



DEGREE PROJECT, IN PROJECT MANAGEMENT AND
OPERATIONAL DEVELOPMENT, SECOND LEVEL
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Key Performance Indicators (KPIs)

A study of key performance indicators
(KPIs) at one of the production sites of
Fresenius Kabi in Brunna, Sweden

Amin Behzadirad,
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Amin Behzadirad and Fredrik Stenfors

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Abstract

In today's competitive environment, companies need to keep track of the actual performance updated result in order to steer the organization in doing the right things. Most successful organizations nowadays implement a performance measurement system within their companies. This is done to give them true attention to results, responsibilities and targets. In order for the organization to have control and improve processes, the organization needs to measure and identify the performance indicators. One of the manager's responsibilities is to realize what the critical metrics are in their organizations and how those metrics should be identified, measured, reported, and managed so that the organization can be viewed as a successful one by its stakeholders. Key performance indicators (KPIs) are specific metrics which show early warning signs if there is an unfavorable situation in the system. KPIs give everyone a clear picture of what is important for the organization. KPIs also give us information to make informed decisions and reduce uncertainty by managing risks.

In this research based on the needs of the factory and suggestions of managers, six KPIs including OEE, availability, performance ratio, quality ratio, lead time, and delivery performance were selected to examine their applicability at the production site.

The data was gathered and analysis was done. Loss time model was selected as the reference time model. The KPIs were measured according to this time model. The measured KPIs were studied for their measurability, applicability and usefulness. Lead time and delivery performance were measurable, applicable and useful to the production site while OEE and quality ratio were neither measurable nor applicable. Availability and performance ratio were measurable but they did not bring any value to the system.

Key words: Key Performance Indicator (KPI), Overall Equipment Effectiveness (OEE), Availability, Performance Ratio, Quality Ratio, Lead Time, Delivery Performance

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Abbreviations

ADET	actual unit delay time
ADOT	actual unit down time
APT	actual production time
ASUT	actual unit set up time
AUBT	actual unit busy time
AUPT	actual unit processing time
CIP	cleanings in progress
CM	consumed material
GQ	Good quantity
kg	kilograms
KPI	key performance indicator
KRI	key result indicator
LT	loading time
NaGlyP	sodium glycerophosphate
NOT	net operating time
OEE	overall equipment effectiveness
OPT	operating time
PBT	planned busy time
PDT	planned down time
PI	performance indicator
PL90	phospholipids
POT	planned operation time
PQ	Produced Quantity
QA	quality assurance
QC	quality control
RI	result indicator
RT	reference time
TPM	total productive maintenance
VOT	valued operating time
WT	waiting time

1. Introduction

1.1. Background

In today's competitive environment, companies need to keep track of the actual performance updated result in order to steer the organization in doing the right things (Franceschini, Galetto et al. 2007). Most successful organization nowadays implements a performance measurement system within the company, this is done to give them true attentions to results responsibilities and targets (Franceschini, Galetto et al. 2007). In order for the organization to have control and improve processes, the organization needs to measure and identify the performance indicators. However, according to Franceschini, Galetto et al. (2007); the most critical aspect does not include identifying the performance indicators, but rather identifying the proper Key performance Indicators (KPI). Kerzner (2013) writes that one of the manager's responsibilities is to realize what the critical metrics are in their organizations and how those metrics should be identified, measured, reported, and managed so that the organization can be viewed as a successful one by its stakeholders. Kerzner (2013) mentions also that key performance indicators (KPIs) are specific metrics which show early warning signs if there is an unfavorable situation in the system, and it is not addressed so far and KPIs give everyone a clear picture of what is important for the organization. KPIs also give us information to make informed decisions and reduce uncertainty by managing risks.

1.2. Company Overview

The Company Fresenius Kabi is a world known producer of different pharmaceuticals and medical devices to customers all over the world. The mother company Fresenius SE & Co. KGaA derives from a pharmacy called "Hirsch Apotheke" located in Frankfurt, Germany. The pharmacy was founded as early as 1492. The family Fresenius owned and managed the pharmacy from the 18th century. In 1911 Dr. Eduard Fresenius inherited the pharmacy from his father and one year later, in 1912, he registered the company Fresenius as a producer of pharmaceuticals. The company where later moved from Frankfurt to Bad Homburg where the head office is still located. Fresenius acquired the nutrition part of Kabi-Pharmacia in 1999 and formed Fresenius-Kabi.

The company has about 216,000 employees around the world and is active in more than 100 countries. Fresenius-Kabi is one of four subsidiaries of Fresenius SE & Co. KGaA and

represents 25 % of the company. Fresenius-Kabi has two production sites located in Sweden; Plant Uppsala and Plant Brunna. Plant Brunna serves Plant Uppsala with raw material for the manufacturing of parenteral nutrition. The service includes receiving, sampling, chemical analysis and dispensing of raw materials such as amino acids and vitamins. Plant Brunna purifies oils for parenteral nutrition and manufactures some materials in house such as phospholipids (PL90) and sodium glycerophosphate (NaGlyP).

Fresenius Kabi Plant Brunna has 180 employees and is located approximately 40 km from the center of Stockholm. The plant consists of several buildings such as media central, production, storage and laboratory.

This thesis will focus on the production of phospholipids. Phospholipids act as an emulsifier in lipid emulsions. In order to create an emulsion oil and water is mixed under high pressure (homogenization) together with phospholipids. The emulsion stays homogenic thanks to the phospholipids. Fresenius Kabi produces fat emulsions with different strengths and fat compositions for different purposes. A number of finished products based on fat emulsions with phospholipid are illustrated in Figure 1.

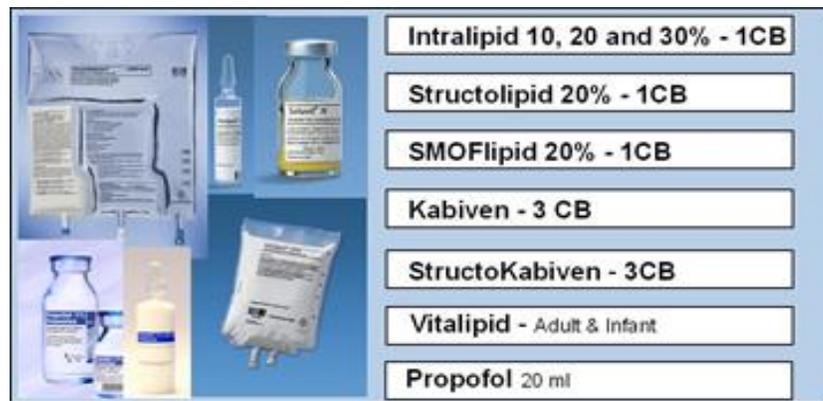


Figure 1 - Products based on fat emulsions with phospholipid (Fresenius Kabi's products catalogue)

1.3. Problem Statement

The factory in Brunna where this study takes place, produces three main products: purified oil (liquid), PL90 (powder) and NaGlyP (powder form). The main focus in this thesis centers around the production of phospholipid called PL90. These products are the raw materials for mixing with other substances before becoming finished pharmaceutical products for the market. The actual production and mixing of the substances takes place in other production sites within the Fresenius Kabi group, such as Sweden (Uppsala), Italy, Austria, and China. Fresenius Kabi

works according to LEAN based concept with eight areas of focus: Quality, Human, Leadership, Sustainability, Cost, Capacity, Processes, and Values. According to the company's statement of direction, Fresenius Kabi is focusing on delivering sustainable goals within these areas of focus in order to make the company even better. However, within these 8 focused areas, they have some metrics in form of performance and key performance indicators that visualize the direction of their processes. In fact, this performance measurement provides an overview for the processes and the areas for improvement. The most important indicators in their model are the Cost, Quality, and Capacity. The existing metrics at the production site at Brunna do not give any sufficient measurements which reflect the areas of productivity and capacity. The company's main issues concerning those two areas are “what to measure?”; “how to measure them?”; “what do the results mean?”; “how the processes are developing?” and “what KPIs are applicable in this production site?” The main focus of this study centers on providing KPIs and methods for measuring them in the area of the capacity and productivity in the production of PL90.

1.4. Research Questions

The study seeks to address the following questions:

- How are the KPIs identified at Fresenius Kabi Company?
- What are the KPIs for the Fresenius Kabi Company?
- What are the benefits of identifying, measuring, monitoring, and controlling KPIs for the Fresenius Kabi Company?

1.5. Scope

As it is mentioned, Fresenius Kabi is a very large company with more than 74 production sites all over the world. The main focus of this will be on the production site in Brunna, Sweden on the product PL90 out of three main products including oils, PL90 and NaGlyP. Therefore, the emphasis within this thesis focuses on the identifying and measuring KPIs in area of capacity and productivity for the production of PL90. Though there are many performance indicators at place, the main focus of the study is on identifying and investigating three to five key performance indicators in those areas.

1.5.1. In Scope

The following parameters are in scope:

- KPIs for the production site in Brunna;
- KPIs in the area of productivity and capacity;
- KPIs for the production line of PL90;
- A suggested way of measuring KPIs for the selected KPIs.

1.5.2. Out of Scope

Everything out of the mentioned scope lies out of scope. Some of the out of scope area are as follows:

- The performance indicators within Human, quality, leadership, sustainability and values;
- The KPIs for the whole organization;
- The performance indicators for the factory in Uppsala;
- The implementation plan of the KPI for the factory in Brunna.

2. Methodology

In this chapter, the methodological approach to this research, data collections, validity and reliability of data, and the workflow the whole research are presented and described.

2.1. Research Design and Approach

The possible approaches to a research design are qualitative, quantitative and mixed approach as containing both qualitative and quantitative methods (Conrad and Serlin 2011). It is essential to choose one of those methods and use it as a dominant research method to have a well-structured research report and to reach to desired outcomes. So as to do that, the best start is to learn each method.

Conrad and Serlin (2011) describe qualitative research as allowing a thorough survey of a subject of interest which within the information is gathered by researchers or examiners through interviews, case studies, ethnographic work, and so on. Inherent in this method is the explanation of the interactions amongst participants and researchers or examiners in a realistic setting with few boundaries resulting in a flexible and open research process. These distinctive interactions indicate that different outcomes could be gained from the same participant depending on who the researcher is, because outcomes are shaped by a participant and researcher in a certain situation (Conrad and Serlin 2011). “Qualitative research methods are also described as inductive, in the sense that a researcher may construct theories or hypotheses, explanations, and conceptualizations from details provided by a participant” (Conrad and Serlin 2011).

“Quantitative research can be constructed as a research strategy that emphasizes quantification in the collection and analysis of data and that entails a deductive approach to the relationship between theory and research, in which the accent is placed on the testing of theories” (Bryman and Bell 2007). Quantitative research methods try to increase objectivity, replicability, and generalizability of results, and are normally attentive in prediction (Conrad and Serlin 2011). Ivankova, Creswell et al. (2006) describe that the logic for using both quantitative and qualitative methods is that neither quantitative nor qualitative approaches are appropriate to capture the details and trends of the research situation. Qualitative and quantitative methods used in mixture complement each other for a more thorough analysis by using and implying the strengths of each of two methods (Ivankova, Creswell et al. 2006).

Research is the methodical and systematic study of existing or new knowledge. Deduction, induction and abduction are three different categories of scientific research approaches that the researcher can follow to perform the research (Rothchild 2006). “Deduction approach starts with the existing theories and then formulates a framework that will be examined. The induction approach is the formation of a generalization derived from examination of a set of facts. Combining the induction and deduction approaches needs the third approach abduction” (Shah 2013).

The research design for this study is qualitative by performing the interviews and the research approach is deductive by starting from the more general KPIs to narrow down to the more specific KPIs.

2.2. Literature Review

According to Fink (1998), “A research literature review is a systematic, explicit, and reproducible method for identifying, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners” (Fink 1998). Hart (2003) describes literature review as, “the selection of available documents on the topic, which contains information, ideas, data and evidence. This selection is written from a particular standpoint to fulfill certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research is being proposed” (Hart 2003). Hart (2003) also explains that without literature review is almost impossible to understand the research topic, what has already been done on the subject, and what the key issues are regarding the research. The main purpose of the literature review is to assure that the research is able to conceptualize the related information for the work scope, to form a validate theoretical framework for the research subject, to be able to define keywords, definitions and terminologies, and to determine preceding research works so as to justify the research subject. The writing initiates with recognizing the research questions followed by investigating and finding the required information. According to Hart (2003), a draft writing should be the first step while considering the readers’ expectations. Reworking the draft is the next step whereas it should be taken into consideration the clarity and structure of the paper until gaining a last draft. After checking and controlling the grammar and spelling, the literature review is ready and done. A deep study has been performed within the research area of

manufacturing operations management, and related key performance indicators by reviewing associated literature. The literature review of the research topic is presented in chapter 3.

2.3. Data Collection

Kumar (2005) defines two types of data collection; primary sources and secondary sources (Figure 2), regarding analyzing and responding to the research question. The sources are defined as follows.

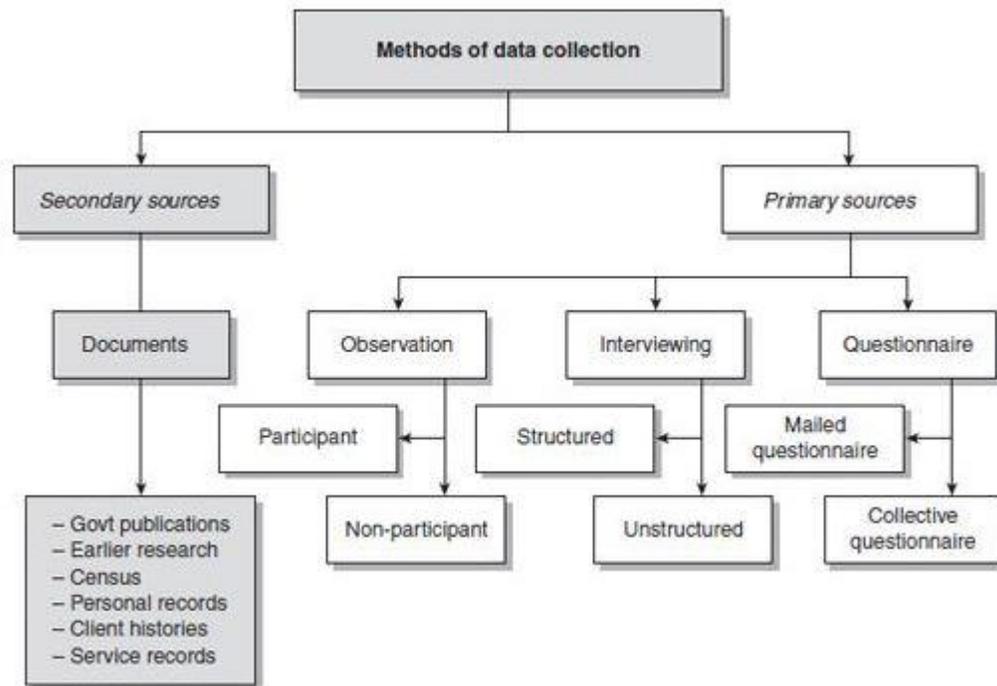


Figure 2 - Methods of data collection (Kumar 2005)

Both sources of data are used in this research. For the primary data, many open and unstructured interviews with several people with different job responsibilities were held during the performing of the study as well as considerable amount of manufacturing site visits to observe the production and collect data. Quite a few academic resources were also reviewed as the secondary data.

2.3.1. Primary Data

Kumar (2005) defines the primary data as the first-hand information which is collected by the researcher and they have not been issued beforehand. The primary data and its sources are observations, interviews and questionnaires or surveys. There are some benefits to have a research based on primary data. Knowing the validity and reliability of data and being designed data for the very specific research topic are amongst the most important advantages of using primary data.

2.3.2. Secondary Data

Kumar (2005) outlines the secondary data as all non-first-hand information which are developed by anyone except the researcher and they have been published. The secondary data can be in the form of article, journal, magazine, book, rules or regulations, governmental publications, and so forth. Using the secondary data has its own benefits including: making comparison of greater amount of data, using different outcomes from different researchers, being less time consuming and much more cost effective for the data collection in comparison with the primary data.

2.4. Workflow

The project workflow and details about each phase is illustrated in Figure 3. The project workflow is divided into four main phases including:

- pre-study,
- in-depth study,
- analysis,
- conclusion and proposal.

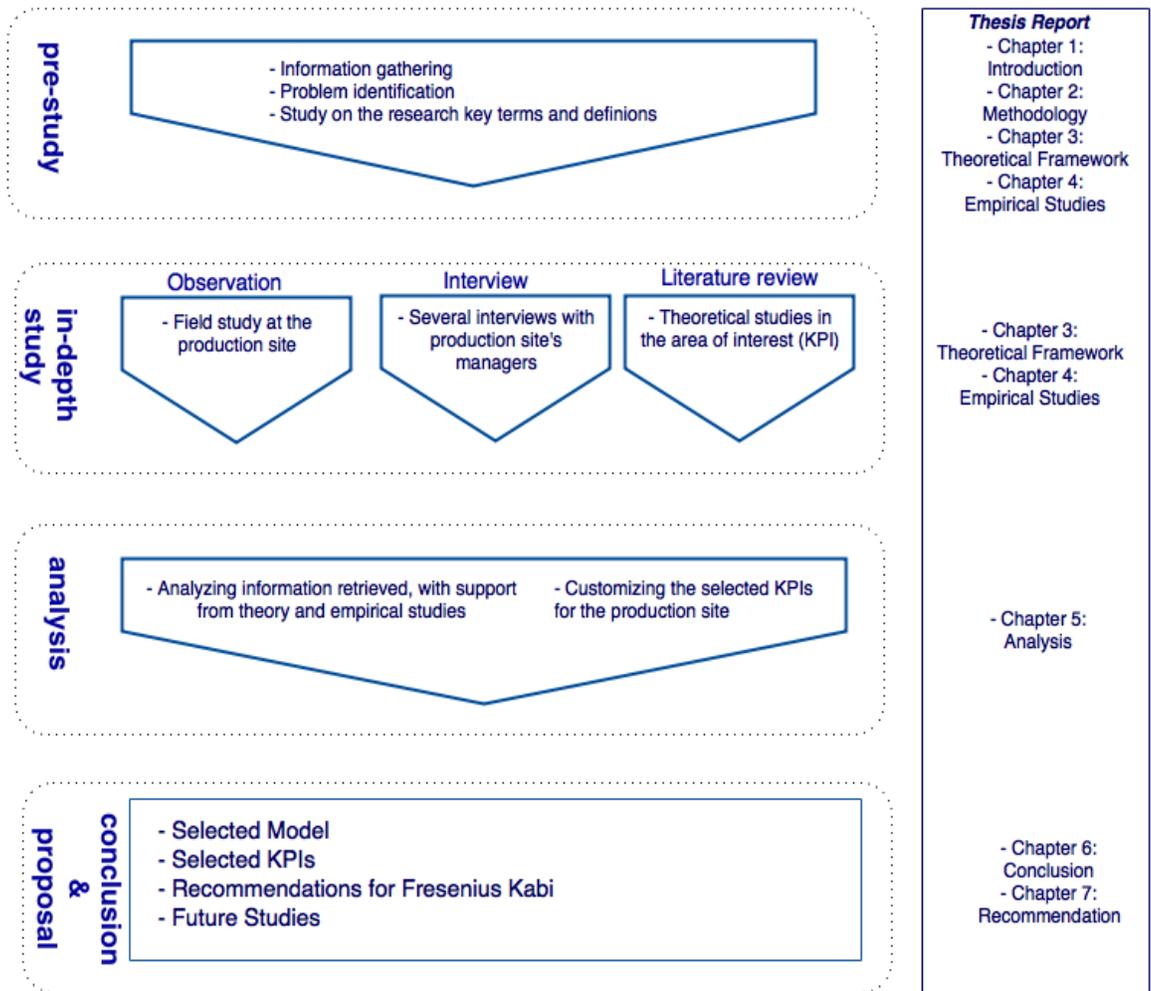


Figure 3 - Project Workflow (drawn by authors)

2.5. Credibility

The qualitative approach requires to critically be assessed regarding the credibility of the research. The research should be analytically appraised to measure its quality, and to identify if the concluded information is factual and accurate. According to Cooper and Schindler (2014), validity, reliability, and practicality are three characteristics of a good measurement tool which in the research measurement procedures should be obtained. Thus, the research has to meet the requirements of reliability, validity and practicality. "Reliability is an expression of the proportion of the variation among scores that are due to object of measure" (McClure, Brian et al. 1999). Golafshani (2003) writes reliability is the degree to which outcomes are constant over time and accurate representation of the under study population referred as reliability. Golafshani (2003) mentions if the outcomes of a research can be reproduced under a similar method, the

study instrument is considered to be reliable. Cooper and Schindler (2014) believe that the reliability is related with the accuracy and precision of a measurement procedure. “Validity is the extent to which a test measures what we actually wish to measure” (Cooper and Schindler 2014). Golafshani (2003) describes that validity defines whatever it was intended to measure by the research if it is precisely measured or how accurate the research results are. The relation between reliability and validity is shown in Figure 4.

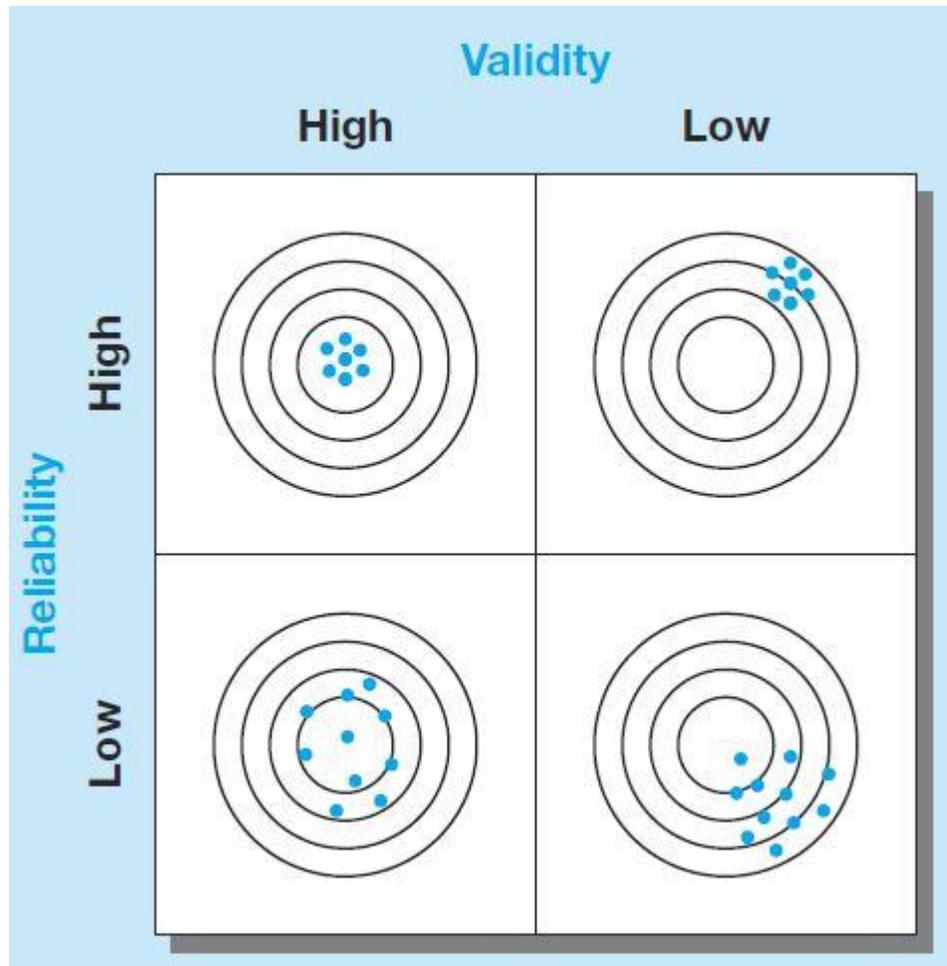


Figure 4 - Validity and Reliability relation (Cooper and Schindler 2014)

Practicality is concerned with a widespread range of factors of economy, convenience, and interpretability. According Cooper and Schindler (2014), based on economy theory, some trade-off generally befalls between the ideal study project and the budget. Data are not free to use, and length of usage of instruments and tools are among the area where economic pressures dominate. More inputs give more reliability, but it is limited to available time and budget for

collecting data by holding interviews or doing observations. The selection of data gathering method is also frequently dictated by economic factors. Cooper and Schindler (2014) state that convenience is a measuring tool to see how the collecting data methods were convenience or easy to administer. Cooper and Schindler (2014) define interpretability as part of the practicality. It is related to interpretation of the results by other specialist rather than test designers.

In this research report, the field study is based on interviews with employees at Fresenius Kabi in Brunna and production site's visits as observations. It is always the risk of being affected the interviewed personnel by the interviewees while gathering information. To avoid the risk of manipulating the interview results, all information carefully collected and recorded during interviews. Information has been gathered from several sources in order to have a high reliable and valid research results.

3. Theoretical framework

In this chapter, the theoretical concepts of manufacturing operations management, different indicators in organizations including: results indicators and performance indicators are introduced. The KPI and selected KPIs related to our research are thoroughly explained. The presented theory will be used when analyzing the empirical data.

3.1. Manufacturing Operations Management

An operation in an organization is included all the tasks are done to transform resources to desired goods or services, and to generate and deliver value to the customers in order to reach to the anticipated organizational goals. Operations in the organization can be classified in two manufacturing and service operations. Manufacturing operations are transformation or conversion processes that lead to tangible outputs like products whereas service operations produce intangible outputs. Products as tangible outputs of manufacturing use less labor and more equipment. Manufacturing operations has some characteristics such as the products are used overtime, no customer contribution is in the transformation processes, there are small amount of customer contacts, and complex approaches are considered for measuring production activities and resource consumption as the products are made. In service operations, outputs consume immediately, tasks use more labor and less equipment, there is direct and frequent contributions of customers during transformation processes, and there are elementary approaches for measuring conversion activities and resource consumption (Anil Kumar, Suresh et al. 2008).

Different levels of the functional hierarchy model for manufacturing operations management are illustrated in Figure 5 according to (ISO22400-2:2014 2014).The model includes 4 levels: business planning and logistics (level 4), manufacturing operations and control (level 3), and batch, continuous, or discrete control (level 1-2). Each level offer different functions in different timeframes (ISO22400-2:2014 2014).

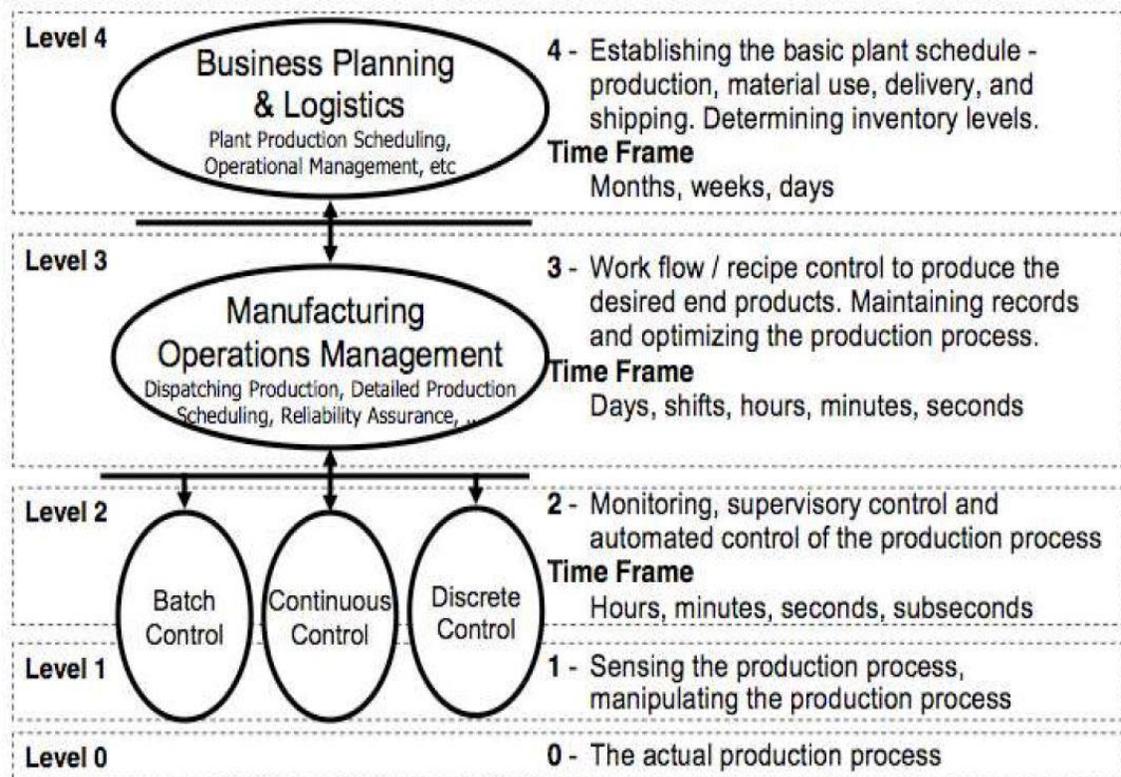


Figure 5 - Functional hierarchy (ISO22400-2:2014 2014)

There are three types of production in manufacturing: batch production, continuous production, and repetitive or discrete production. (ISO22400-2:2014) has defined a hierarchical structure for the physical equipment for manufacturing (Figure 6). “Enterprise, site and areas are generic terms, whereas there are specific terms for work centers and work units that apply to batch production, continuous production, discrete or repetitive production, and for storage and movement of materials and equipment” (ISO22400-2:2014 2014).

For having better control over manufacturing operations and managing it more properly, there should be some controlling tools. Performance measurements are among those tools for manager to know how their organization is performing, where they are going, and if they are on track.

“Measuring performances of the organization means qualitative, and quantitative expression of some results by chosen indicators. Performance measurement enable to effective organizations to express their success by numbers. Selection of appropriate indicators that will be used for measurement and appraisal of the performances is a very important activity. Among

all information that can be get it is necessary to choose some critical quantity that on the best way represent the whole business” (Velimirović, Velimirović et al. 2011).

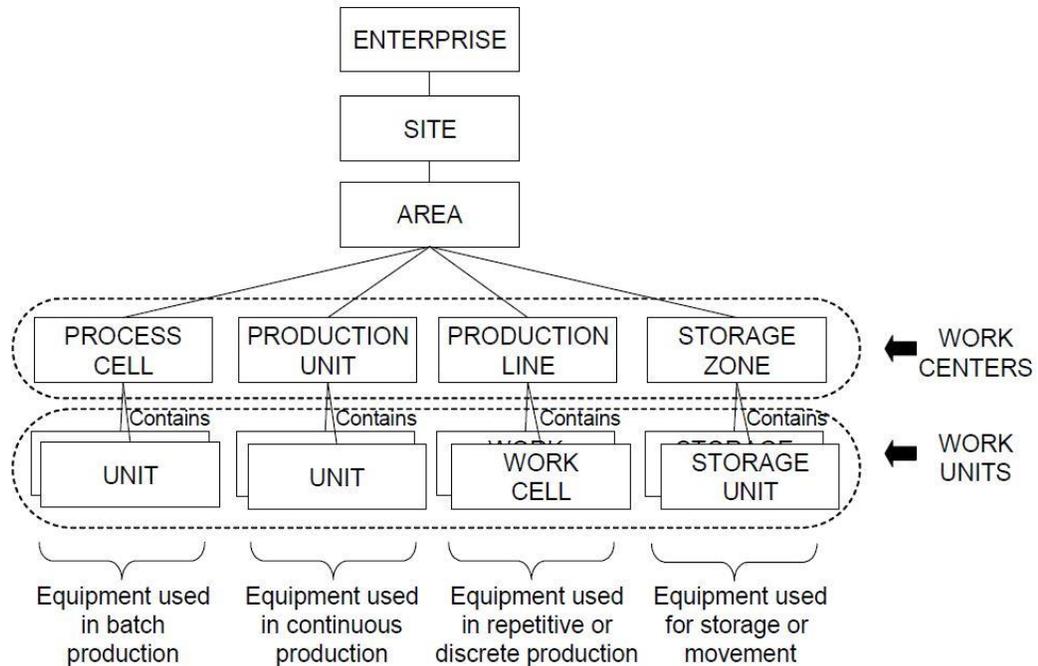


Figure 6 - Role based equipment hierarchy (ISO22400-2:2014 2014)

3.2. Indicators as Measurements

Parmenter (2010) in his book “Key Performance Indicators” mentions that there are four types for measurement indicators for organizations (Figure 7).

“1. Key result indicators (KRIs) tell you how you have done in a perspective or critical success factor.

2. Result indicators (RIs) tell you what you have done.

3. Performance indicators (PIs) tell you what to do.

4. KPIs tell you what to do to increase performance dramatically” (Parmenter 2010).

According to Parmenter (2010), inappropriate and incorrect mixture of these four types of indicators in different organizations for measuring their performance is a common mistake.

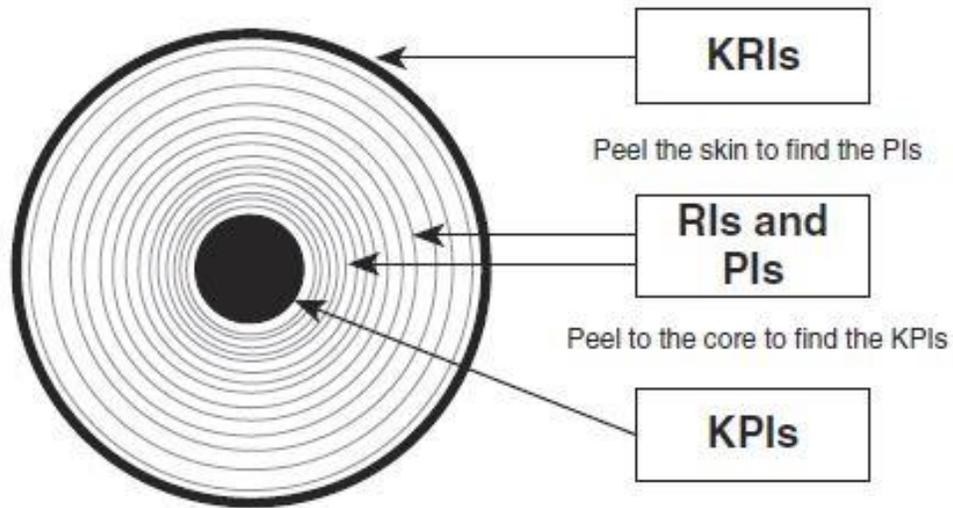


Figure 7 - Four types of measurement indicators (Parmenter 2010)

3.2.1. Result Indicators

As it has been mentioned, result indicators are to show what the organizations have done and how they have done them. There are plenty of result indicators (RIs). RIs summarize activities. All financial performance measures whether daily, weekly or in other type of periodical time frame are RIs. Key Result Indicators (KRIs) characteristically include indicators which show a longer period of time than KPIs. KRIs are usually calculated and revised on monthly, quarterly cycles or even annually not on a daily or weekly basis as KPIs are done. The KRIs are the results of many actions which can give a clearer and better view of moving the organization towards its goals and visions. They can show whether the organization is in the right direction or not (Parmenter 2010).

3.2.2. Performance Indicators

The same as RIs, there are numerous Performance Indicators (PIs). While PIs are important for the organizations but they are not key to them. PIs can be used by teams by means of being able them to follow the organization's strategy. They are generally nonfinancial complements to the KPIs (Parmenter 2010).

There are some key indicators among all performance indicators like KRIs which are called Key Performance Indicators (KPIs). Because the main focus of this research is on KPIs, they are described thoroughly in next section, 3.3. KPI.

3.3. KPI

The anatomy of a KPI is as follows:

Key is defined as a main contributor to the success or failure;

Performance is illustrated as a metric that can be measured, quantified, adjusted and controlled; and,

Indicator is explained as a rational and realistic depiction of present and future performance (Kerzner 2013).

“KPIs are defined as quantifiable and strategic measurements that reflect an organization’s critical success factors” (ISO22400-2:2014 2014). Parmenter (2010) in his book describes the KPIs as a set of measures that mostly concentrate on the most critical aspects of organizational performance for the existing and upcoming success of the organization and KPIs are not often new to the organizations.

“Key Performance Indicators (KPIs) are among the most commonly used tools that companies employ to help manage more effectively and guide their progress. In brief, KPIs are the top level data companies use to measure performance and plan for the future. Managers need KPIs for a number of reasons:

1. To determine where you have been and what performance looks like from the past
2. To track the progress of change
3. To plan and prepare where you are going, what success looks like in the future and identify how to achieve success” (Pacific-Crest-Group 2012).

Managers by help of KPIs can realize how their organizations are acting in relation to their strategic goals and objectives. KPIs offer indicators to senior managers as how the organization is performing. By setting and using those proper KPIs, managers recognize whether the performance is on track or not (Pacific-Crest-Group 2012).

Using just KPIs are not adequate to manage and execute the operations of an organization. Specific thresholds and warning limits for each indicator should be defined. As the indicators exceed or fall below them, appropriate and timely actions should be initiated (ISO22400-2:2014 2014).

ISO22400-2:2014 (2014) offer a set of KPIs in a table (Table 1), parameter-indicator matrix, in manufacturing operations management. Each KPI is calculated based on some parameters in different categorizes. According to ISO22400-2:2014 (2014), there is a production time model for work unit (Figure 8). It includes the reference time, planned operation time (POT), planned busy time (PBT), planned down time, actual unit busy time (AUBT), actual unit down time (ADOT), actual unit processing time (AUPT), actual unit delay time (ADET), actual production time (APT), and actual unit set up time (ASUT). All the aforementioned terms regarding the production time model for work units are brought in table 2 and the relations among them are shown in Figure 8. ISO22400-2:2014 (2014) defines another time model for production, loss time model (Figure 9), when the batch production times do not fit into the previous model.

Table 1 - Parameter-indicator matrix (ISO22400-2:2014 2014)

		Key Performance Indicators																									
		Worker Efficiency	Allocation Ratio	Throughput Ratio	Allocation Efficiency	Utilization Efficiency	OEE-Index	NEE-Index	Availability	Effectiveness	Quality Ratio	Set up Rate	Technical Efficiency	Production Process Ratio	Actual to Planned Scrap Ratio	Frist Pass Yield	Scrap Ratio	Rework Ratio	Fail-off Rate	Machine Capability Index	Critical Machine Capability Index	Process Capability Index	Critical Process Capability Index	Mean Operation Time between Failures	Mean Time to Failures	Mean Time to Repair	Corrective Maintenance Ratio
Planned Time	Planned Busy Time (PBT)				■		■	■																			
	Planned Run Time per Unit (PRTU)									■																	
Real Time	Actual Personnel Work Time (APWT)	■																									
	Actual Unit Processing Time (AUPT)						■				■																
	Actual Unit Busy Time (AUBT)		■		■	■																					
	Actual Order Execution Time (AOET)		■	■									■														
	Actual Personnel Attendance Time (APAT)	■																									
	Actual Production Time (APT)					■			■	■			■	■													
	Actual Unit Delay Time (DET)											■															
	Actual Set up Time (ASUT)											■															
Logistical Quantities	Scrap Quantity (SQ)													■		■		■									
	Planned Scrap Quantity (PSQ)													■													
	Good Quantity (GQ)										■																
	Rework Quantity (RQ)																	■									
	Produced Quantity (PQ)				■					■	■						■	■									
	Produced Quantity (PQ) in first operation Process																	■									
Quality Numbers	Good Part (GP)														■												
	Inspected Part (IP)														■												
	Average of Averages																			■	■		■				
	Upper Specification Limit (USL)																			■	■	■	■				
	Standard Deviation (s)																			■	■						
	Lower Specification Limit (LSL)																			■	■	■	■				
	Estimated Deviation																					■	■				
Performance Indicators	Availability						■																				
	Effectiveness						■	■																			
	Quality Rate						■	■																			
Maintenance Terms	Time to Failure																								■		
	Operating Time Between Failures																							■			
	Time to Repair																							■		■	
	Failure Event																							■	■	■	
	Corrective Maintenance Time																								■		■
Preventive Maintenance Time																										■	

Table 2 - Elements used in production time model for work units (ISO22400-2:2014 2014)

Elements used in KPI	Abbreviation	Definition
Reference time	-	A reference time is the base timeline used for the time models defined in this International Standard. It is the planned maximum time interval available for production and maintenance tasks.
Planned time	-	The duration a specific time period.
Actual time	-	The realized duration of a specific time period.
Planned operation time	POT	The planned operation time shall be the planned time in which a work unit can be used. The operation time is a scheduled time.
Planned unit setup time	PSUT	The planned unit setup time shall be the planned time for the setup of a work unit for an order.
Planned busy time	PBT	The planned busy time shall be the operating time minus the planned downtime.
Planned run time per unit	PRI	The run time per item shall the planned time for producing one quantity unit.
Actual unit busy time	AUBT	The actual unit busy time shall be the actual time that a work unit is used for the execution of a production order.
Actual production time	APT	The actual production time shall be the actual time during which a work unit is producing. It includes only the value-adding functions.
Actual unit down time	ADOT	The actual unit down time shall be the actual time when the work unit is not executing order production although it is available.
Actual unit delay time	ADET	The actual unit delay time shall be the actual time associated with malfunction-caused interrupts, minor stoppages, and other unplanned time intervals that occur while tasks are being completed that lead to unwanted extension of the order processing time.
Actual unit setup time	ASUT	The actual unit setup time shall be the time consumed for the preparation of an order at a work unit.
Actual unit processing time	AUPT	The actual unit processing time shall be the actual production time plus the actual unit setup time.
Good quantity	GQ	The good quantity shall be the produced quantity that meets quality requirements.
Produced quantity	PQ	The produced quantity shall be the quantity that a work unit has produced in relation to a production order.

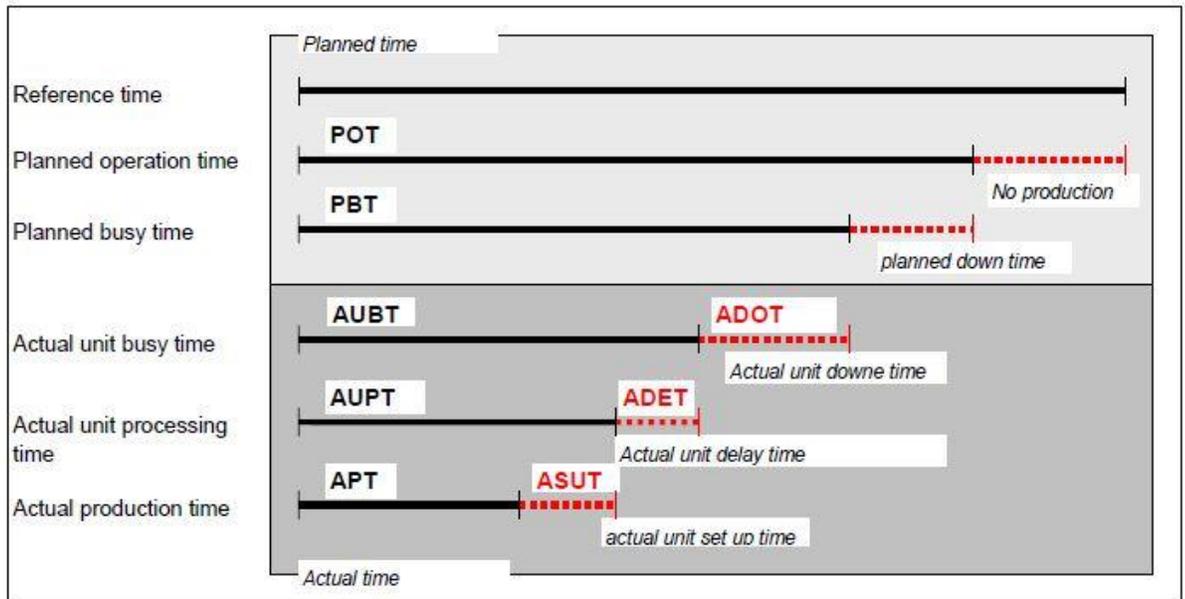


Figure 8 - Production Time Model for work units (ISO22400-2:2014 2014)

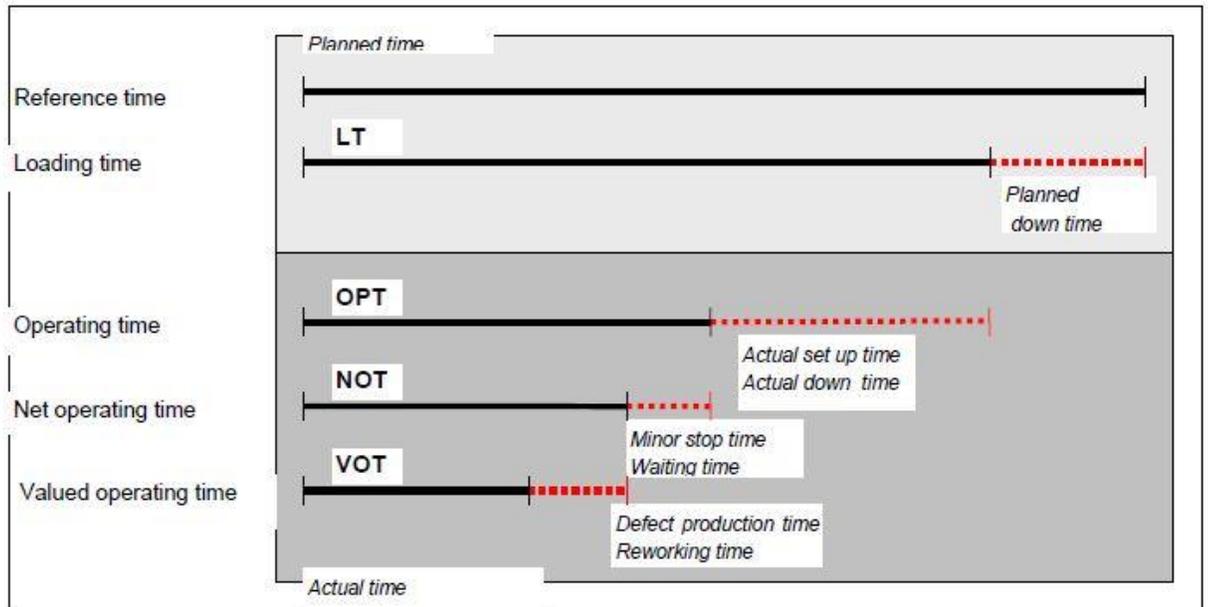


Figure 9 - Production Time Model for batches or Loss Time Model (ISO22400-2:2014 2014)

In this research based on the needs of the factory and suggestions of managers, four KPIs were selected from the parameter-indicator matrix: OEE, availability, performance ratio, and quality ratio. Two other KPIs also were selected from other resources. Lead time and delivery performance are the other selected KPIs.

3.3.1. OEE

Nakajima (1988) presented OEE as a method to assess the progress attained through the enhancement of initiatives carried out as part of his offered total productive maintenance (TPM) philosophy. According to Nakajima (1988), OEE is a metric or measure for the assessment of equipment effectiveness. Nakajima (1988) consequently proposes that OEE is: "A measure that attempts to reveal [the] hidden costs". Nakajima (1988) describes the most effective applicability of OEE is applying it by process teams in conjunction with the application of the quality control tools, such as cause and effect, fishbone or Pareto diagram. Such applications can be significant supplements to the existing factory performance measurement system. Within this framework, OEE should consequently be considered as an operational measure, rather than a strategic one (Nakajima 1988).

It is very important to recognize and assess manufacturing process disturbances. Jonsson and Lesshammar (1999) categorize those disturbances as sporadic and chronic based on their frequency of occurrence. "Chronic disturbances are usually small, hidden and complicated because they are the result of several concurrent causes. Sporadic disturbances are more obvious since they occur quickly and as large deviations from the normal state. Sporadic disturbances occur irregularly and their dramatic effects are often considered to lead to serious problems however, research evidence suggests that it is the chronic disturbances that result in the low utilization of equipment and large costs because they occur repeatedly" (Dal, Tugwell et al. 2000). Dal, Tugwell et al. (2000) state the chronic disturbances are harder and more problematic to recognize because they can frequently be recognized as the normal process state. Dal, Tugwell et al. (2000) also mention that the recognition of chronic disturbances is only probable through comparison of theoretical capacity of the equipment with its performance. According to Dal, Tugwell et al. (2000) sporadic and chronic disturbances both have different undesirable impacts on the manufacturing processes. They use resources without adding any value to the finishing product. OEE tries to classify these losses. Therefore, according to Nakajima (1988), OEE is a bottom-up method where an integrated force tries to achieve overall equipment effectiveness by eliminating the six big losses. The six big losses are brought in table 3.

Table 3 - Six Big Losses (<http://www.oeo.com/>)

Six Big Loss Category	OEE Loss Category	Event Examples	Comment
Breakdowns	Down Time Loss	<ul style="list-style-type: none"> ▪ Tooling Failures ▪ Unplanned Maintenance ▪ General Breakdowns ▪ Equipment Failure 	There is flexibility on where to set the threshold between a Breakdown (Down Time Loss) and a Small Stop (Speed Loss).
Setup and Adjustments	Down Time Loss	<ul style="list-style-type: none"> ▪ Setup/Changeover ▪ Material Shortages ▪ Operator Shortages ▪ Major Adjustments ▪ Warm-Up Time 	This loss is often addressed through setup time reduction programs.
Small Stops	Speed Loss	<ul style="list-style-type: none"> ▪ Obstructed Product Flow ▪ Component Jams ▪ Misfeeds ▪ Sensor Blocked ▪ Delivery Blocked ▪ Cleaning/Checking 	Typically only includes stops that are under five minutes and that do not require maintenance personnel.
Reduced Speed	Speed Loss	<ul style="list-style-type: none"> ▪ Rough Running ▪ Under Nameplate Capacity ▪ Under Design Capacity ▪ Equipment Wear ▪ Operator Inefficiency 	Anything that keeps the process from running at its theoretical maximum speed (a.k.a. Ideal Run Rate or Nameplate Capacity).
Startup Rejects	Quality Loss	<ul style="list-style-type: none"> ▪ Scrap ▪ Rework ▪ In-Process Damage ▪ In-Process Expiration ▪ Incorrect Assembly 	Rejects during warm-up, startup or other early production. May be due to improper setup, warm-up period, etc.
Production Rejects	Quality Loss	<ul style="list-style-type: none"> ▪ Scrap ▪ Rework ▪ In-Process Damage ▪ In-Process Expiration ▪ Incorrect Assembly 	Rejects during steady-state production.

OEE is measured in terms of these six big losses and it is calculated from the following equation:

$$\text{OEE} = \text{Availability} * \text{Performance Ratio} * \text{Quality Ratio}.$$

OEE calculation base on time model for batches is shown in Figure 10.

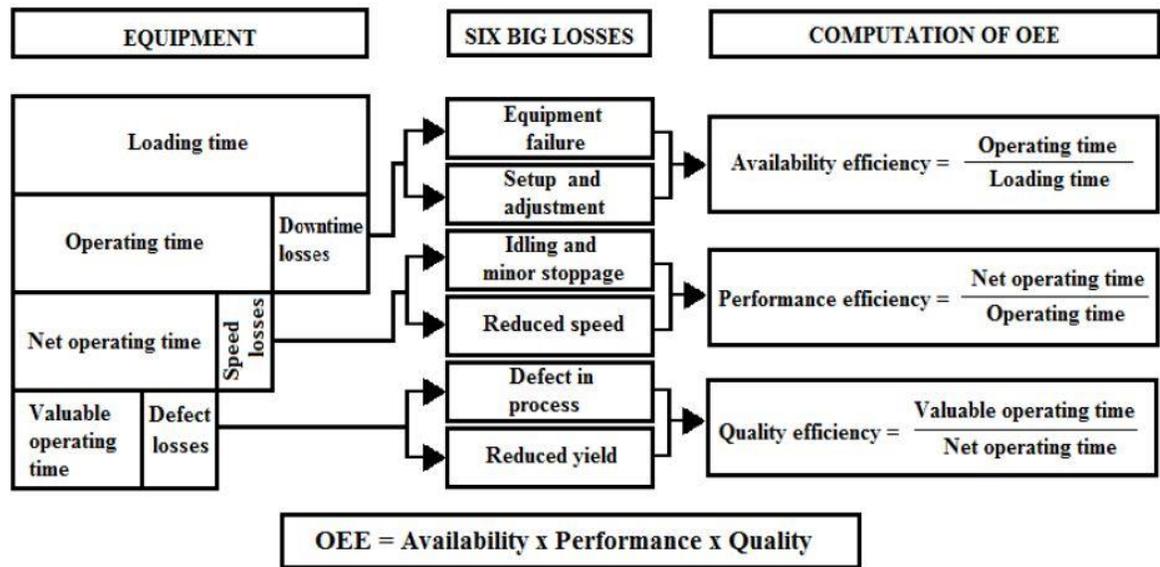


Figure 10 - OEE Calculation (Nakajima 1988)

Different elements of OEE including availability, performance ratio, and quality ratio are considered as KPIs based on ISO22400-2:2014 (2014) and explained separately in this chapter.

3.3.2. Availability

“The availability element of the OEE measure is concerned with the total stoppage time resulting from unscheduled downtime, process set-up and changeovers, and other unplanned stoppages. In simple terms, it is the ratio of actual operating time to the planned operating time, and takes into account the theoretical production time against which unplanned downtime is highlighted. Planned preventative maintenance is not therefore regarded as a loss in this respect” (Dal, Tugwell et al. 2000).

Dal, Tugwell et al. (2000) indicate that a significant aspect of the availability is loading time. Loading time can be defined as the total length of the operating time after any planned downtime deductions. Planned downtime can be as follows:

- Waiting time due to current orders completions;
- No operator available;
- Planned maintenance activities;
- Process improvement activities and equipment trials;
- Machine cleaning; and

- Operator training.

In general and based on time model for work units (Figure 8), the “availability is a ratio that shows the relation between the actual production time (APT) and the planned busy time (PBT) for a work unit” (ISO22400-2:2014 2014). But based on loss time model (Figure 9) the “availability indicates the proportion of time the equipment is actually utilized (OPT) against the loading time (LT). The availability represents the magnitude of equipment stoppage loss” (ISO22400-2:2014 2014).

Availability show how firmly the capacity of the production work unit is used in relation to the available capacity. Availability is also labeled as the degree of utilization or capacity factor.

Availability based on two definitions is calculated respectively as follows:

Availability = Actual Production Time (APT) / Planned Busy Time (PBT)

Availability = Operating Time (OPT) / Loading Time (LT).

Availability is a percentage number between 0 and 100, and the higher the number is better.

3.3.3. Performance Ratio

Performance ratio is the second element of OEE calculation. It is called also performance rate, performance efficiency or effectiveness. Performance ratio is calculated in different ways. Nakajima’s measurement is based on a fixed amount of output of production and performance shows the actual deviation in production time from the idle cycle time (Nakajima 1988). Groote (1995) alternatively concentrates on a fixed time, and computes the deviation in production time from that planned time.

“Performance efficiency is the product of the operating speed rate and net operating rate. The operating speed rate of equipment refers to the [difference] between the ideal speed and its actual operating speed. The net operating rate measures the achievement of a stable processing speed over a given period of time. This calculates losses resulting from minor recorded stoppages, as well as those that go unrecorded on daily logs, such as small problems and adjustment losses” (Dal, Tugwell et al. 2000).

Performance Ratio = (Net Operating Rate * Operating Speed Rate)*100

Where:

Net Operating Rate = (No. Produced * Actual Cycle Time) / (Operating Time)

Operating Speed = Theoretical Cycle Time / Actual Cycle Time

Therefore:

Performance Ratio = (No. Produced * Theoretical Cycle Time) / (Operating Time)

According to loss time model of ISO22400-2:2014 (2014), the performance ratio is calculated by dividing Net Operating Time (NOT) to Operating Time (OPT).

Performance ratio = Net Operating Time (NOT) / Operating Time (OPT).

3.3.4. Quality Ratio

Dal, Tugwell et al. (2000) mention that the third and last component of the OEE computation is the quality ratio. It is used to designate the fraction of imperfect, defective, or faulty production to the total production volume. The quality ratio is comprised of defects that just lie in the selected stage of production, usually on a specific machine or production line.

Quality Ratio = (Total No. Produced - No. Scrapped) / (Total No. Produced)

According to ISO22400-2:2014 (2014), the quality ratio is calculated by dividing Good Quantity (GQ) to Produced Quantity (PQ)

Quality Ratio = Good Quantity (GQ) / Produced Quantity (PQ).

In the loss time model, the quality ratio is called finished goods ratio and it is calculated by dividing the Good quantity produced (GQ) to the Consumed material (CM).

Finished Goods Ratio = Good quantity produced (GQ) / Consumed material (CM).

3.3.5. Lead Time

Lead time is all the duration of time passed from the receiving an order or perception of the need of an item until the item reaches and is provided for use by customer. This includes all the materials cycle duration (Anil Kumar, Suresh et al. 2008). The customer sees lead time as the elapsed time from order to delivery. Lead time is a crucial competitive variable because markets become more and more time competitive (Christopher 2011).

“From a marketing point of view the time taken from receipt of a customer’s order through to delivery (sometimes referred to as order cycle time (OCT) (Figure 11)) is critical. In today’s just-in-time environment short lead times are a major source of competitive advantage. Equally important, however, is the reliability or consistency of that lead time. It can actually be argued

that reliability of delivery is more important than the length of the order cycle because the impact of a failure to deliver on time is more severe than the need to order further in advance” (Christopher 2011).

It is desirable to analyze each component of the lead time to reduce the waste times. Lead time for manufacturing consists of the preprocessing lead time, processing lead time, and post-processing lead time (<http://en.supply-chain-consultant.eu/10/lead-time-supply-chain/> 2015-05-22, 16:00).

The lead time components based on the supply chain management perspective are illustrated in Figure 12.

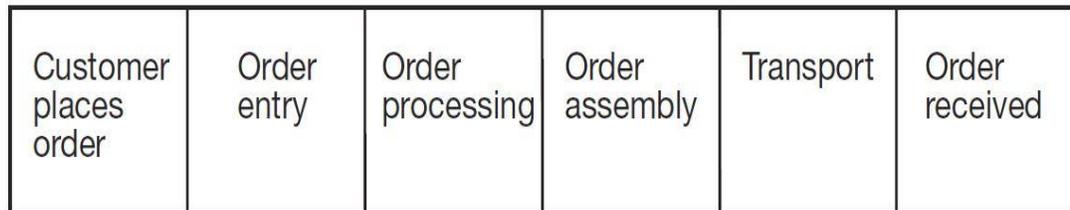


Figure 11 - The Order Cycle (Christopher 2011)

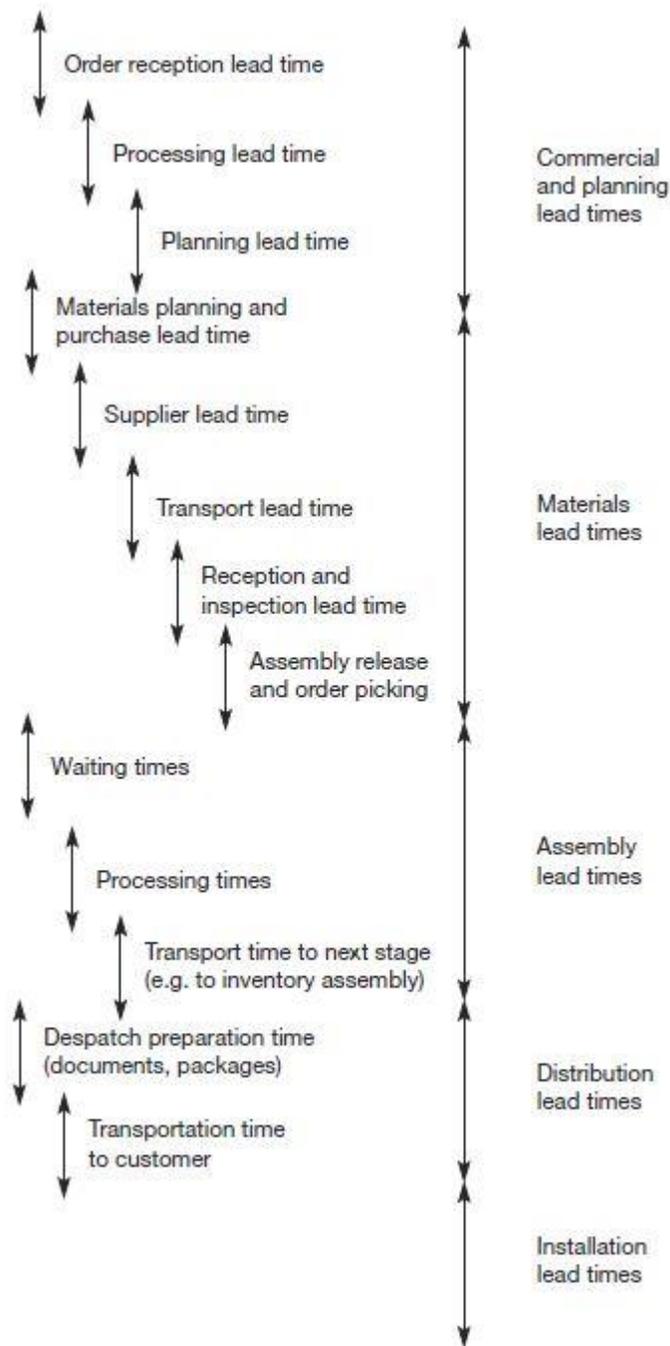


Figure 12 - The lead time components based on the supply chain management perspective (Christopher 2011)

3.3.6. Delivery Performance

Delivery precision or delivery performance as mentioned in some literatures is a widely used term in supply-chain management and logistics. According to Stadtler and Kilger (2008), each supply chain is unique while there are some performance measurements like delivery

performance which are applicable within all supply chains. Because merely flawless order fulfillment which is reached by delivering the right product at the right time to the right place ensures customer satisfactions, the delivery performance is calculated in terms of the actual delivery date compared to the delivery date mutually agreed upon (Stadtler and Kilger 2008). Delivery performance is measured in certain time intervals and results reflect how accurate companies are in delivering their goods or service to their customers. "An important indicator in the context of delivery performance is the order lead-time. Order lead-times measure, from the customer's point of view, the average time interval from the date the order is placed to the date the customer receives the shipment. As customers are increasingly demanding, short order lead-times become important in competitive situations. Nevertheless, not only short lead-times but also reliable lead-times will satisfy customers and lead to a strong customer relationship, even though the two types of lead-times (shortest vs. reliable) have different cost aspects" (Stadtler and Kilger 2008).

4. Empirical study

This chapter aims to describe the result from several interviews, field studies at the production site in Brunna. This step is necessary to chart the steps in production, in order to understand and identify which areas to measure for identifying the KPI's for the capacity and productivity. The description of the production is a result of the interviews and on site collected data. It has not brought some part of the descriptions due to the not invasion of the company privacy.

4.1. Production structure

The structure for the manufacturing process of the phospholipid, PL90, can be described as batch production. As it is described, batch production differs from the line production where the components or goods are produced in continuous stream. Within batch production the components or goods are manufactured in large groups (batches). The output for production in the factory in Brunna is measured in the amount of kilograms (kg) and each produced batch usually is usually between 320-370 kg. This is due to a combination of the natural variation of the raw material (hen egg yolk) and differences in output from the parallel production lines.

The production system for the PL90 can be considered as a push production system, where the company produces according to full year customer demand forecast. This production planning is considered as the baseline for the whole year. The full year demand is divided into monthly and weekly plans. In this stage the production plan needs to consider both the weekly capacity of the factory and the number of available weeks. There are normally two service shut downs every year, one in the summer and one in the winter for about 6-8 weeks in total.

The main plan covers "batches per week" for all available weeks of the year. This information is later on transferred to a specific production schedule.

Example:

The main plan says 12 batches week 38. The production schedule says "batch A starts Monday at 9:00, batch B on Monday at 18:00" and so on in order to meet the weekly demand of 12 batches.

The detailed production schedule is revised daily to be accurate for the next shift.

4.2. Material flow

The main raw material for PL90 is egg yolk powder. The egg yolk is sampled and analyzed before it is released to production by the Quality Assurance responsible (QA). It is not possible to use egg yolk that is not approved and released by QA.

In addition, several solvents are used to extract and purify the phospholipid.

4.3. Production unit

The organization is divided in two sections with two responsible section managers; extraction and purification. The production is running twenty four hours a day, seven days a week except for the service shut downs. There is a five shift schedule with five or six operators and one team leader for each of the five teams. The team is operating the entire process; both extraction and purification.

The process could be summarized in five steps: extraction, purification, dispensing, quality control and release, Figure 13. Each step will be explained in the next chapters.



Figure 13 - Overview of PL90 Production

4.4. Extraction process

Egg yolk from hen naturally contains around 20 % phospholipids. The egg yolk powder is mixed with ethanol to extract the phospholipid. The phospholipid and ethanol is separated from the egg yolk using a filter machine called beltfilter. Mixing the egg yolk into the ethanol is a manual operation and two mixing vessels are used. The mixing vessels need to be filled three times to extract one batch PL90. The filtering process is continuous and it takes about 9-10 hours to mix and filter one batch. The residual 80 % of the egg yolk powder is dried from ethanol and sold as a separate product.

There is about 10 ton of ethanol mixed with the phospholipid after extraction and the next step is to reduce the ethanol content from the phospholipid solution by evaporation. The ethanol is evaporated using heat exchangers in two steps called “pre-evaporation” and “end-evaporation”. The output of the extraction and evaporation is called “crude PL”. Extraction process is illustrated in Figures 14 and 15.

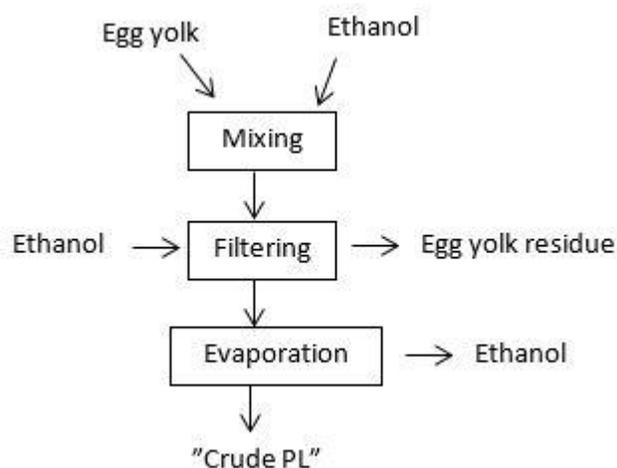


Figure 14 - Extraction process

4.5. Purification

A part from phospholipids some other substances will be extracted from the egg yolk such as cholesterol and egg oils. These “impurities” will be removed during the purification process. The purification is done with three precipitations in acetone and ether and filtering, including sterile 0.2 µm filter. The product is dried from solvents after the third precipitation. The last step is to pack the dry product in plastic bags, of 3 kg each. This is called “dispensing”. The finished PL90 must be stored in a freezer. There is parallel equipment in several of the process steps. (Figure 16 and 17)

4.6. Quality control and assurance

When the products are produced, the quality of the produced batches must be controlled and checked to see whether they meet the tough pharmaceutical rules and standards. The quality control is done by the quality control section through several checks at its laboratory. The quality assurance department checks that the batch records from the production and quality control if they are traceable.

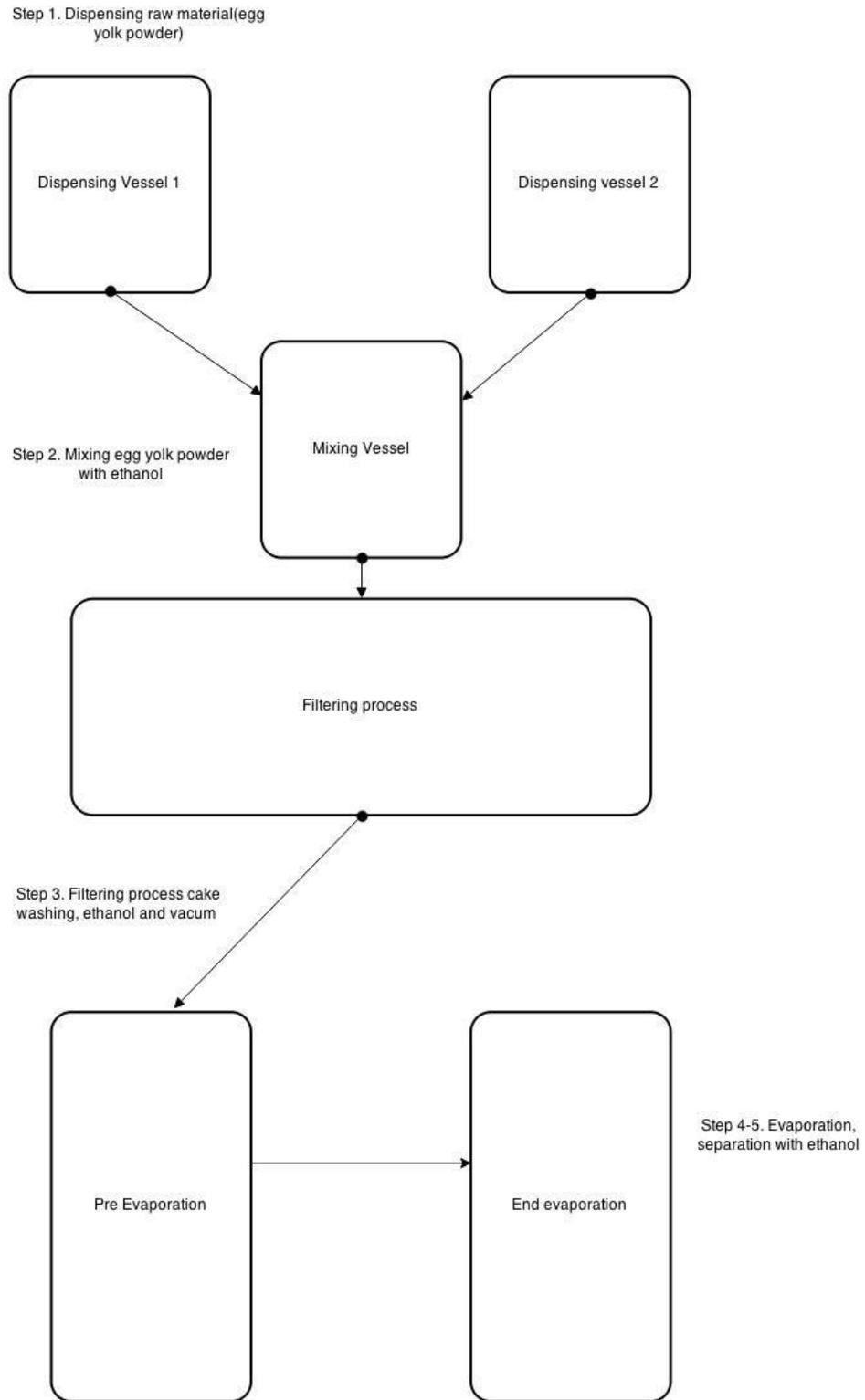


Figure 15 - Extraction process in details

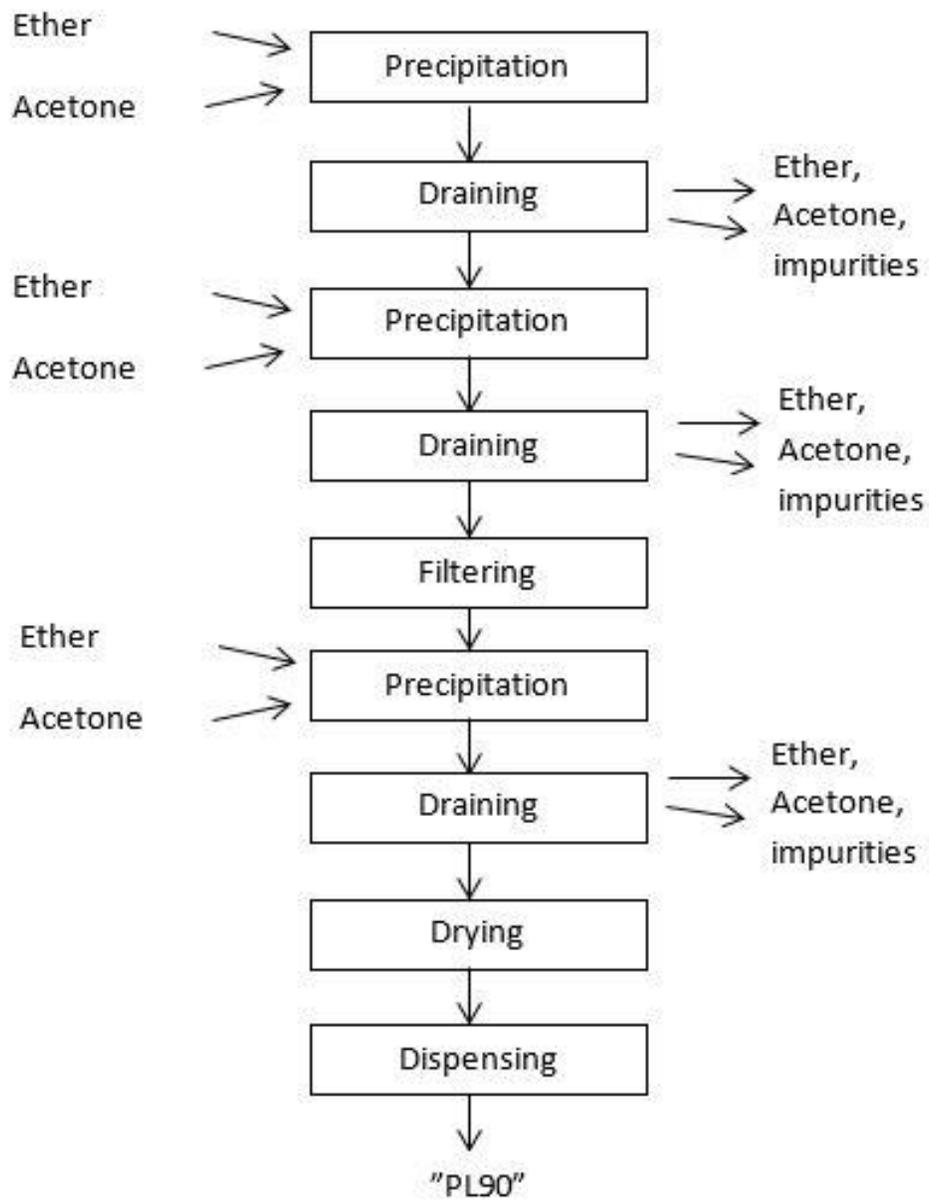


Figure 16 - Purification and Dispensing Processes

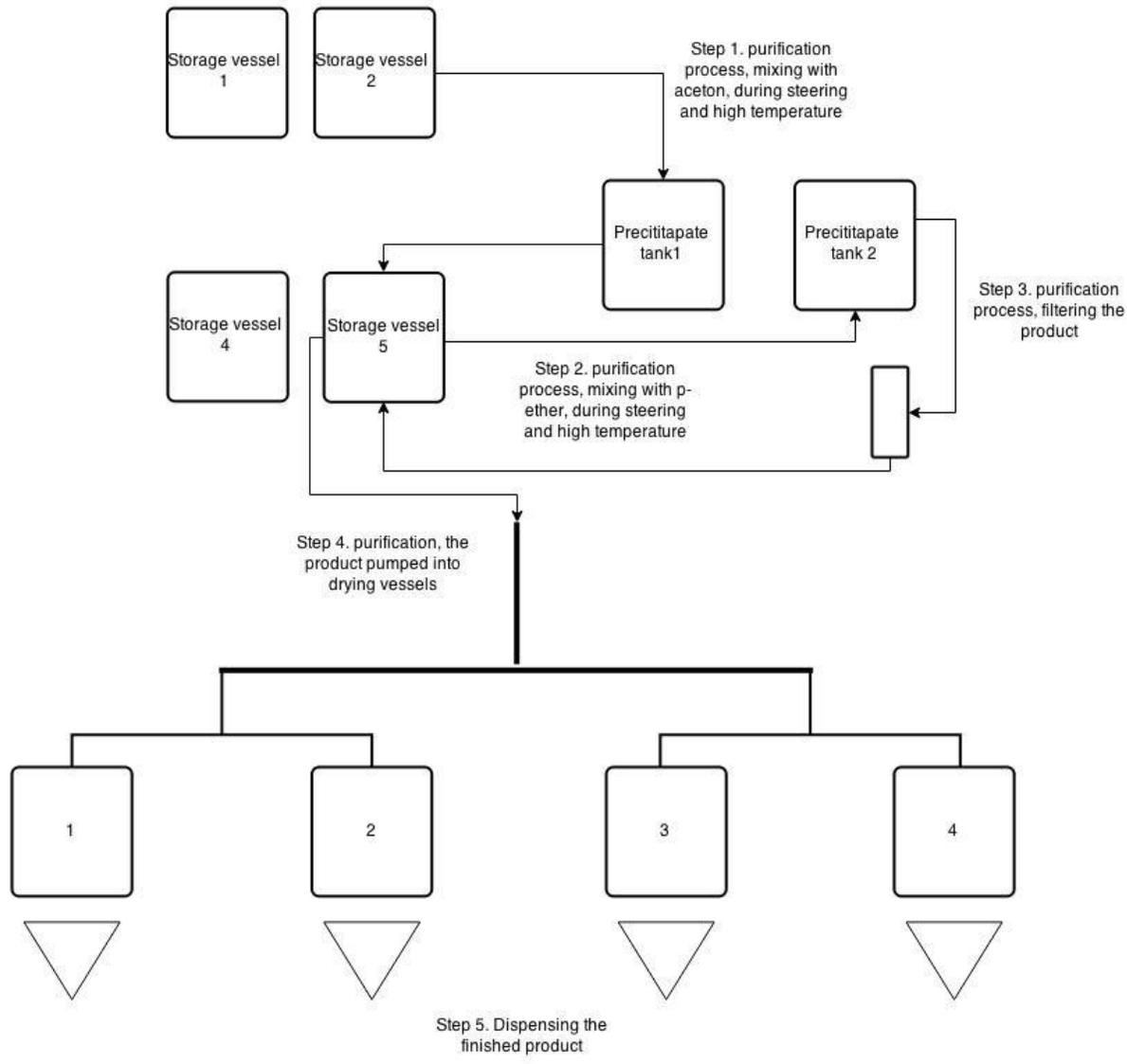


Figure 17 - Purification and Dispensing processes in details

5. Analysis

In this chapter, we have tried to examine the selected methods and KPIs if they fit into the research area and whether they are applicable for the Fresenius Kabi in Brunna.

5.1. Selected Model

Because of the nature of batch production which is being used in the Fresenius Kabi manufacturing production in Brunna and based on the very complex process steps there, and also according to extracted data from onsite databases and log books, the loss time model (Figure 9) was selected as the main reference model for calculating the KPIs.

In the selected model, there are different parameters in two areas of planned time and actual time including: reference time, loading time (LT), planned down time, operating time (OPT), actual set up time, actual down time, net operating time (NOT), minor stop time, waiting time, valued operating time (VOT), defect production time, and reworking time.

In planned time area, the reference time is all the working durations excluding the 11 weeks of factory shut down. The reference time can be 24 hours (one day), 168 hours (one week), or any other contractual or adaptive duration of time. Planned down times are any planned actions or happenings that stop planned production for a considerable length of time. Down time should be long enough to be logged as a track-able event. Planned down times in the production site mostly include all the planned maintenance cleanings in progress (CIPs) and changing filters for some machines. Loading time is calculated by subtracting all planned down time from the reference time. For example if we consider the reference time for beltfilter 24 hours and if there is a planned CIP for the belt filter during that 24 hours for 5 hours, so the loading time will be 19 hours.

In actual time area and based on the theory, operating time (OPT) is calculated by subtracting actual setup times and actual down times from the loading time (LT). Net operating time (NOT) is measured by deducting the minor stops time and waiting times from the operating time (OPT). If defect product times and reworking times is subtracted from the net operating time, valued operating time (VOT) is attained.

The aim of this research is to proposing some KPIs for the production of PL90 at Fresenius Kabi in Brunna. Based upon this assumption and the investigations at the PL90 production site, it is found that there are no actual setup times, minor stops times and defect production times.

There are no actual setup times because there are no changes regarding the different products in any machines in the PL90 production line. There are also no minor stops times recorded in the system. No defect production times happen concerning the PL90 production because any defect reports receiving from QC cause the product to be scrapped. According to team leaders in production site, reworks rarely happen (around 5 to 6 batches out of almost 486 batches (2014) each year) in the PL90 production line. There are some actual down times in system and they are recorded the same as deviations that do not stop the production line. Therefore, in current situation, it is almost impossible to distinct the down times from the deviations. In order to be able to calculate some KPIs, it is considered that there are no actual downtimes in the system. The times that the machines do not work because of any reasons except downtimes are considered as waiting times. The machine in this situation is ready to work but maybe because of non-proper planning does not work and is idle. Based upon what has been explained and because there is no defect production time and almost no rework time, the valued operating time (VOT) is equal to net operating time (NOT). Loading time (LT) is considered as operating time (OPT) because there is no record of actual down time and also there is no setup time. It should be mentioned that there is no appropriate and accurate production planning regarding the production of PL90. Thus, the planning is not reliable for any investigation like this research. Though there are no minor stops, huge amount of waiting times is seen in the system. Hence, the operating time (OPT) is calculated by adding net operating time (NOT) to waiting times. (Figure 18)

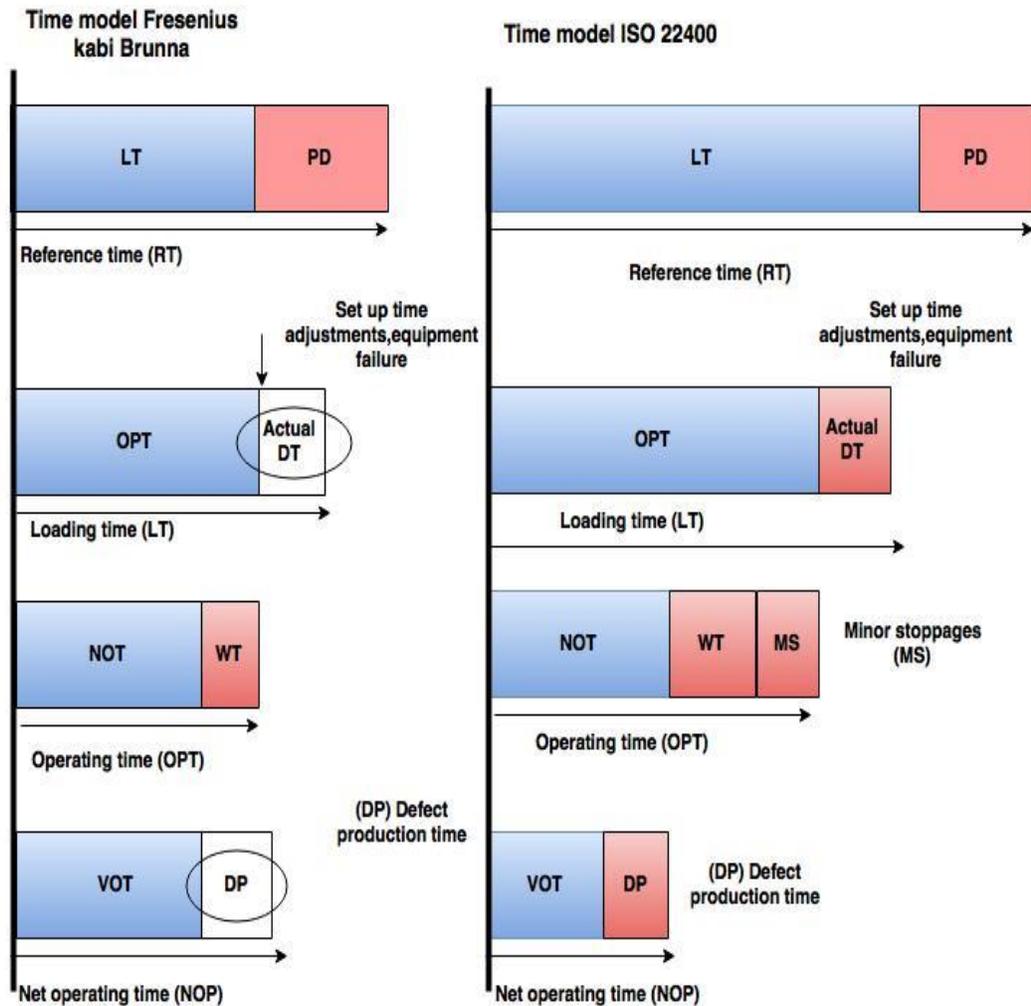


Figure 18 - Fresenius Kabi time model vs ISO 22400 loss time model

5.2. Data Collection

In order to perform a thorough, valid and reliable analysis, one excel sheet by means of collecting data from the production site was created and it was to be filled by production staff within two weeks but because of strict rules regarding the pharmacy industry, the proposal was rejected by production manager. Instead of recording of current batches in the production, 30 batch protocols were examined and reviewed carefully from the archive. All the relevant data concerning the analysis chapter were taken from those batch protocols.

5.3. Selected KPIs

Among several KPIs regarding manufacturing production, six KPIs were selected in chapter three, literature review. OEE, Availability, Performance Ratio, Quality Ratio, Lead Time, and Delivery Performance are those six KPIs. In the following chapter, each of those KPIs are examined and evaluated to see if they are appropriate and applicable to the Fresenius Kabi in Brunna and if they are applicable to be applied how they can be calculated.

According to the needs from the problem statement and the recorded data in the production site, and based on the loss time model, we decided to extract the different processes durations from the extraction process until the releasing the finished product in the factory. The extracted durations were necessary in order to see what kind of KPIs are viable to compute within this production site.

5.3.1. Availability

According to loss time model, availability is measured as a ratio of OPT to LT. As it is explained in 5.1 Selected Model, LT is considered as OPT because there is no record of actual down time and there is also no setup time in the Brunna factory concerning PL90 production. In this situation, the Availability is always 100%.

$$\text{Availability} = \text{OPT} / \text{LT} = \text{LT} / \text{LT} = 1.$$

Therefore, the availability is not a proper KPI for PL90 production at Fresenius Kabi in Brunna and it will not be considered as an appropriate one until they record the actual downtimes accurately and have a precise production planning.

5.3.2. Performance Ratio

Based upon the loss time model, performance ratio is calculated as a ratio of NOT to OPT. As it is explained in chapter 5.1, OPT is NOT plus waiting times.

There are several alternatives regarding the calculation of performance ratio in the production line of PL90 at Fresenius Kabi. Measuring the performance ratio for each machine can be one alternative while considering all machines in the production line from start to end as a single machine and measuring the performance ratio for that can be the other alternative. Dividing the production into smaller parts and considering that part as a machine can be the other alternative. Some of those alternatives are illustrated in Figure 19 and 20.

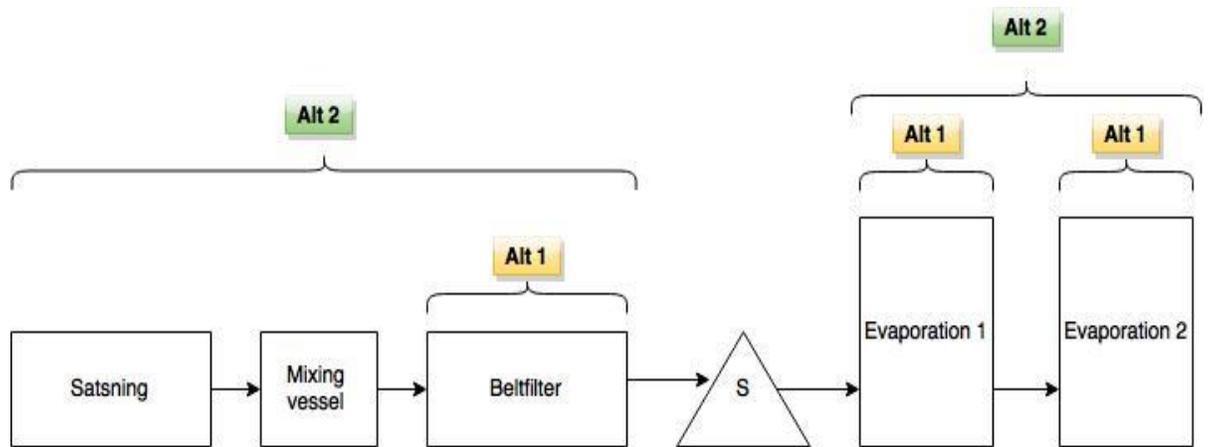


Figure 19 - Alternative measurements of performance ratio - sample 1: extraction

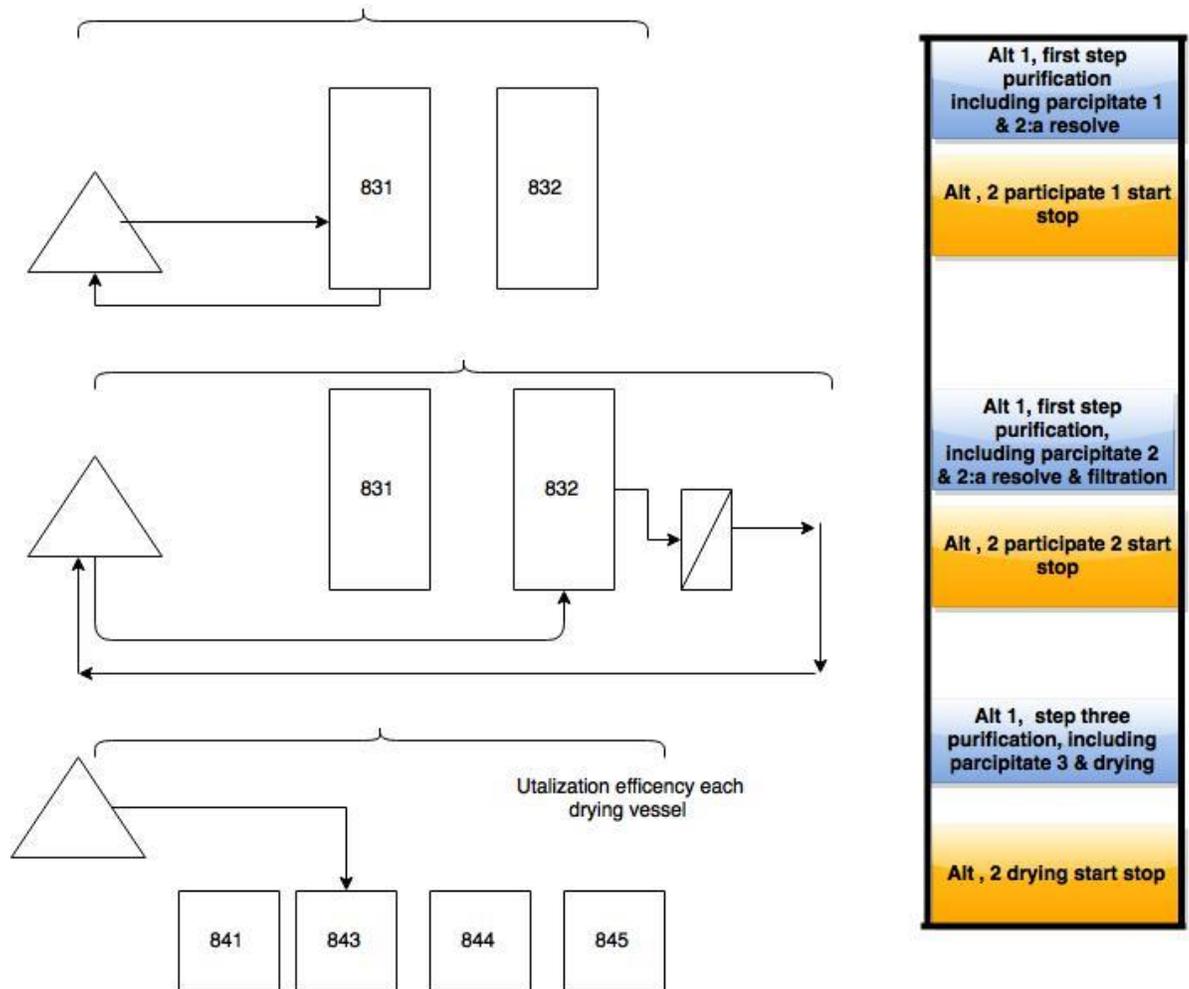


Figure 20 - Alternative measurements of performance ratio - sample 1: extraction

Beltfilter, pre-evaporation and end-evaporation machines are considered as sample alternatives for calculating performance ratio KPI while evaporation process including pre-evaporation and end-evaporation machines is deliberated as one other alternative. The result of those calculations are brought in table 4 to table 7.

Table 4 - Performance ratio - beltfilter

Date	Beltfilter Time (NOT)	Waiting time in Beltfilter (WT)	Beltfilter Performance Ratio (daily)
2015-04-06	9:35:00	14:25:00	39,93%
2015-04-07	16:30:00	7:30:00	68,75%
2015-04-08	20:50:00	3:10:00	86,81%
2015-04-09	18:20:00	5:40:00	76,39%
2015-04-10	16:25:00	7:35:00	68,40%
2015-04-11	15:50:00	8:10:00	65,97%
2015-04-12	15:50:00	8:10:00	65,97%
2015-04-13	5:20:00	18:40:00	22,22%
2015-04-14	19:05:00	4:55:00	79,51%
2015-04-15	18:30:00	5:30:00	77,08%
2015-04-16	18:45:00	5:15:00	78,12%
2015-04-17	18:00:00	6:00:00	75,00%
2015-04-18	18:55:00	5:05:00	78,82%
2015-04-19	15:40:00	8:20:00	65,28%

Table 5 - Performance ratio - beltfilter (weekly)

Date	Beltfilter Performance Ratio (weekly)	Sastnig and Beltfilter performance Ratio (weekly)
2015-04-06 to 2015-04-12		
NOT	113:20:00	98:45:00
WT	54:40:00	69:15:00
Performance Ratio	67,46%	58,78%
2015-04-06 to 2015-04-12		
NOT	114:15:00	143:45:00
WT	53:45:00	24:15:00
Performance Ratio	68,01%	85,57%

Table 6 - Performance ratio - pre-evaporation and end-evaporation

Date	Förindustnig Duration (NOT)	Slutindustnig (NOT)	Total Industnig Duration (NOT)	Förindustnig Performance Ratio (daily)	Slutindustnig Performance Ratio (daily)
2015-04-07	8:10:00	0:55:00	9:05:00	34,03%	3,82%
2015-04-08	18:20:00	2:20:00	20:40:00	76,39%	9,72%
2015-04-09	16:30:00	3:20:00	19:50:00	68,75%	13,89%
2015-04-10	14:30:00	2:50:00	17:20:00	60,42%	11,81%
2015-04-11	16:45:00	2:40:00	19:25:00	69,79%	11,11%
2015-04-12	16:40:00	3:55:00	20:35:00	69,44%	16,32%
2015-04-13	8:25:00	2:50:00	11:15:00	35,07%	11,81%
2015-04-14	10:35:00	2:05:00	12:40:00	44,10%	8,68%
2015-04-15	8:25:00	3:20:00	11:45:00	35,07%	13,89%
2015-04-16	16:45:00	6:40:00	23:25:00	69,79%	27,78%
2015-04-17	19:55:00	3:45:00	23:40:00	82,99%	15,63%
2015-04-18	16:40:00	3:00:00	19:40:00	69,44%	12,50%
2015-04-19	16:35:00	3:20:00	19:55:00	69,10%	13,89%
2015-04-20	3:20:00	1:20:00	4:40:00	13,89%	5,56%

Table 7 - Performance ratio - evaporation (weekly)

Date	Total industning Performance Ratio (weekly)
2015-04-07 to 2015-04-13	
NOT	117:15:00
WT	50:45:00
Performance Ratio	69,79%
2015-04-014 to 2015-04-20	
NOT	129:55:00
WT	38:05:00
Performance Ratio	77,33%

The performance ratio increases as the waiting time decreases or meanwhile a machine processes more material. This ratio will not reflect how efficient the machine has been during the selected period of time. For example, the beltfilter processes two batches in 24 hours with the performance ratio of 100% and two other batched in 18 hours with the performance ratio of 75%. The 24 hours of processing should not be considered as more efficient than the 18 hours processing because maybe the later has been more efficient and if the machine was used properly, it was able to process more than 2 batches in 24 hours. Therefore, this KPI reflects how much a machine or process has been used according to the available machine time, regardless of the efficiency of way of performing it. Though this KPI is fully applicable within this production plant, it will not show useful result for managerial system.

5.3.3. Quality Ratio

There are two ways of calculating quality ratio: GQ / PQ ; or GQ / CM . The problem regarding the computing of the first ratio in this factory is that because of complexity of the processes and changing alternatively the nature of output (product) at end of each process or machine, it is very hard or almost impossible to measure the amount of produced quantity. The second calculation can be done for the whole processes, from start to the end, which gives the yield¹. It is almost impossible to measure the ratio for each machine because of what has been reasoned for the first calculation.

¹- The yield is the ratio of amount of input raw materials to amount of produced products.

Hence, this performance indicator is not suitable to be considered as a KPI. If there is a possibility to measure the amount of output of each machine at the end of each process, then the ratio should be considered as a KPI and the KPI should be measured and monitored.

5.3.4. OEE

OEE is computed by multiplying availability to performance ratio to quality ratio. OEE can be considered as an appropriate, practical, and efficient KPI when all those three affecting elements are calculated accurately. In this factory, the availability cannot be calculated precisely for each machine because of not recording downtimes and poor and inaccurate production planning system. It is not feasible to measure the quality ratio in this production site because there is no possibility to measure the quantity of product at the end of each process for each machine. Though the performance ratio can be measured, it will not help to shape an effective OEE. Thus, based on the current planning and production recording system, the computing of OEE is useless, inaccurate and irrational.

5.3.5. Lead Time

According to the literature review, lead time is all the duration of time passed from the receiving an order or perception of the need of an item until the item reaches and is provided for use by customer. There can be several lead times in a supply chain including production (Figure 12). In this report, several lead times are calculated regarding the manufacturing. The calculated lead times are presented in Appendix A. One of those lead times, total lead time, is brought as a sample in the main context of the research report. The total lead time is calculated by measuring the time from receiving an order to the production line until releasing of the produced product to deliver to the customer. In Table 8 and Figure 21 the total lead time for the 30 examined batches are shown. Figure 22 shows the component of total lead times including manufacturing lead time, waiting time between the end of production and starting of quality control, quality control lead time and quality assurance lead time.

This KPI is fully applicable based on the exciting measurements within the production of PL90. Providing this kind of performance indicator will make each batch lead-time traceable through all value and non-value added durations and wasted times as waiting time and unnecessary storage periods. Lead time KPI will reflect the reliability of the processes.

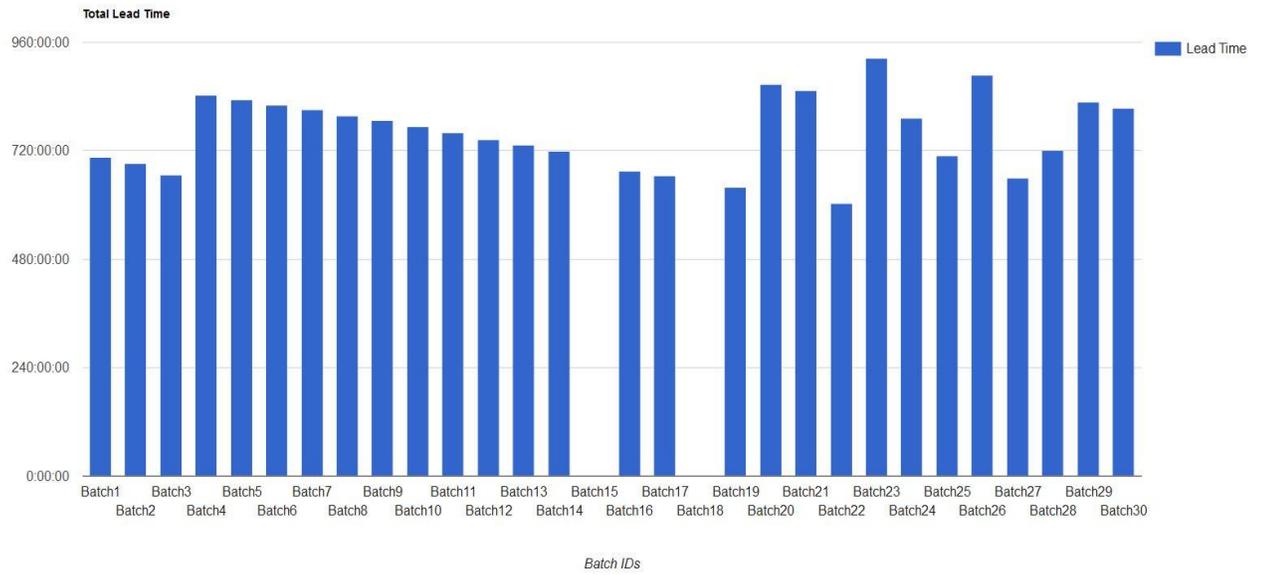


Figure 21 - Total lead times in hours

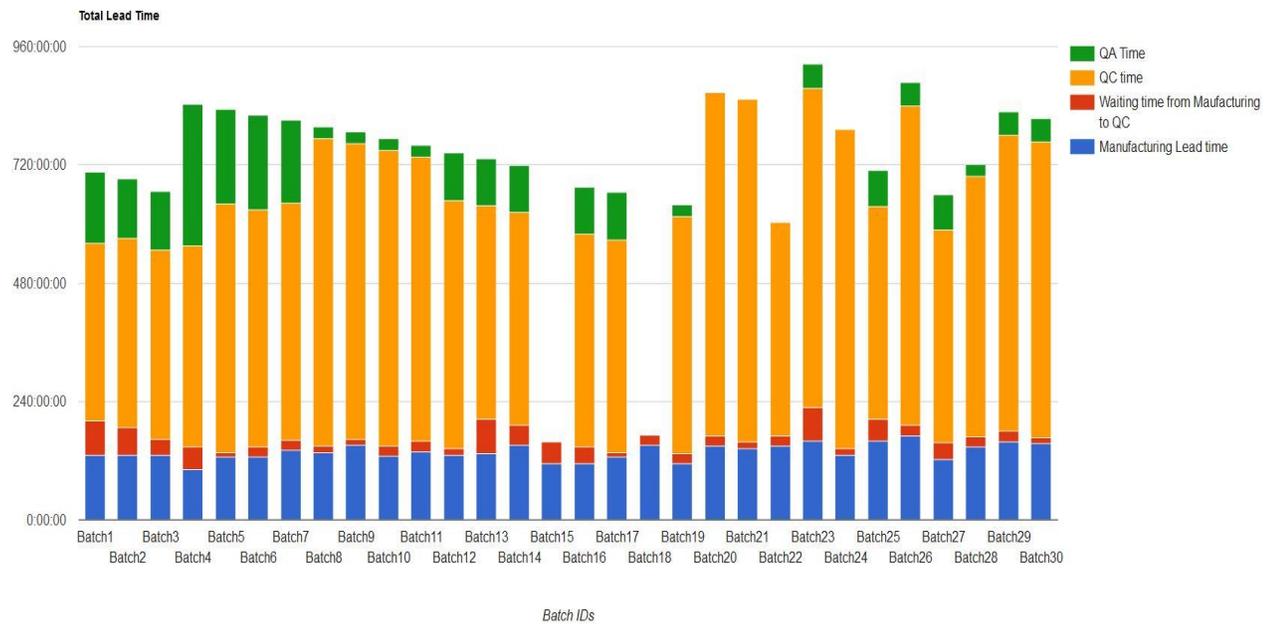


Figure 22 - Total lead time (including its components)

Table 8 - Total lead time

Batch ID	Lead Time	Lead Time
Batch1	704:30:00	29 Days 8 Hours and 30 Minutes
Batch2	690:45:00	28 Days 18 Hours and 45 Minutes
Batch3	666:50:00	27 Days 18 Hours and 50 Minutes
Batch4	843:30:00	35 Days 3 Hours and 30 Minutes
Batch5	831:45:00	34 Days 15 Hours and 45 Minutes
Batch6	820:20:00	34 Days 4 Hours and 20 Minutes
Batch7	810:00:00	33 Days 18 Hours and 0 Minutes
Batch8	797:25:00	33 Days 5 Hours and 25 Minutes
Batch9	786:35:00	32 Days 18 Hours and 35 Minutes
Batch10	773:40:00	32 Days 5 Hours and 40 Minutes
Batch11	759:55:00	31 Days 15 Hours and 55 Minutes
Batch12	743:55:00	30 Days 23 Hours and 55 Minutes
Batch13	732:30:00	30 Days 12 Hours and 30 Minutes
Batch14	719:15:00	29 Days 23 Hours and 15 Minutes
Batch15		
Batch16	675:10:00	28 Days 3 Hours and 10 Minutes
Batch17	664:15:00	27 Days 16 Hours and 15 Minutes
Batch18		
Batch19	638:20:00	26 Days 14 Hours and 20 Minutes
Batch20	866:35:00	36 Days 2 Hours and 35 Minutes
Batch21	853:25:00	35 Days 13 Hours and 25 Minutes
Batch22	602:25:00	25 Days 2 Hours and 25 Minutes
Batch23	923:45:00	38 Days 11 Hours and 45 Minutes
Batch24	792:00:00	33 Days 0 Hours and 0 Minutes
Batch25	707:45:00	29 Days 11 Hours and 45 Minutes
Batch26	887:35:00	36 Days 23 Hours and 35 Minutes
Batch27	660:00:00	27 Days 12 Hours and 0 Minutes
Batch28	720:50:00	30 Days 0 Hours and 50 Minutes
Batch29	828:05:00	34 Days 12 Hours and 5 Minutes
Batch30	814:40:00	33 Days 22 Hours and 40 Minutes

5.3.6. Delivery Performance

The delivery performance is calculated in terms of the actual delivery date compared to the delivery date mutually agreed upon. Delivery performance is measured in certain time intervals and results reflect how accurate companies are in delivering their goods or service to their customers. In this report, the delivery performance is calculated by the ratio of total number of produced and delivered batches on time to total number of delivered batches in a certain amount of time. For example, for the 30 examined batches if the target time is set to 28 days, 5 batches were delivered on time and 23 batches were not delivered on time (the data regarding two of thirty batches were not available concerning the total production time). In this example, the delivery performance is the ratio of 5 to 23 and it is equal to 0.17 or 17%. The delivery performance of the 30 examined batches for the target times of 28, 29 and 30 days are respectively illustrated in Figures 23, 24 and 25.

In conclusion, this KPI is fully applicable in this production site.

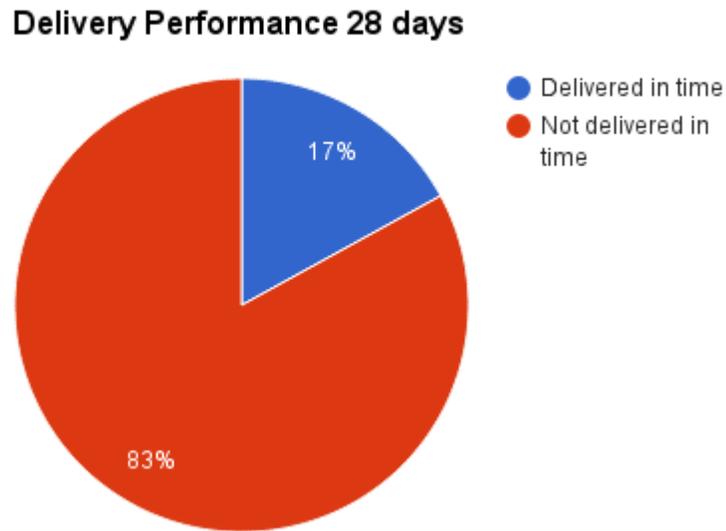


Figure 23 - Delivery performance - target time 28 days

Delivery Performance 29 days

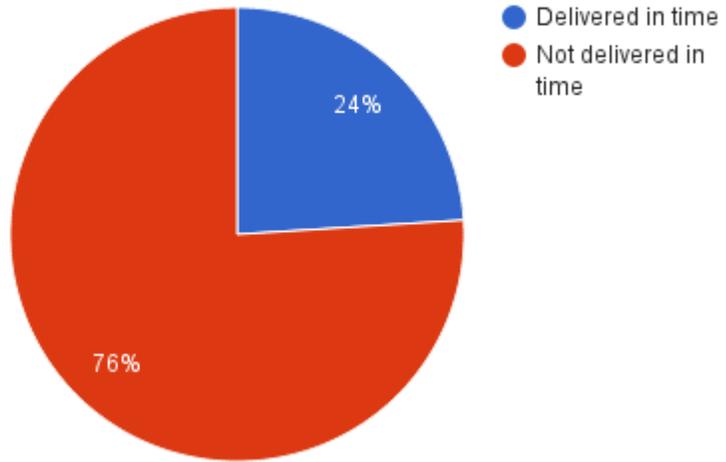


Figure 24 - Delivery performance - target time 29 days

Delivery Performance 30 days

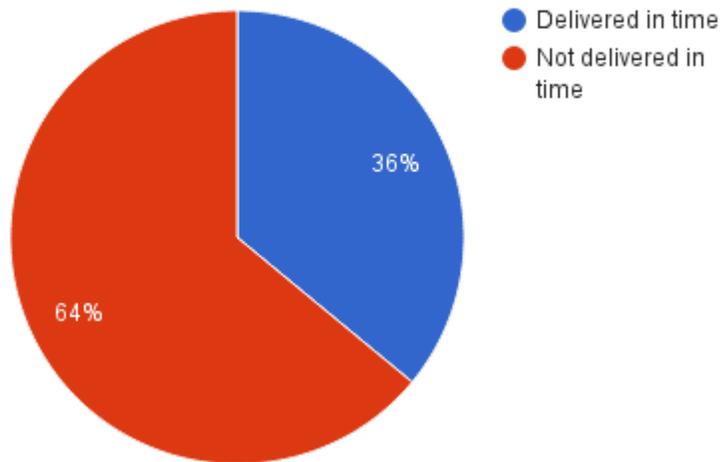


Figure 25 - Delivery performance - target time 30 days

6. Conclusion

This section will summarize the finding of this research and provide conclusion based on the evaluated KPIs from the analysis. The conclusion will foremost focus on the KPIs applicability in this plant, measurements needed, in order to take them into use and what they will provide. Furthermore, to conclude this research, the research question from section 1.2 will be answered.

The aim of this master thesis is to focus on providing some KPIs for PL90 production at Fresenius Kabi. The selected KPIs from the academic resources have been reviewed and analyzed in order to see if they are applicable in the production site. A summary of KPIs and their applicability in the factory are brought in Table 9. There are several other KPIs which can be implemented but because of non-proper time measuring and recording system in the production line and no accurate production scheduling, it is not possible to consider them as KPIs for this production site.

One of the largest obstacles in assessing the proposed KPIs in order to see if they are applicable and appropriate to be implemented in this factory was measuring the times. The selected KPIs are calculated just based on the existing time measurements. In conclusion, using just KPIs are not adequate to manage and execute the operations of an organization.

Table 9 - Applicability of KPIs

Lead time: This KPI is fully applicable based on the exciting measurements within the production of PL90. Providing this kind of performance indicator will make each batch lead-time traceable through all value and non-value added durations and wasted times as waiting time and unnecessary storage periods. Lead time KPI will reflect the reliability of the processes.

Delivery Performance: It is a fully applicable KPI in this production site. The main component of this KPI is the lead time. This KPI shows how on time and accurately products have produced from the starting point of manufacturing until releasing from the QA in comparison with the targeted time. This type of KPI does not reflect the delivering performance for the whole value chain or the shipment of products. Those indicators should be calculated separately.

Quality ratio: This performance indicator is not suitable to be considered as a KPI. The problem regarding the computing of the ratio in this factory is that because of complexity of the processes and changing alternatively the nature of outputs (products) at end of each process or machine, it is very hard or almost impossible to measure the amount of produced quantity. If there is a possibility to measure the amount of output of each machine at the end of each process, then the ratio should be considered as a KPI and it should be measured and monitored.

Availability: As it has been mentioned, according to the loss time model, with the existing measurements, the ratio always will be equal to 1 and show untrue results. Therefore, the availability is not a proper KPI for PL90 production at Fresenius Kabi in Brunna and it will not be considered as an appropriate KPI until the actual downtimes are recorded accurately and a precise production planning is implemented.

Performance ratio: This KPI is fully applicable within this production plant. Nevertheless, this ratio will not reflect how efficient the machine has worked during the selected time of duration. The calculations will just consider any machine time as value adding time regardless of the duration it takes to process the material. Therefore this KPI is not appropriate within this production plant.

OEE: OEE is computed by multiplying availability to performance ratio to quality ratio. OEE can be considered as an appropriate, practical, and efficient KPI when all those three affecting elements are calculated accurately. In this factory, the availability cannot be calculated precisely for each machine because of not recording downtimes and poor and inaccurate production planning system. It is not feasible to measure the quality ratio in this production site because there is no possibility to measure the quantity of product at the end of each process for each machine. Therefore, the KPI OEE is not considered as an applicable KPI for the plant in Brunna.

6.1. Research Objectives

The research objectives of this report have been brought in three research questions.

- How are the KPIs identified at Fresenius Kabi Company?
- What are the KPIs for the Fresenius Kabi Company?

- What are the benefits of identifying, measuring, monitoring, and controlling KPIs for the Fresenius Kabi Company?

Based on the needs of the factory found by observation and extracted data, and suggestions of managers from the interviews with them, four KPIs were selected from the parameter-indicator matrix of ISO22400-2:2014 (2014): overall equipment effectiveness (OEE), availability, performance ratio, quality ratio, and utilization efficiency. Two further KPIs were selected from other resources: Lead time and delivery performance. After a thorough analysis, it was found that three of them; performance ratio, lead time, and delivery performance are appropriate and applicable at the production site while three others are not worth to invest in, based on the current situation. The KPIs offer indicators to senior managers as how the organization is performing and by setting and using those KPIs, managers recognize whether the performance is on track or not. KPIs show where the organizations have been and how performance looks like from the past. They help the managers to plan and prepare where they are going, what success looks like in the future and identify how to achieve the success.

7. Recommendation

This chapter presents two sets of recommendations: first for Fresenius Kabi based on the research results and analysis of the research results to measure current KPIs more accurately, and adapt and implement more KPIs; and second for future studies to investigate further on the proposed subjects.

7.1. Recommendations for Fresenius Kabi

7.1.1. Data Recording System

As it is explained, when we wanted to collect data regarding production site, we found that there was not a comprehensive data recording system there. Different data is recorded in different systems or places mostly without using the computer system. We extracted the data from the batch protocols which even the data is not recorded in them completely. There are other log books for data recordings but they are also included insufficient data for thorough analyses.

It is highly recommended to implement a comprehensive data recording system like a database in order to be recorded production data on it accurately. All kind of data concerning the production including: times at different stages, consumed raw material, amount of end products and so on, should be measured and stored precisely.

7.1.2. Production Planning

During our investigation regarding this research and after the interviews with the team leaders, we found that there has not been an accurate production scheduling or planning in the production site. They plan the production weekly for the coming week but at the end of each day they adjust and change it. They change the plan according to the actual events. The changed plan will be saved and used as a reference plan for the production. The plan at the end of a week is completely changed and saved. Hence, it cannot be considered as a plan. Thus, it is strongly recommended to revise the planning system at Fresenius Kabi.

7.1.3. Non-operating Time

Non-operating time includes all the times that machines do not work because of any reasons and also reworking times. Planned downtimes, actual downtimes, actual setup or adjustment times, waiting times, minor stop times, defect production time, reworking time are parts of the

non-operating time. In order to measure many of the KPIs, it is needed to record all those non-operating times carefully and precisely. Planned down times should be set cautiously to have a correct performance indicator such as availability. Actual down times are recorded with deviation data in one file and it is hard to distinguish them from each other. They should be measured and registered in a separate system properly. There are the recordings of waiting times in the factory but it is not clear what other times are included. Therefore, there should be an investigation on the waiting times and after the investigation, the waiting times should be clearly recorded without any other non-operating times. The Fresenius Kabi should perform a study on minor stop times and defect production times to see their applicability in this production site. If they are applicable, they should be taken into the consideration. The reworking times should also be recorded and used in the KPI calculations. The speed losses are one of the most ambiguous elements we faced during our study at Fresenius Kabi. It is recommended to perform a thorough study to see what it is happening regarding them.

7.2. Future studies

The authors of this report during the period of time spent at the company have thought of many different subjects in different areas for future studies. We suggest the benchmarking studies against other companies with the same type of processing with changing quantities and chemical processes in order to extract ideas of how to measure the productivity and effectiveness while determining relevant KPIs. Another suggestion is an investigation regarding the whole supply chain for production of PL90 which includes all the processes that affect the supply chain from forecasts, order handling until shipment of the finished products to customers. This supply chain investigation should include how the company can strive to work according to a more (JIT) just in time concept and decrease inventory levels.

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Appendix A

