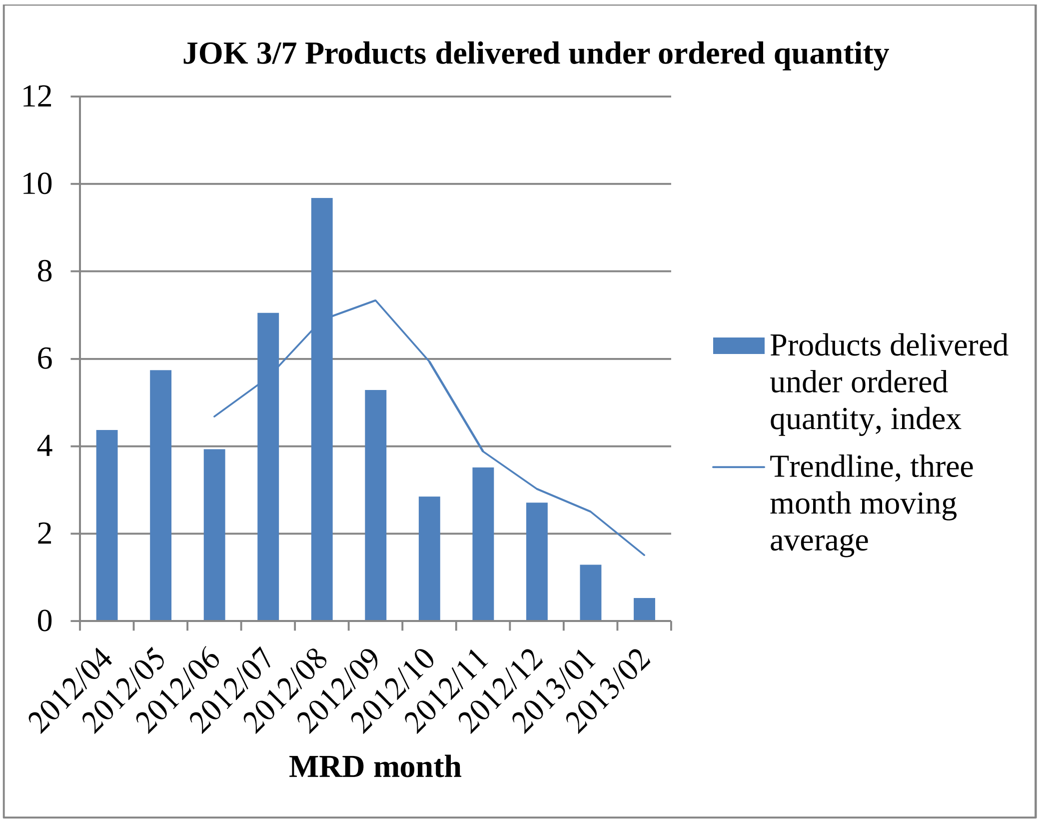
**APPENDIX 4/9:** Monthly overproduction and underproduction in JOK 2/7.



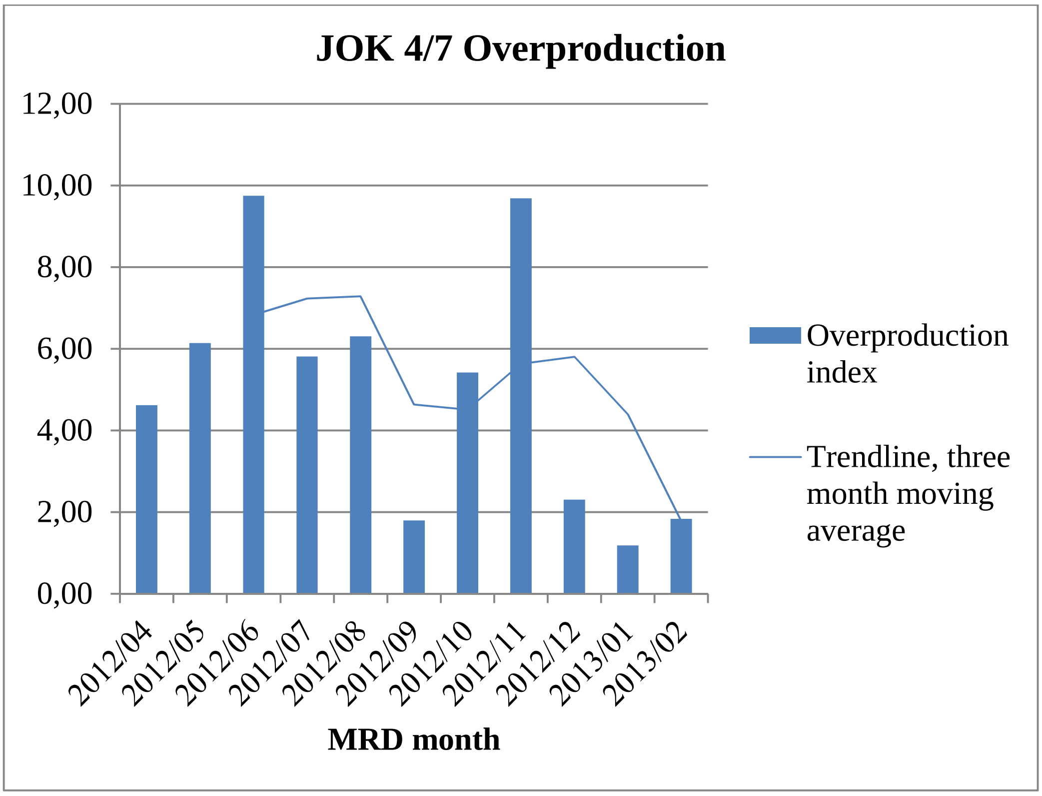



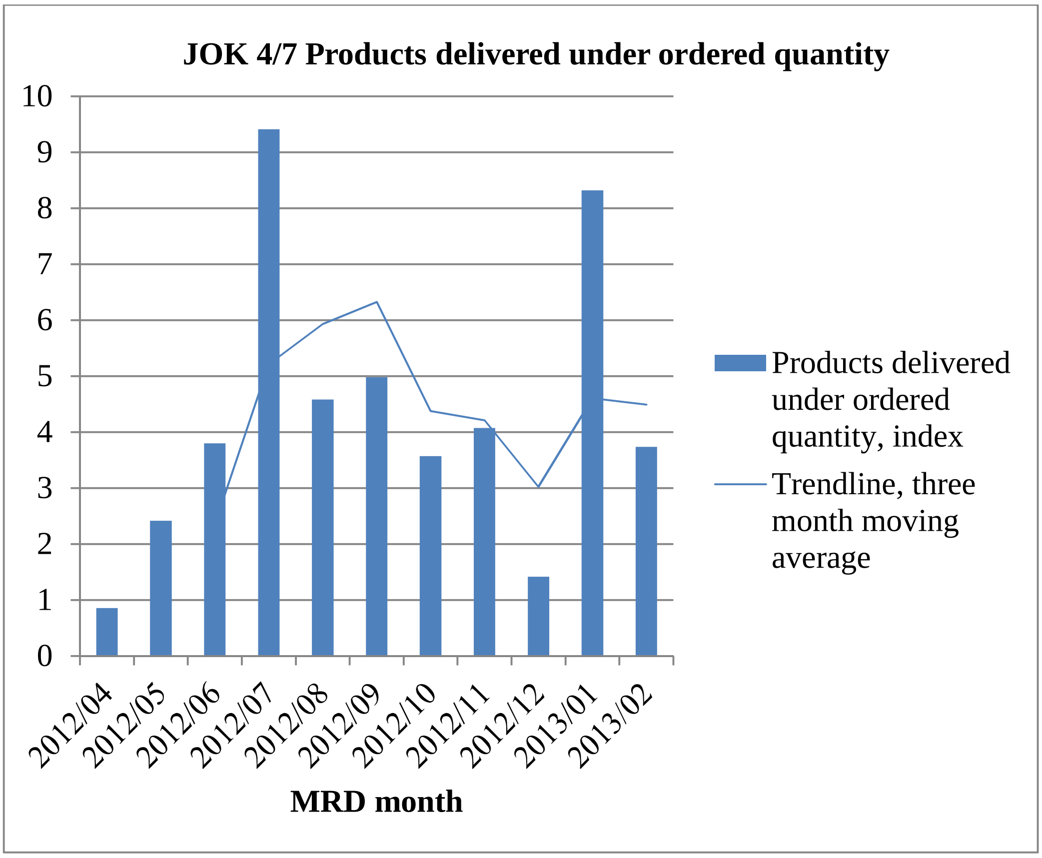
**APPENDIX 5/9:** Monthly overproduction and underproduction in JOK 3/7.



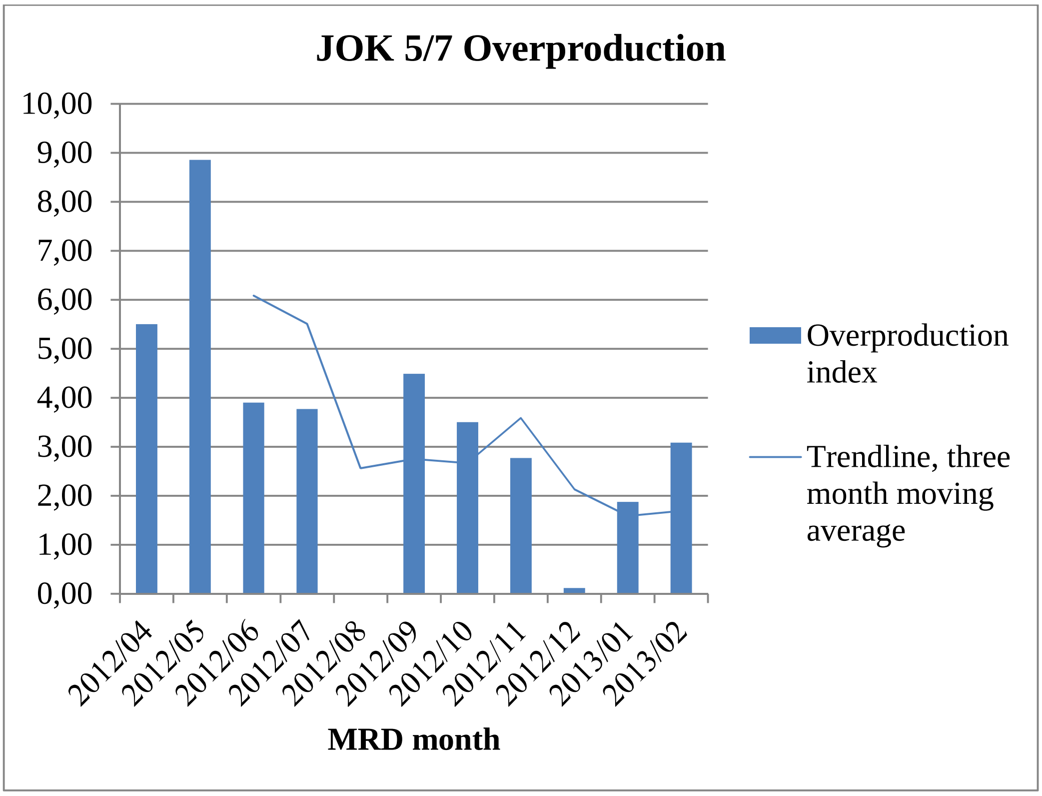



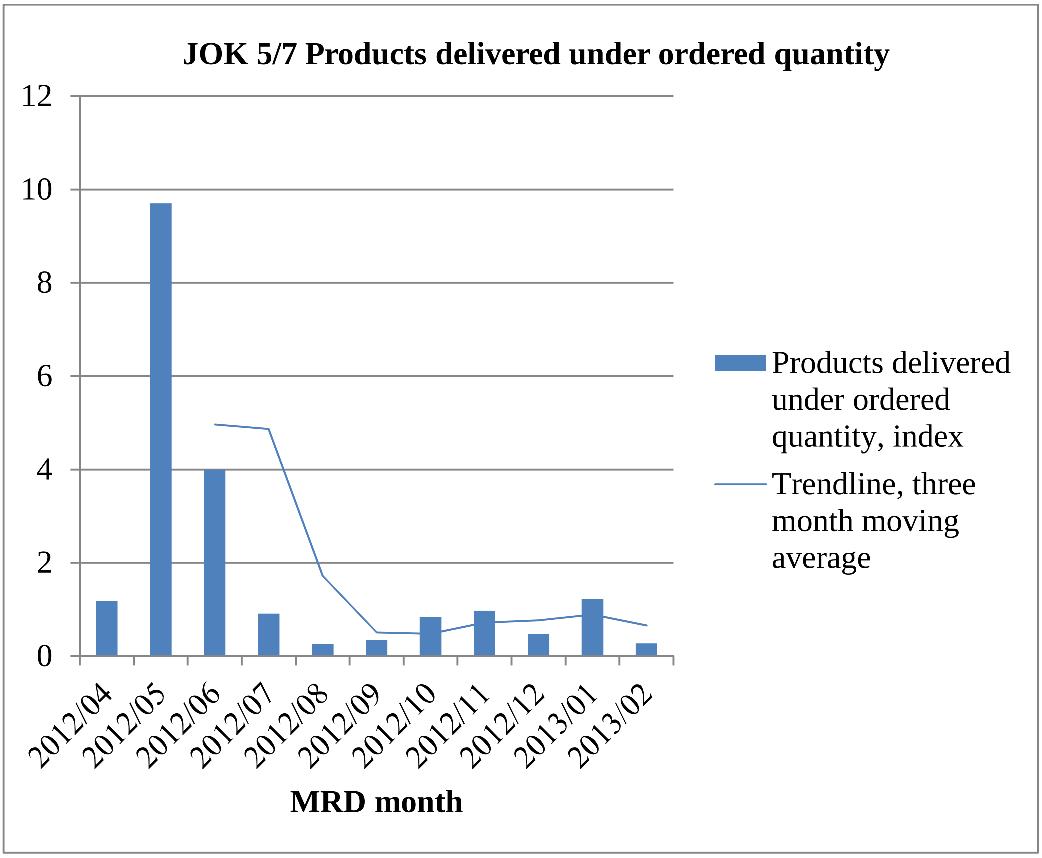
**APPENDIX 6/9:** Monthly overproduction and underproduction in JOK 4/7.



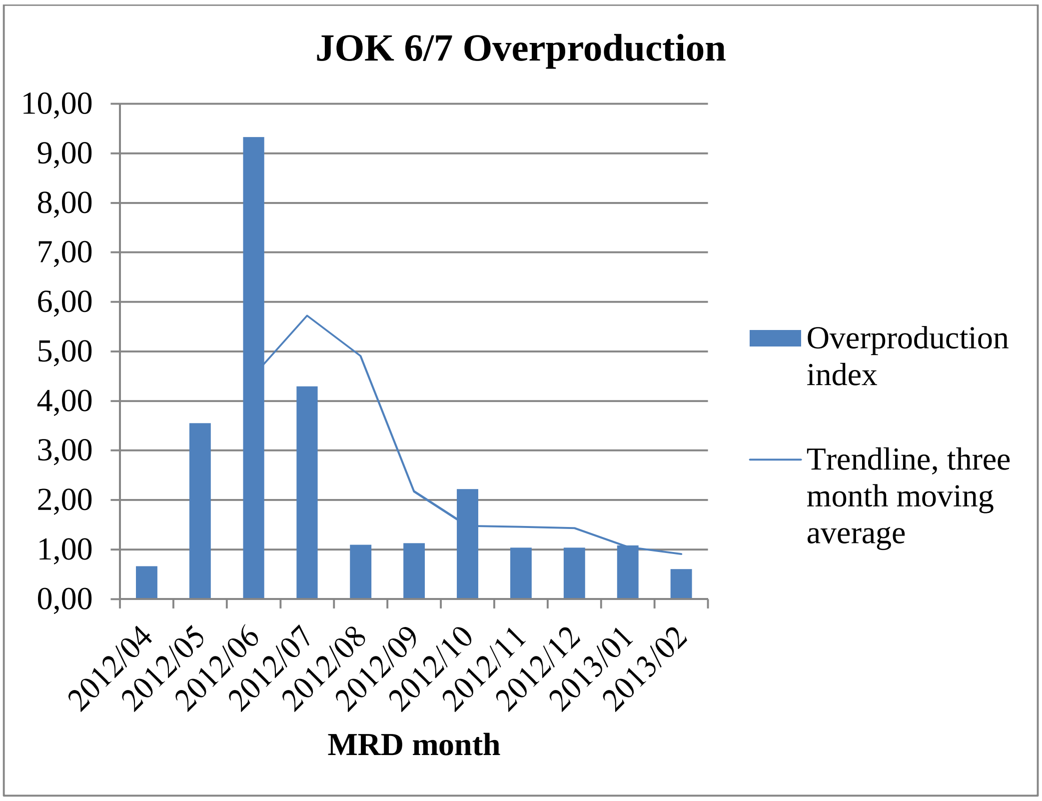



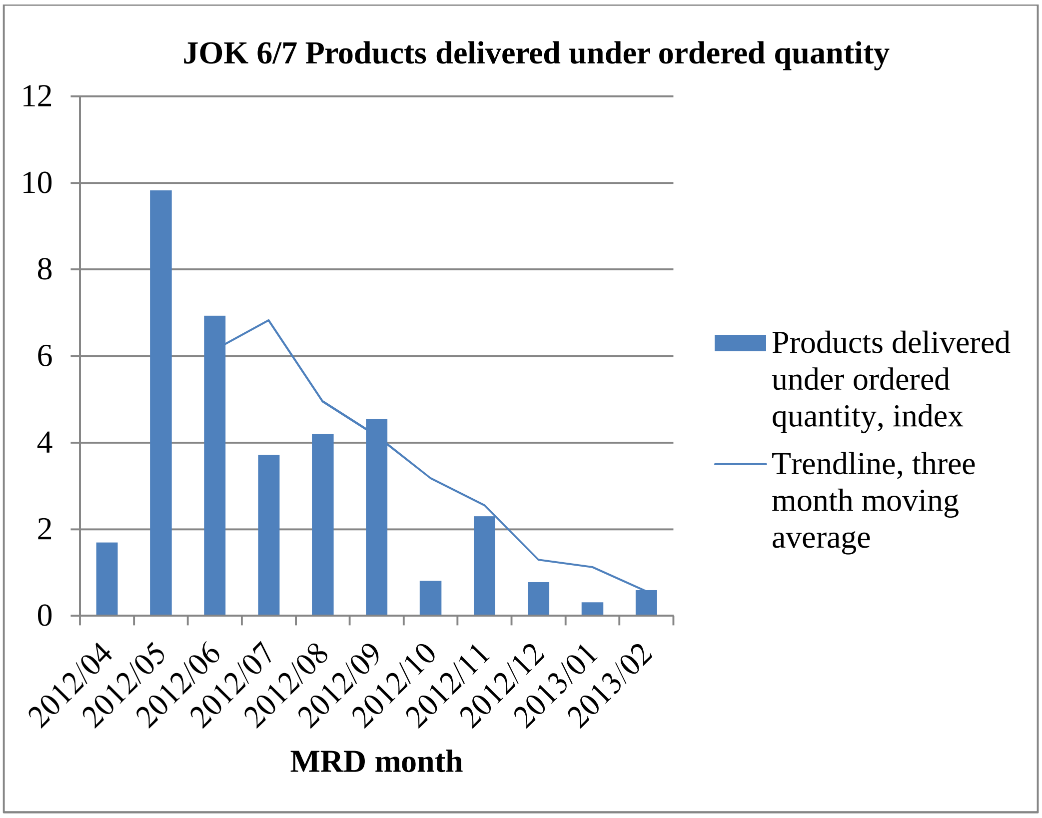
**APPENDIX 7/9:** Monthly overproduction and underproduction in JOK 5/7.



**APPENDIX 8/9:** Monthly overproduction and underproduction in JOK 6/7.



**APPENDIX 9/9:** Monthly overproduction and underproduction in JOK 7/7.