MSc Program
Engineering Management

Key Performance Indicators in Shop Floor Management and the Case of an Austrian Medium-Sized Equipment Manufacturing Company

A Master's Thesis submitted for the degree of
“Master of Science”

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ACADEMY FOR CONTINUING EDUCATION

Affidavit

I, **KARL MÖRATH**, hereby declare

1. that I am the sole author of the present Master's Thesis, "KEY PERFORMANCE INDICATORS IN SHOP FLOOR MANAGEMENT AND THE CASE OF AN AUSTRIAN MEDIUM-SIZED EQUIPMENT MANUFACTURING COMPANY", 65 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

Vienna, 11.04.2023

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Signature

I Acknowledgement

To my wife, Anna, and our daughter, Paula, for their sacrifices, love, and support on this journey.

II Abstract

The thesis discusses some of the main principles, methods, strategies, and tools that have been developed and find application in the field of shop floor management and manufacturing. The research question focuses on the evaluation and reasons for choosing Key Performance Indicators (KPIs) in manufacturing.

The thesis also provides a literature review of the key terms, methods, tools, and strategies applied in shop floor management, including the PDCA or Deming cycle, the PDSA cycle, and the Kaizen method, the 5S, Just In Time (JIT), Kanban, Value Stream Mapping (VSM), the KPI Overall Equipment Effectiveness (OEE), alternatives to OEE, Six Sigma and Lean Management.

The case study in chapter 3 explores the shop floor management practices of Rosendahl Nextrom, a medium-sized equipment manufacturer located in Austria. The company specializes in machinery production for industries such as cable and wire, fiber optics, and battery. To manage essential metrics and indicators, Rosendahl Nextrom employs a Business Intelligence Software Suite integrated with the MES/ERP System in its processes. The company is committed to lean processes and has implemented various tools and shop floor management systems to ensure efficient, high-quality production. Additionally, the company follows a continuous improvement approach that emphasizes a strong customer focus and clear roles and duties for departments and staff functions. The case study delves into the company's communication patterns, highlighting their importance in achieving quick solutions. Furthermore, the thesis discusses the weekly continuous improvement project (CIP) meeting that uses a straightforward CIP dashboard to monitor and follow up on projects and ideas, as the company faces challenges due to the special machinery business' nature, which requires quick reactions to changes. Therefore, transparency and human resource management are critical to maintaining staff motivation and continuously improving processes. The case study also describes the status of implementation of key performance indicators (KPIs) at Rosendahl Nextrom, including Capacity, Overall Equipment Effectiveness (OEE), quality, and 5S and Health and Safety. Finally, a few dashboards taken from the Business Intelligence Software of Rosendahl Nextrom will help to describe the current KPIs in use and give an overview of the company’s main focus in terms of shop floor KPIs.

III Table of Content

1 Introduction

1.1 Problem Statement and Methodology

Manufacturing companies are facing a daily challenge to keep cost at a minimum while producing demanded quantities at defined quality. Any waste of time and money during the manufacturing process and its adjacent processes are to be avoided. A discipline focusing on improving production methods, tools, and strategies has evolved throughout the years and has taken many shapes and forms. Production managers are keeping track of key performance indicators to define and check their goals and production related targets. This thesis discusses some of the main principles, methods, strategies, and tools that have been developed and find application in the field of shop floor management and manufacturing. A premium is put on Key Performance Indicators (KPIs) that are applied in the field. A case study of an Austrian manufacturing company will help illustrate an example of different strategies and KPIs currently in use and will relate theory and application in practice. A conclusion and outlook will be given at the end of this thesis.

The author chose to carry out a literature review of existing methods, tools, and strategies and selected a case study which is mainly based on a qualitative interview conducted by the authors with the plant manager of the company and research in the company's Business Intelligence Software.

1.2 Research question

Focus of the thesis lies on finding out the reasons for choosing certain key performance indicators. So the questions that finally should be answered is "What are the KPIs that are chosen to keep track of manufacturing targets?

2 Literature review: Definitions and key terms in Shop Floor Management

In the following chapter some of the key terms, methods, tools, and strategies that can be applied in shop floor management will be described and Key Performance Indicators (KPIs) will be defined and discussed.

2.1 Methods and strategies of shop floor management

2.1.1 PDCA or Deming Cycle

The systematic and periodic (quarterly) application of improvement programs dates back to an idea of Deming and Shewhart. The improvement process is illustrated as a moving wheel with four main activities:

- Plan: Planning of improvement
- Do: Execution of improvement measure
- Check: Checking of effectiveness
- Act: Application, Standardization or Modification

This PDCA or Deming cycle restarts when the execution did not lead to success or when other improvement measures are available. (Sihn, Sunk, Nemeth, Kuhlang, & Matyas, 2016, pp. 239-240). The two figures below depict the PDCA in figure 1 and PDSA cycle in figure 2, differing in the bottom left quadrant: check vs study.

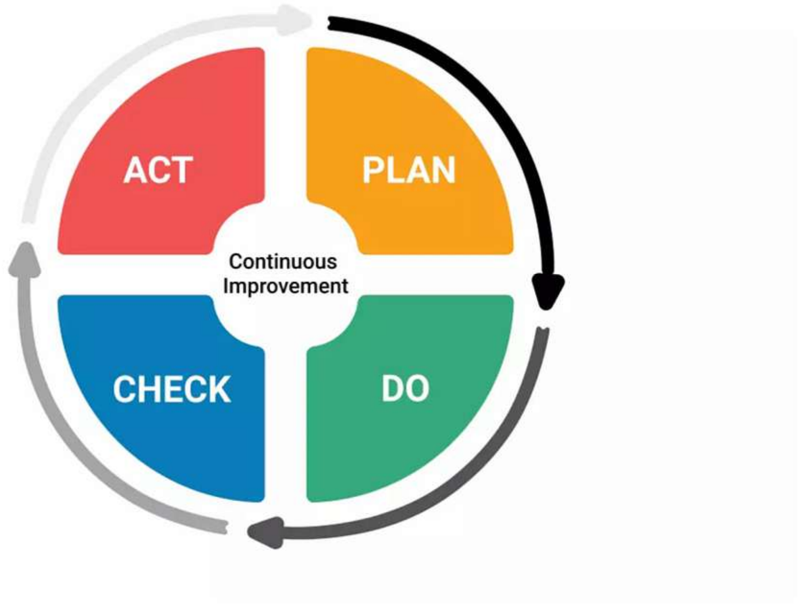


Figure 1: PDCA cycle (kanbanize, 2023)

It is commonly believed and stipulated above that Deming defined the PDCA cycle, but in reality, Deming emphasized the PDSA Cycle, not the PDCA Cycle, with a third step emphasis on Study (S), not Check (C), as can be seen in Figure 2 below.

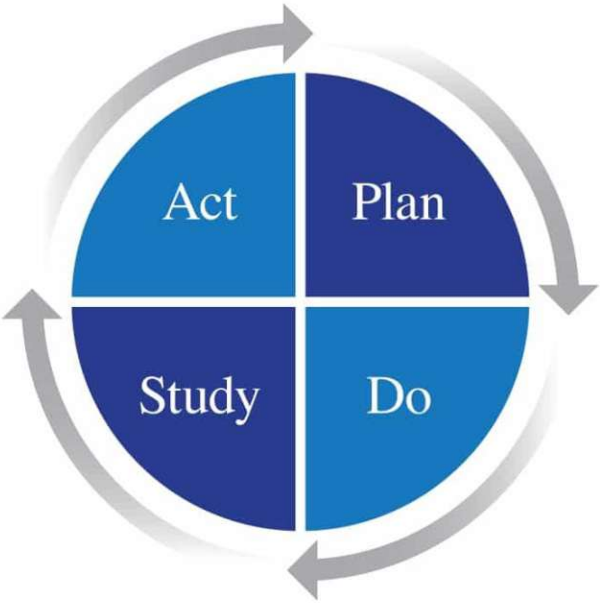


Figure 2: PDSA cycle (The W. Edward Deming Institute, 2023)

Deming discovered that the check phase is primarily concerned with the implementation of a change and determining its success or failure. His emphasis was on forecasting the outcomes of an improvement initiative, analyzing the real outcomes, and then modifying the theory, as necessary. He emphasized that the acquisition of new knowledge through learning should always be guided by a theory. In contrast, the check stage of the PDCA cycle concentrates on assessing the success or failure of a plan and making appropriate adjustments to the plan in the event of failure. (The W. Edward Deming Institute, 2023).

Still, scholars and practitioners worldwide use the terms PDSA, PDCA and Deming cycle quite often synonymously and mean a management approach or attitude towards continuous improvement. The PDSA cycle has kept on evolving. To enhance the PDSA cycle, Thomas Nolan introduced three fundamental questions:

- What are we trying to accomplish?
- How will we know that a change is an improvement?
- What change can we make that will result in improvement?

This novel methodology offers a fundamental structure for creating, testing, and executing modifications to existing processes that result in enhancement. This approach facilitates a broad spectrum of improvement endeavors, ranging from casual to intricate, such as introducing a new product line or service for a significant organization. (Moen & Norman, 2010, p. 28). Figure 3 below shows the PDSA cycle and the mentioned questions as suggested by Nolan as a model for improvement.

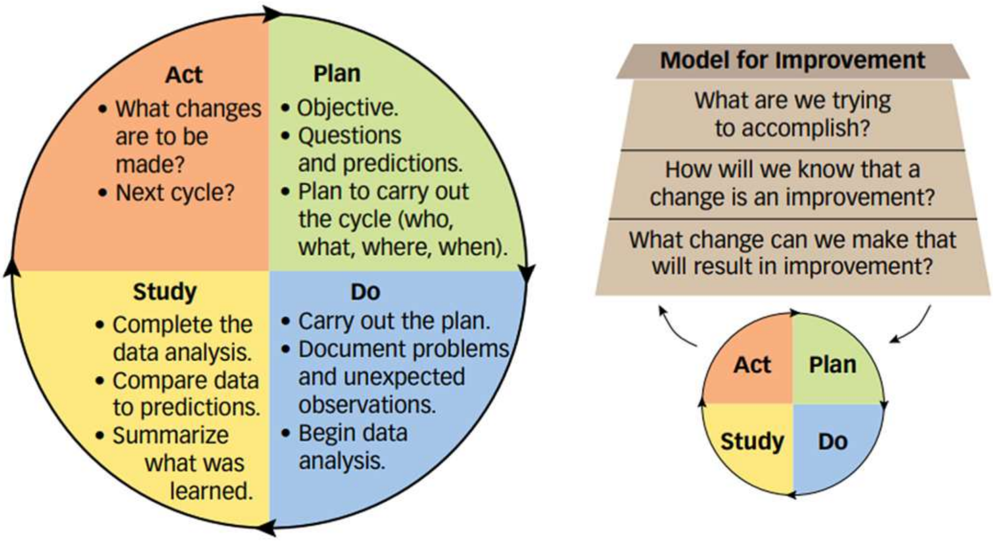


Figure 3: PDSA cycle and model for improvement (Moen & Norman, 2010, p. 27)

2.1.2 Kaizen

The Kaizen method is generally based on the principle of small steps and the observation and perception of small moments which in sum lead to bigger improvements. The Japanese word Kaizen is made up of the symbol KAI (change) and the symbol ZEN (good). Added together, it means “change for the better”. In Japan it is a commonly used term and is a synonym for continuous improvement in small steps. (Brunner, 2017, p. 11). Figure 4 below shows the Japanese Kanji.

Figure 4: Japanese kanji for KAIZEN (LEAN UK)

Kaizen is not a method that can be used on the spot to solve a problem, it is more a process-oriented way of thinking. (Brunner, 2017, p. 11). In principle, Kaizen is the continuous application of PDCA, PDSA or Deming cycles. (Sihn, Sunk, Nemeth, Kuhlang, & Matyas, 2016, p. 241).

2.1.2.1 The 5 Kaizen principles

Every Kaizen tool and behavior embodies 5 essential Kaizen principles:

- Know your Customer
- Let it Flow
- Go to Gemba (Japanese term for "actual place", used for the specific part of the shop floor or any place where work or the problem actually happens)
- Empower People
- Be Transparent

Incorporating these 5 principles into an organization is crucial to establishing a thriving continuous improvement culture and a significant turning point in the advancement of quality, productivity, and labor-management relations. (KAIZEN INSTITUTE, 1985-2023). Figure 5 below shows these 5 principles circling around pure improvement, the goal of Kaizen.

Figure 5: The 5 fundamental Kaizen Principles (KAIZEN INSTITUTE, 1985-2023)

2.1.2.2 The 3 types of waste in Kaizen and Lean methodology

Throughout literature one meets the 3 types of waste within the Lean and Kaizen framework. Eliminating waste is a crucial objective within these frameworks. Taiichi Ohno, who is credited as the founder of the Toyota Production System (TPS), identified those three types of waste, and made them known to public: Mura, Muri, and Muda. Although Muda is the most commonly recognized type of waste, it is essential to understand the significance of Muri and Mura as well. (Ohno, 1988, p. 41). Figure 6 below gives a quite simple explanation to illustrate the difference between the three types of waste.

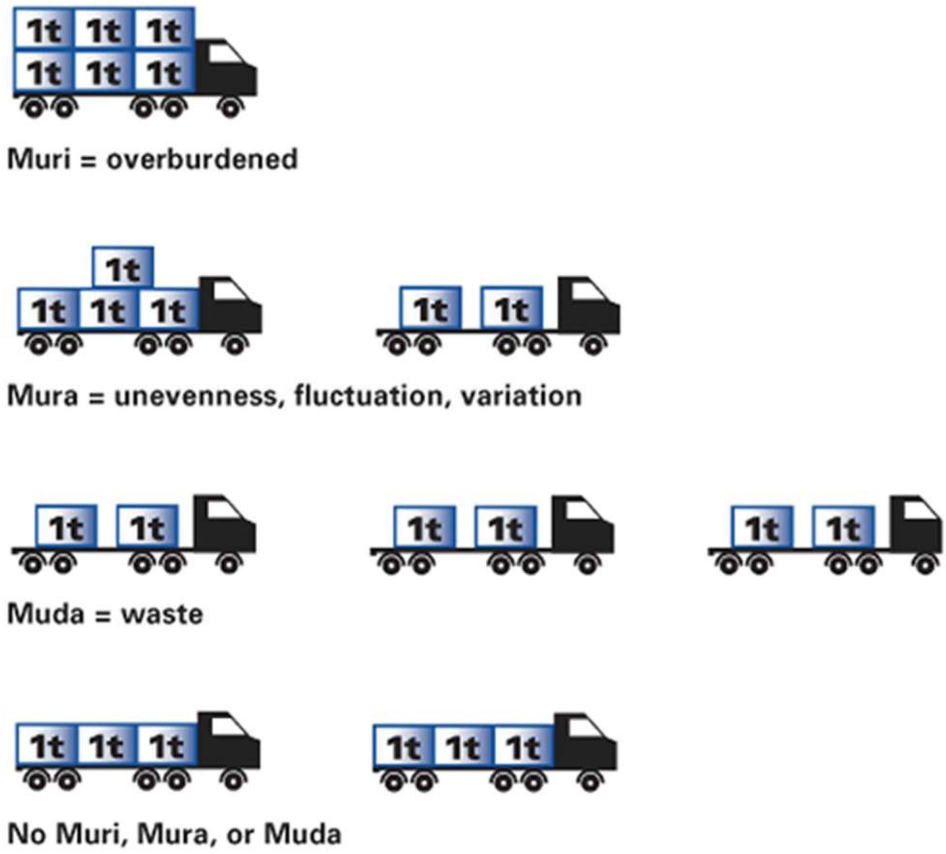


Figure 6: Simple example for Muda, Mura, and Muri. (Smalley, 2020)

- Muda:

Muda is a Japanese term used in the Lean methodology, which refers to processes or activities that do not add value to the customer or organization. These wastes are not useful and increase costs, which ultimately results in inefficient operations. The following seven types of wastes are commonly identified in the manufacturing and service industries:

Transportation - Unnecessary movement of products or goods during the production process.

Inventory - Storing excess inventory of raw materials, work in progress, or finished products.

Motion - Excessive movement of workers or machinery, leading to increased time and costs.

Waiting - Time lost due to waiting for materials, equipment, or information to complete a task.

Overproduction - Producing more goods than the customer requires or producing them earlier than needed.

Overprocessing - Adding more features or processes than necessary, resulting in increased time and costs.

Defects - Producing faulty goods, leading to rework, scrap, and customer dissatisfaction.

- Mura:

Mura is another type of waste in the Lean methodology, which refers to unevenness in the production process or service delivery. This waste is caused by a lack of standardization, inconsistency, and instability in the workflow. Examples of Mura include:

Inconsistent workload - uneven demand or production rates resulting in underutilization or overburdening of resources.

Inconsistent quality - varying levels of quality due to a lack of standards, process variation, or fluctuation in the production process.

Inconsistent lead time - different wait times or processing times for customers, leading to uneven service quality.

- Muri:

Muri is a third type of waste in the Lean methodology, which refers to overburdening of workers, processes, or equipment. This waste is caused by excessive workloads or difficult tasks, leading to errors, defects, and dissatisfaction. Examples of Muri include:

Physical strain - overexertion, injuries, or accidents due to excessive manual labor, carrying heavy loads, or working long hours.

Mental strain - stress, fatigue, or burnout caused by excessive workloads, lack of training, or complex tasks.

Equipment strain - wear and tear on machinery caused by overuse, lack of maintenance, or inappropriate use.

In summary, the methodology focuses on identifying and eliminating all three types of waste (Muda, Mura, Muri) to create a more efficient and productive workplace. By reducing waste, companies can achieve cost savings, increased productivity, and improved customer satisfaction. (Bradbury, 2017)

The 7 different types of waste mentioned in the Muda category are often also called TIMWOOD due to their beginning letters or also TIMWOODS as an eights type of waste was added. The S stand for skill as in unused skill also not as unused talent. The following figure depicts these 8 wastes.

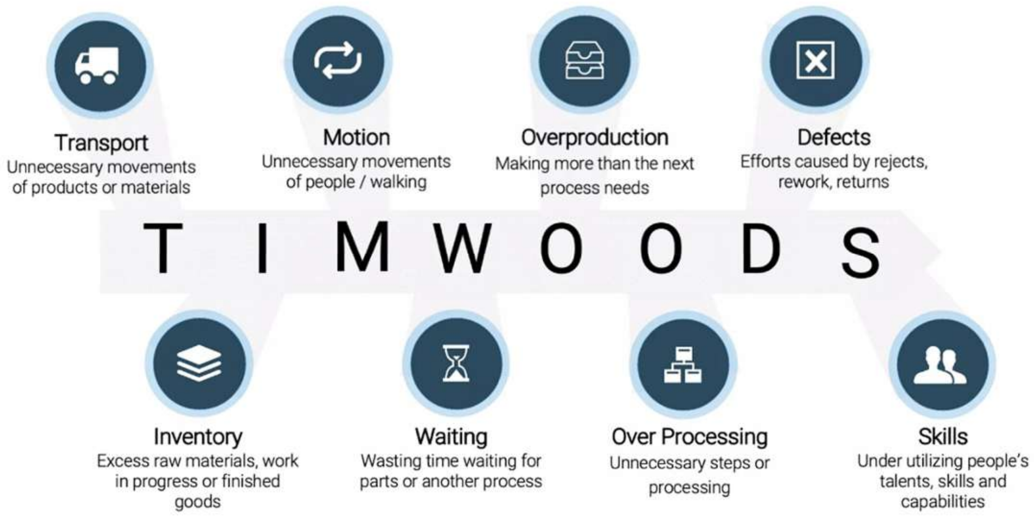


Figure 7: TIMWOODS the 8 types of waste (Leanscape, 2020)

2.1.3 5S

The concept of 5S involves a set of improvement activities on the shop floor that aim to enhance cleanliness, organization, hygiene, and safety. These activities are categorized into five distinct areas:

- Seiri
- Seiton
- Seiso
- Seiketsu
- Shitsuke

Figure 8 below shows and gives definitions of these 5 areas.

Kaizen activity	Definition
Seiri	Throw away useless stuff
Seiton	Align, sort materials, workpieces, tools, finished goods, etc
Seiso	Clean the shop floor
Seiketsu	Keep the cleanliness of the shop floor
Shitsuke	Educate people to get used to the continuous implementation of 5S activities

Figure 8: Definition of 5S (Chen & Wang, 2022, p. 3)

The Japanese consider 5S as a daily practice of wisdom in life, which makes it highly compatible with management practices. By maximizing efficiency and effectiveness, 5S promotes cost-effectiveness. In Lean Manufacturing, 5S is a widely adopted and highly effective improvement approach. However, many organizations only carry out the first three activities of 5S, limiting the potential benefits that could be realized. (Chen & Wang, 2022, p. 3)

Filip and Marascu-Klein propose the process shown in Figure 9 below when implementing the 5S method:

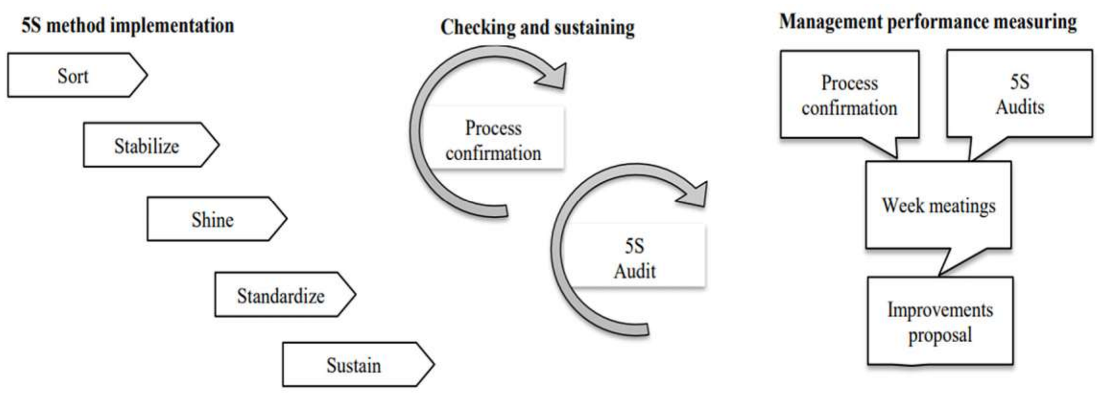


Figure 9: Phases of implementing the 5S method (Filip & Marascu-Klein, 2015, p. 5)

This 5S audit as mentioned in the figure above is part of the checking and sustaining phase of 5S and is a commonly utilized tool to periodically or permanently review and confirm the adherence to the 5S methodology. It is the responsibility of lean management to develop, implement, and continually monitor the 5S methodology, not the auditor's. The results of a 5S audit evaluation can be used to determine if there has been an improvement or decline in the situation compared to previous audits.

Filip and Marascu-Klein continue by explaining that proper implementation of 5S can bring along benefits such as:

- development of a quality-conducive working environment
- errors can be eliminated
- visualization of mistakes and problems
- waste reduction
- waiting and searching time reduction
- workflow and workplaces become transparent and clear
- establishment of standards (e.g.: where to find things)
- ergonomics and safety for operators (Filip & Marascu-Klein, 2015, pp. 2-5)

2.1.4 Just in Time (JIT)

JIT is a management philosophy that emphasizes the reduction of inventory to encourage changes and improvements. However, it is only feasible in manufacturing systems with good product quality, high process reliability, low setup times, and low demand variability. It requires highly predictable demand. To implement JIT, a manufacturing system must address problems such as poor product quality, frequent machine failures, and unstable demand, to enhance its competitiveness. JIT offers several advantages, including shorter lead times, better ability to meet deadlines, increased flexibility, easier automation, and better utilization of workers and equipment. The purpose of JIT is to supply the necessary materials or finished goods at the precise time and location they are needed. JIT utilizes a pull production system, in which a workstation provides a workpiece only when the next workstation requires it. JIT reduces inventory and promotes changes and improvements. JIT offers several benefits, including shorter lead times, better ability to meet deadlines, increased flexibility, easier automation, and better utilization of workers and equipment. (Chen & Wang, 2022, p. 4)

2.1.5 Kanban

Kanban is a Japanese term that means signal or card. In the manufacturing context, Kanban is a system that uses visual signals to manage production and inventory. Kanban is a component of the Just-in-Time (JIT) manufacturing philosophy that aims to minimize inventory while maintaining optimal levels of raw materials, work-in-progress, and finished goods. The Kanban system is based on the idea of pull production, which means that production is initiated only when there is a need for a product or service. The Kanban system is designed to ensure that the right amount of inventory is available at the right time, allowing companies to reduce inventory costs, improve delivery times, and increase efficiency. The Kanban system uses visual signals, such as cards or containers, to communicate information about the production process. These signals indicate when to produce, how much to produce, and when to order more materials. By using visual signals, the Kanban system provides real-time information about the status of inventory, production, and customer demand. Kanban has several benefits, including reducing inventory costs, improving delivery times, increasing efficiency, and enhancing communication between different departments in the organization. Kanban is widely used in various industries, including manufacturing, healthcare, software development, and construction. (kanbanize, 2023)

A Kanban card is a physical or digital representation of a task or work item in the Kanban system. The word "Kanban" comes from Japanese, where "kan" means visual and "ban" means card or board. The Kanban card is a crucial component of the Kanban system, as it visually represents the work that needs to be done, is currently in progress, or has already been completed. (kanbanize, 2023)

The Kanban card typically contains essential information about the task or work item, such as a brief description of the assignment, the person responsible for completing it, the deadline for completion, and any other pertinent details. This information is crucial for keeping track of the status of work items, identifying bottlenecks, and ensuring that everything is progressing smoothly. Figure 10 below gives an example of Kanban cards.

Part description				Item number		Process
Wheel pinion				XV001T		Forging F1
Quantity	30	Lead time	2 weeks	Order date	7 march	
Supplier	WP Corporation			Due date	21 march	Subseq. Process
Planner	John T.		Card number	Card 1 out of 10		Machining B7
			Location	Store shelf 2 no. 325F		

Withdrawal kanban

Part description				Item number		Process
Steering wheel				VF120T		Machining M8
Quantity	10	Lead time	2 weeks	Order date	1 april	
Supplier	/			Due date	15 april	
Planner	Fred D.		Card number	Card 2 out of 5		
			Location	Store shelf 3 no. 601D		

Production kanban

Figure 10: Example of Kanban cards (Lean Six Sigma Belgium, 2023)

2.1.6 Value Stream Mapping (VSM)

Value stream mapping (VSM) is a crucial tool for lean production that enables the identification and reduction of errors, losses, and lead time, resulting in improved value-creating time. By empowering production units, VSM facilitates the reduction of production risks and costs in the long term, leading to enhanced product quality. Value stream mapping encompasses all the value-adding activities necessary for delivering a product to the customer. These activities consume similar resources across the main processes, starting from the raw material stage up to the delivery of the final product to the customer. The primary objective of VSM is to identify all the losses throughout the value stream and eliminate them. (Dadashnejad & Valmohammadi, 2019, pp. 466-467).

For many years, one of the main criticisms of the classic Kaizen approach or Lean projects was that although improvements were made in certain areas, in the end more units were not produced, and costs were not significantly reduced. The entire system may even have deteriorated. This is one of the reasons for the widespread use of value stream mapping (VSM) as described by Womack and Jones (Womack & Jones 2004). In this value stream analysis, all information flows from the customer via production planning to the supplier are to be shown on the one hand and the material flows in the opposite direction. Two insights gained from this analysis are central:

First, the total lead time of a product through the value stream is compared to the times for the non-value-adding activities. Shares of value-adding times in the total DLZ of less than one percent are not uncommon.

Secondly, so-called "red flags" are used to highlight the waste in the entire process. These serve as the basis for the value stream design (VSD – Value Stream Design), which represents the future, desired state. The implementation from the VSM to the VSD is defined by measures derived from the "Red Flags" that improve the entire value stream and not just individual sections. (Brenner, 2016, p. 135)

Womack and Jones explain that Value Stream Mapping is a key tool used in Lean manufacturing to identify and eliminate waste in a process. They describe VSM as a graphical representation of the flow of materials and information through a process, from supplier to customer, which helps to identify areas of waste and inefficiency. The authors also highlight the importance of engaging all stakeholders in the process to ensure that improvements are sustainable and effective. (Womack & Jones, 2003)

Chen and Wang emphasize in their definition that VSM is a method within the Lean methodology that involves recording, examining, and refining the movement of information or materials required to make a product or deliver a service to a consumer. The aim is to evaluate the various actions involved in designing, selling, and manufacturing a product (or providing a service) and categorize them into three groups in order to reduce or eliminate waste:

- Actions that add value which the customers can perceive.
- Waste that does not add value but cannot be eliminated at the moment.
- Unnecessary steps that provide no value to the customers and can be eliminated right away.

Chen and Wang go on by saying that a VSM comprises six primary components: the customer, production planning and control, suppliers, receiving, production steps, and delivery (Chen & Wang, 2022, pp. 7-8). This can be seen in Figure 11 below.

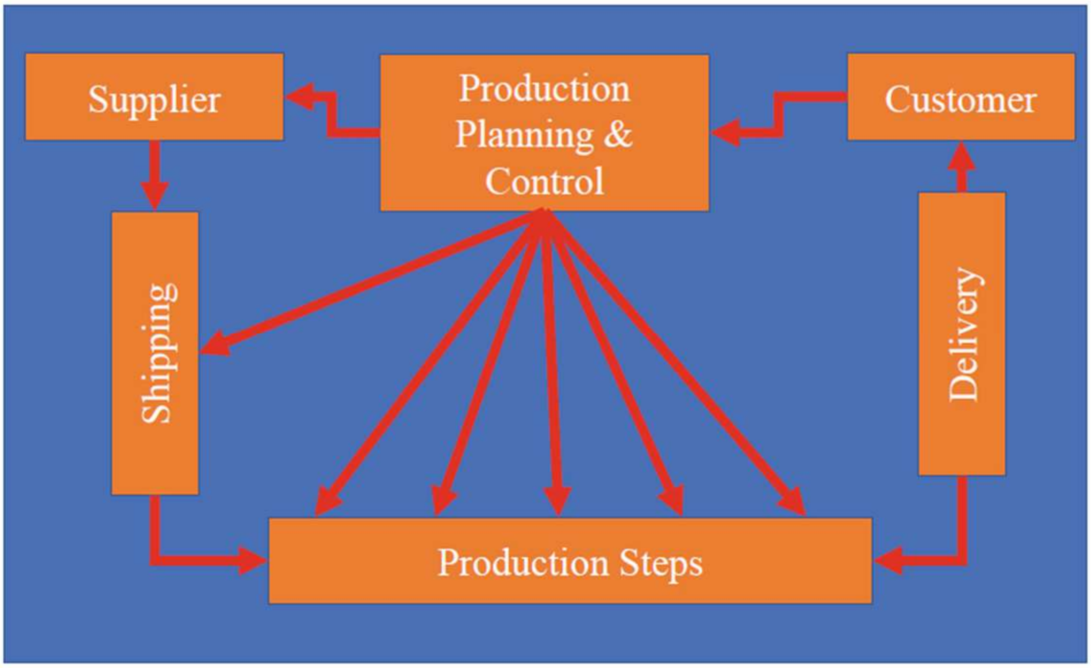


Figure 11: The structure of VSM (Chen & Wang, 2022, p. 8)

According to Chen and Wang, the primary focus is on reducing the manufacturing process's cycle time. This can be achieved by implementing pull production, adjusting storage space capacity, optimizing workstation operations to reduce processing time, and dividing or merging operations. A VSM is created before and after the improvements have been made. (Chen & Wang, 2022, p. 8)

While 5S is the most commonly used lean manufacturing method, value stream mapping is considered one of the most effective techniques.

Charron et al. see VSM as a tool to identify possible constraints (step 1: identify constraint) while giving valuable information in the process of defining a strategy (step 2: exploitation) to eliminate the. Therefore, VSM is a diagnostic tool used in constraint management. VSM makes processes visible that produce the product or service and at the same time illustrates the ratio of value-added versus non-value-added activities. (Charon & al., 2014, p. 345)

2.1.7 Six Sigma Management

Six Sigma Management was developed by Motorola and has meanwhile widely spread. It follows the way to zero defects and minimization of variation around the target value. The normal distribution acting as a base line should reach the boundaries of tolerance on both sides at 6 Sigma only. Six Sigma Management follows a structured method for process improvement. In the core of the Six Sigma method there is an improvement dynamic consisting of 5 steps (DMAIC):

- Define
- Measure
- Analyze
- Improve
- Control (Brunner, 2017, p. 47)

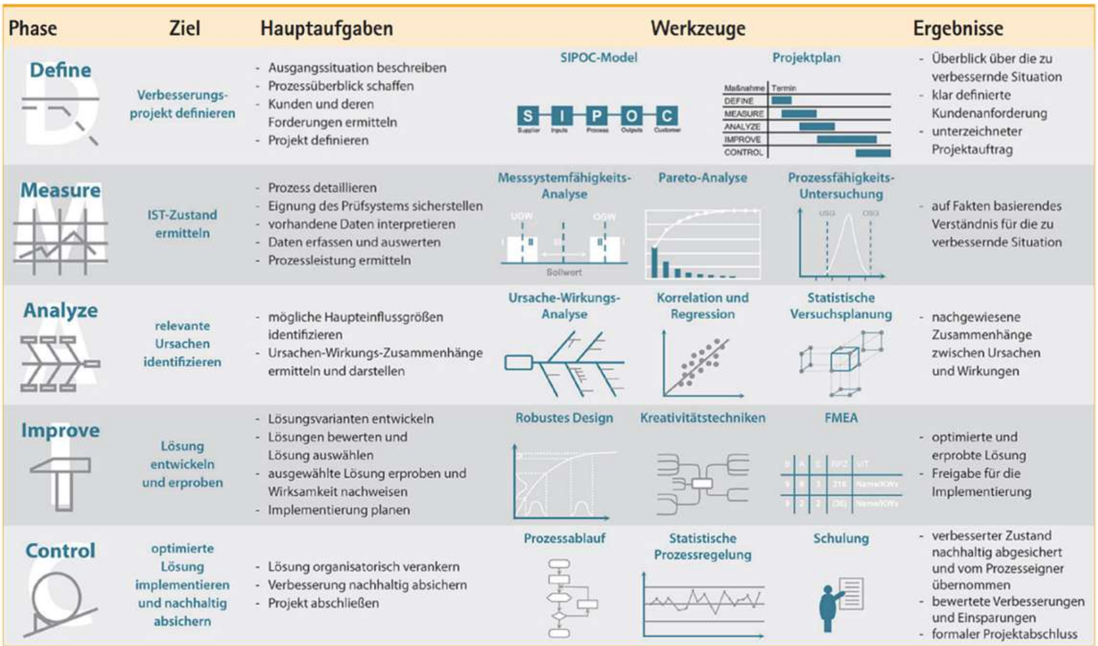
Charon at al. clearly distinguish between Lean's -which will be explained in a later chapter- main objective to eliminate waste and Six Sigma's DMAIC or DMADV, which aims to identify and keep variation within a process at a minimum. DMADV in contrast to DMAIC stands for:

- Define
- Measure
- Analyze
- Design
- Verify/Validate

Charon et al. go on by explaining that both tools, DMAIC and DMADV use tollgate reviews to assess progress and readiness to move to the next phase of the project. Tollgate reviews are process checkpoints where the project team presents their deliverables and progress to the stakeholders. These reviews are conducted at the end of each phase of the DMAIC/DMADV process. The stakeholders review the deliverables and determine whether the team is ready to move on to the next phase. An effective tollgate review is a two-way, fact-based dialogue between the project team and stakeholders. The stakeholders should be able to challenge the team's findings and provide feedback. The team should be able to defend their work and provide evidence to support their findings.

Leaders do not have to work the mechanics of the Six Sigma tools, but they need to have considerable knowledge in reading and interpreting each tool's outputs. This knowledge helps them to anticipate the tools and data that will be useful in an upcoming review. It also helps them to coach teams that get stuck or off-track and challenge some team findings. By understanding the Six Sigma tools and their outputs, leaders can expect teams to use certain tools to answer specific questions, thereby driving the proper use of tools. This helps to ensure that the project stays on track and that the team is using the most appropriate tools and data to solve the problem at hand. (Charon & al., 2014, p. 323)

Wappis and Jung developed the Six Sigma Roadmap as illustrated below. Figure 12 below shows the proceedings to apply improvement projects in the shape of the Six Sigma-Roadmap. Every line describes a Six Sigma-Phase. For any phase there are goals, main tasks, tools, and results. The main tasks correspond to the structured project plan. They are guiding the entire project execution. During the project planning, the main tasks help to define the necessary tasks, the planning of deadlines and the estimation of resources. If one bases the project presentations and the project reporting according to the main tasks, outsiders can quickly get an overview of the project. Last but not least, this structure also helps the project team not to get lost in detail. A periodic glance at the entire structure of the project helps to check whether or not the right actions are taken. The main tasks enable the project team, to set the right steps and apply the right tools at the right time. (Sihn, Sunk, Nemeth, Kuhlang, & Matyas, 2016, p. 276)



Phase	Ziel	Hauptaufgaben	Werkzeuge	Ergebnisse
Define	Verbesserungs-projekt definieren	- Ausgangssituation beschreiben - Prozessüberblick schaffen - Kunden und deren Forderungen ermitteln - Projekt definieren	SIPOC-Model (S Supplier, I Inputs, P Process, O Outputs, C Customer); Projektplan (Maßnahme / Termin: DEFINE, MEASURE, ANALYZE, IMPROVE, CONTROL)	- Überblick über die zu verbessernde Situation - klar definierte Kundenanforderung - unterzeichneter Projektauftrag
Measure	IST-Zustand ermitteln	- Prozess detaillieren - Eignung des Prüfsystems sicherstellen - vorhandene Daten interpretieren - Daten erfassen und auswerten - Prozessleistung ermitteln	Messsystemfähigkeits-Analyse (UGW, OGW, Sollwert); Pareto-Analyse; Prozessfähigkeits-Untersuchung (USG, OSG)	- auf Fakten basierendes Verständnis für die zu verbessernde Situation
Analyze	relevante Ursachen identifizieren	- mögliche Haupteinflussgrößen identifizieren - Ursachen-Wirkungs-Zusammenhänge ermitteln und darstellen	Ursache-Wirkungs-Analyse; Korrelation und Regression; Statistische Versuchsplanung	- nachgewiesene Zusammenhänge zwischen Ursachen und Wirkungen
Improve	Lösung entwickeln und erproben	- Lösungsvarianten entwickeln - Lösungen bewerten und Lösung auswählen - ausgewählte Lösung erproben und Wirksamkeit nachweisen - Implementierung planen	Robustes Design; Kreativitätstechniken; FMEA	- optimierte und erprobte Lösung - Freigabe für die Implementierung
Control	optimierte Lösung implementieren und nachhaltig absichern	- Lösung organisatorisch verankern - Verbesserung nachhaltig absichern - Projekt abschließen	Prozessablauf; Statistische Prozessregelung; Schulung	- verbesserter Zustand nachhaltig abgesichert und vom Prozesseigner übernommen - bewertete Verbesserungen und Einsparungen - formaler Projektabschluss

Figure 12: Six Sigma-Roadmap (Wappis & Jung, 2019, p. 3)

2.2 Lean Management

Lean Management or simply "Lean" is a management philosophy that comprises most of the methods, tools and strategies mentioned in the chapter above. The term Lean was mentioned already in the previous chapter when elaborating about types of waste and in connection with Value Stream mapping. To underline, it needs to be heavily emphasized that Lean Management is not just another tool, but it is the overarching philosophy that assembles and uses the practices described above to enable companies to become more competitive. Chen and Wang explain that Lean is the successor of the Toyota Production System (TPS) and also originated in Japan and is a well-known tool for improving the competitiveness of manufacturers around the world.

Many authors have tried to give definitions or have voluntarily refrained from adding another definition to the ones due to the high number. It is even discussed in literature whether Lean is a toolbox, a philosophy or rather a way of thinking, even leaving space for interpretation if Lean is more on the strategic or on the operational side of approaches. The scope of this thesis of course does not allow to enter this discussion of defining the term s Lean Management or Lean Production or even trying to give a definition. Instead, to give an overview and to underline the overarching importance, the table below stemming from a study and article by Petterson shall show the characteristics associated with lean production. These characteristics are sorted by accumulated frequency.

	Goal								
	Make products with fewer defects to precise customer desires (Womack and Jones and Womack *et al.*)	One-piece flow	Reduce waste and improve value	Customer focus (high quality, low cost, short time)	Robust production operation	Cost reduction	Eliminate waste and reduce costs	Improve quality and productivity	Cost reduction through waste elimination
		Liker	Bicheno	Dennis	Feld	Ohno	Monden	Schonberger	Shingo
Kaizen/continuous improvement	×	×	×	×	×	×	×	×	×
Setup time reduction	×	×	×	×	×	×	×	×	×
Just in time production	×	×		×	×	×	×	×	×
Kanban/pull system	×	×	×	×	×	×	×	×	
Poka yoke		×	×	×	×	×	×	×	×
Production leveling (*Heijunka*)	×	×	×	×	×	×	×		×
Standardized work		×	×	×	×	×	×	×	×
Visual control and management		×	×	×	×	×	×	×	×
5S/housekeeping	×	×	×	×	(×)	×	×	×	
Andon	×	×			×	×	×	×	×
Small lot production		×	×		×	×	×	×	×
Time/work studies	×	×	×	×	×	×	×		
Waste elimination	×	×	×	×		×		×	×
Inventory reduction	×	×		×		×	×	×	×
Supplier involvement	×	×	×	×	×		×		
Takted production		×	×	×	×		×		×
TPM/preventive maintenance		×	×	×	×	×		×	
Autonomation (*Jidoka*)		×		×			×	×	×
Statistical quality control (SQC)	×		×	NO!	×		×	×	
Teamwork	×	×		×	×	×			
Work force reduction				×		×	×	×	×
100% inspection		×		×				×	×
Layout adjustments				×			×	×	×
Policy deployment (*Hoshin kanri*)	×	×	×	×					
Improvement circles		×		×			×	×	
Root cause analysis (5 why)	×	×	×			×			
Value stream mapping/flowcharting	×	×	×	×					
Education/cross training (OJT)		×			×			×	
Employee involvement	×	×		×			(×)		
Lead time reduction		×		×			×		
Multi-manning	(×)					×	×		×
Process synchronization		×						×	×
Cellular manufacturing			×		×		(×)		

Figure 13: A presentation of characteristics associated with lean production. (Petterson, 2009, pp. 130-131)

Petterson explains that this table demonstrates that only two characteristics are discussed by all mentioned authors in connection with Lean, namely continuous improvement, and setup time reduction, which in turn indicates that these two terms are heavily important to the concept of Lean. Some other terms very often mentioned and discussed comprise failure prevention (poka yoke) and production leveling (heijunka). (Petterson, 2009, p. 129)

Petterson then goes on by grouping all characteristics mentioned in Figure 13 above. These groups are presented in Figure 14 below.

Collective term	Specific characteristics
Just in time practices (100%)	Production leveling (*heijunka*)
	Pull system (*kanban*)
	Takted production
	Process synchronization
Resource reduction (100%)	Small lot production
	Waste elimination
	Setup time reduction
	Lead time reduction
	Inventory reduction
Human relations management (78%)	Team organization
	Cross training
	Employee involvement
Improvement strategies (100%)	Improvement circles
	Continuous improvement (*kaizen*)
	Root cause analysis (5 why)
Defects control (100%)	Autonomation (*jidoka*)
	Failure prevention (*poka yoke*)
	100% inspection
	Line stop (*andon*)
Supply chain management (78%)	Value stream mapping/flowcharting
	Supplier involvement
Standardization (100%)	Housekeeping (5S)
	Standardized work
	Visual control and management
Scientific management (100%)	Policy deployment (*hoshin kanri*)
	Time/work studies
	Multi manning
	Work force reduction
	Layout adjustments
	Cellular manufacturing
Bundled techniques (56%, 67%)	Statistical quality control (SQC)
	TPM/preventive maintenance

Note: The figures in parentheses indicate the percentage of the authors that have discussed at least one of the characteristics in the group

Figure 14: A suggestion for grouping of lean characteristics (Petterson, 2009, p. 132)

He argues that this gives a clearer and more homogenous picture of lean characteristics as for all but three groups, all authors have discussed minimum one characteristic per group. From his analysis he then concludes that human relations management and supply chain management are not vital parts defining lean but still important to the concept. (Petterson, 2009, pp. 129, 132)

2.3 Key Performance Indicators (KPIs) applied in Shop Floor Management

KPIs are metrics used to measure the performance and efficiency of shop floor management. The specific KPIs used will depend on the goals and objectives of the organization, but some common KPIs used in shop floor management include the following terms and concepts mentioned in this chapter.

2.3.1 Overall Equipment Effectiveness (OEE)

2.3.1.1 Defining and calculating Overall Equipment Effectiveness

Groover defines Overall Equipment Effectiveness (OEE) as a measure of the performance and productivity of manufacturing equipment, calculated as the product of three factors: availability, performance, and quality. Availability represents the percentage of time that the equipment is available for use, performance represents the speed or rate at which the equipment operates, and quality represents the percentage of good-quality products that the equipment produces. OEE provides a comprehensive picture of equipment performance and can be used to identify areas for improvement in equipment utilization and effectiveness. (Groover, 2016)

Yadzi et al. go more into detail of the applicability and usage of OEE in small and medium enterprises and describe OEE as one of the best analytical methods for evaluating the performance of SMEs. They go on by stating that in general, the link between loading time and the productive time of the processes in industrial systems is the focus of OEE. Operational time is the amount of time that the equipment needs to create enough products, while loading time is the amount of time that the equipment must operate in a specific period. Yadzi et al. state that the use of OEE to assess business performance has been the subject of numerous research. The notion of total productive maintenance (TPM) was first developed by Nakajima in 1988. This idea resulted in the concept of Overall Equipment Effectiveness (OEE), a quantitative indicator for assessing the productivity of different pieces of equipment within an organization. The goal aspects of OEE to be defined and measured were the quality rate, availability, and performance. The OEE concept has been widely applied as a quantitative instrument crucial for the assessment of the productivity of the production system. OEE standards can be used to assess the equipment's performance in production processes in order to identify any flaws or restrictions. (Yadzi & et al., 2019)

Dunn explains OEE in simpler words and describes the metric by visualizing machinery functioning constantly at its maximal output rate (product per hour) for 365 days per year and 24 hours per day (8760h per year). Due to two types of problems:

- downtime for the equipment and
- products that do not meet standards for commercial acceptability

the equipment will practically never produce the potential annual output. Unscheduled time reduces the maximum annual availability of 8760 h, as shown in Figure 15: Time components of OEE which illustrates how further layered deductions shorten "Total Operations time" until a theoretical output is reached (equal to production during the actual running time). That theoretical sum is reduced to the "Good" (saleable) production due to quality difficulties (scrap and reworking off-spec product). (Dunn, 2014, p. 79)

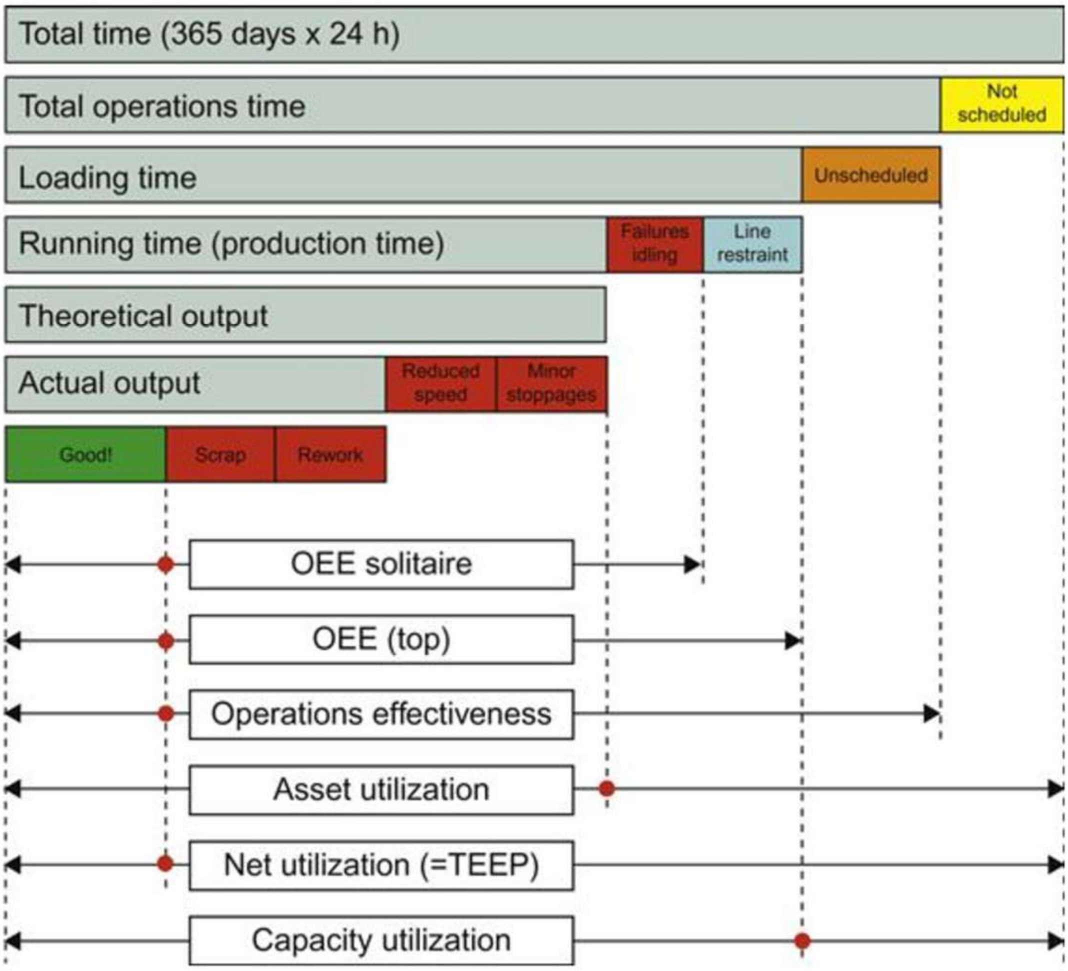


Figure 15: Time components of OEE (Dunn, 2014, p. 79)

So, the definitions above explain that OEE measures the performance of a manufacturing process by considering factors such as availability, performance, and quality. OEE used to identify bottlenecks and inefficiencies in the production process. The OEE or the overall equipment effectiveness is probably one of the most important key figures for production companies. In principle, this is intended to state how well a certain period of time is used to produce good parts. In an extreme case, this period can be 24 hours or 365 days, in the other extreme it can only refer to the actual working time. Which basis is used depends on the application on the one hand and the company philosophy on the other. After the base has been defined, the losses on a plant are broken down into three components - availability (intentional downtime), efficiency (unintentional losses), and quality (scrap and some rework) - and subtracted from the base. The OEE ultimately results from the time it took to produce the good parts. The three factors are intended to focus on the most important sources of loss in order to make targeted improvements. (Brenner, 2016, p. 39). Figure 16 below depicts the 3 main losses in availability, performance, and quality. Their product ultimately gives the Overall Equipment Effectiveness.

Figure 16: The 3 factors of OEE (Vorne Industries Inc., 2011-2023)

Using the preferred OEE calculation (A x P x Q = OEE) makes it easier to take action against the underlying causes of lost productivity. Alongside this formula there is another method: The simplest way to calculate OEE is as the ratio of Fully Productive Time to Planned Production Time. Fully Productive Time is just another way of saying manufacturing only Good Parts as fast as possible (Ideal Cycle Time) with no Stop Time. The simple calculation of OEE is:

OEE = (Good Count x Ideal Cycle Time) / Planned Production Time

Although this is an entirely valid calculation of OEE, it does not provide information about the three loss-related factors: Availability, Performance, and Quality. (Vorne Industries Inc., 2011-2023). This is why we want to focus on the first formular including the three factors for loss.

Availability: Availability takes into account all events that stop planned production long enough where it makes sense to track a reason for being down (typically several minutes).

Availability is calculated as the ratio of Run Time to Planned Production Time:

Availability = Run Time / Planned Production Time

Run Time is simply Planned Production Time less Stop Time, where Stop Time is defined as all-time where the manufacturing process was intended to be running but was not due to Unplanned Stops (e.g., Breakdowns) or Planned Stops (e.g., Changeovers).

Run Time = Planned Production Time − Stop Time

Performance: Performance considers anything that causes the manufacturing process to run at less than the maximum possible speed when it is running (including both Slow Cycles and Small Stops).

Performance is the ratio of Net Run Time to Run Time. It is calculated as:

Performance = (Ideal Cycle Time × Total Count) / Run Time

Ideal Cycle Time is the fastest cycle time that your process can achieve in optimal circumstances. Therefore, when it is multiplied by Total Count the result is Net Run Time (the fastest possible time to manufacture the parts).

Since rate is the reciprocal of time, Performance can also be calculated as:

Performance = (Total Count / Run Time) / Ideal Run Rate

Performance should never be greater than 100%. If it is, that usually indicates that Ideal Cycle Time is set incorrectly (it is too high).

Quality

Quality considers manufactured parts that do not meet quality standards, including parts that need rework. Remember, OEE Quality is similar to First Pass Yield, in that it defines Good Parts as parts that successfully pass through the manufacturing process the first time without needing any rework.

Quality is calculated as:

Quality = Good Count / Total Count

This is the same as taking the ratio of Fully Productive Time (only Good Parts manufactured as fast as possible with no Stop Time) to Net Run Time (all parts manufactured as fast as possible with no stop time).

OEE Formula: OEE takes into account all losses, resulting in a measure of truly productive manufacturing time. It is calculated as:

OEE = Availability × Performance × Quality

If the equations for Availability, Performance, and Quality are substituted in the above and reduced to their simplest terms, the result is:

OEE = (Good Count × Ideal Cycle Time) / Planned Production Time

This is the "simplest" OEE calculation described earlier. And, as described earlier, multiplying Good Count by Ideal Cycle Time results in Fully Productive Time (manufacturing only Good Parts as fast as possible, with no Stop Time). (Vorne Industries Inc., 2011-2023)

2.3.1.2 The Six Big Losses

The consideration of downtime falls under availability losses, while speed losses are factored into performance losses, and quality losses account for any defects in the final product.

The six major losses can be defined as follows:

- Equipment failure refers to any unplanned downtime due to equipment breakdowns or malfunctions. These failures can result in reduced availability, performance, and quality.

- Setup and adjustments: any time spent setting up or adjusting equipment for a new production run is considered a loss of productive time. This includes activities such as tool changes, material changes, and reconfiguration of the equipment.

- Idling and minor stops: idling refers to any period of time where the equipment is running but not producing anything. Minor stops refer to short stops in production that can add up over time. Both types of losses reduce equipment availability and overall productivity.

- Reduced speed: when equipment runs at a slower speed than its optimal speed, it results in reduced performance and productivity. This can be caused by a variety of factors, such as worn-out parts, poor maintenance, or operator error.

- Process defects: quality issues such as product defects or errors can lead to wasted materials and time spent on rework or scrapping defective products. This can result in lower quality and reduced overall productivity.

- Reduced yield: this refers to the amount of good product that is produced compared to the total amount of raw materials used. If the yield is lower than expected, it can result in wasted materials and reduced productivity. (Sowmya & Chetan, 2016, p. 557)

Figure 17: The Six Big Losses below graphically illustrates the Six Big Losses:

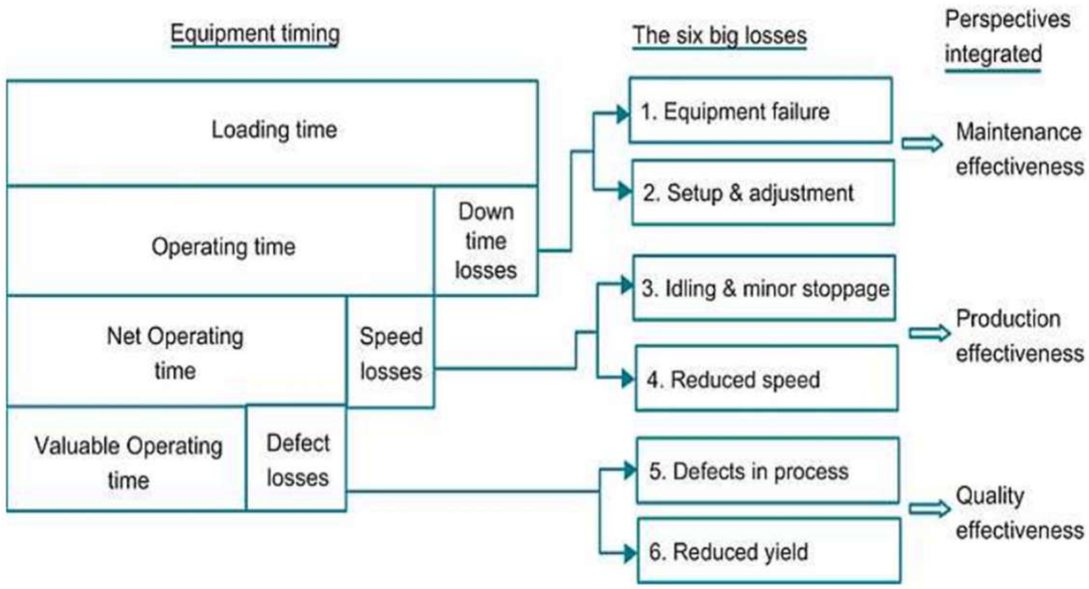


Figure 17: The Six Big Losses (Sowmya & Chetan, 2016, p. 557)

2.3.1.3 Overall Equipment Effectiveness' score ranges

To give a rough idea what scores are achieved in real world companies look like, Sowmya and Chetan give the following numbers: Achieving an OEE score of 100% signifies flawless production with fast output of only high-quality products, without any interruptions. Meanwhile, an OEE score of 85% is considered world-class, while 60% is the average score for discrete manufacturers, indicating ample room for improvement. For companies starting to monitor and enhance their manufacturing performance, an OEE score of 40% is not unusual, and can typically be enhanced using simple measures, such as identifying the leading causes of downtime and addressing them one by one. (Sowmya & Chetan, 2016, p. 558)

The numbers are echoed by Vorne, Figure 18 below illustrates the ranges mentioned above.

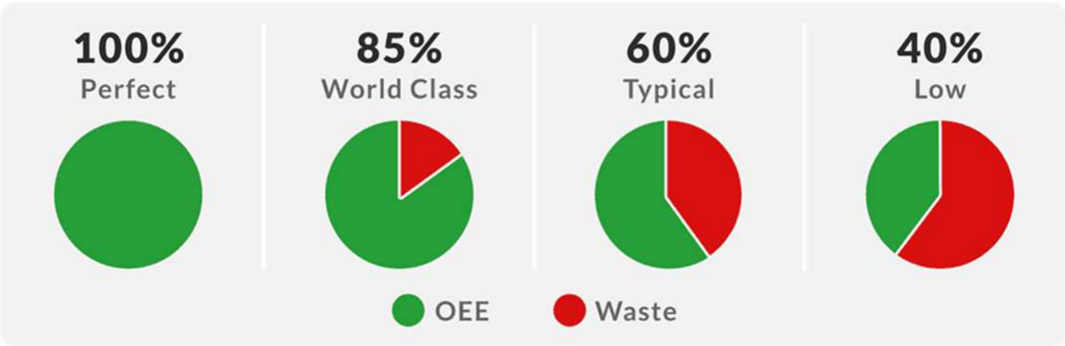


Figure 18: OEE score ranges (Vorne Industries Inc., 2011-2023)

2.3.2 Alternatives to Overall Equipment Effectiveness for the shop floor level

Further metrics and KPIs that are worth measuring but may not give a picture as complete as it is possible with OEE. Still, for defined use cases they can help to keep track and be implemented in management and shop floor dashboards. Mostly, many of them will be measured and can give a good view of the manufacturing company's shop floor performance.

2.3.2.1 Target, Actual, Efficiency, Downtime (TAED)

Vorne suggest that OEE is a useful tool for managers, but it may also be too theoretical for employees on the shop floor. To optimize the performance of these workers, it is essential to establish objectives that are motivational, easily understandable, and in real-time. An example of effective plant floor metrics is TAED, which includes the following components:

- Target: a real-time goal for production, based on planned production rates
- Actual: the actual count of production
- Efficiency: the percentage ratio of Target to Actual, indicating how far ahead or behind production is running
- Downtime: the amount of unplanned downtime accumulated during the shift, updated in real-time, providing a clear focus on improving this area. (Vorne Industries Inc., 2011-2023)

2.3.2.2 Production rate:

Production rate is a key performance indicator that measures the output of a production process over a specified period of time or put in different terms this metric measures the speed at which products are produced, usually measured in units per hour or units per day. It is used by companies to evaluate the productivity of their operations, identify areas for improvement, and estimate the time and cost required to complete a project. Production rate is typically measured in units per hour, day, or week, depending on the industry and type of product being produced.

Factors that can affect production rate include:

- Equipment downtime: Equipment breakdowns and maintenance can cause delays and reduce the amount of time available for production.
- Labor availability: A shortage of skilled workers or high turnover rates can lead to reduced production capacity.
- Material availability: A lack of raw materials or delays in the supply chain can slow down production.
- Production process efficiency: Inefficient processes or poorly designed workflows can cause bottlenecks and reduce production rate.

Although increasing the production rate may seem beneficial, it could also result in a decline in quality if employees are rushing to complete more units. This means that there is a threshold in the process where a reduction in quality might increase costs, despite a shorter production time. (Kenton, 2021)

2.3.2.3 Throughput

Throughput is the rate at which products are being produced. It is typically measured in units per hour or per day. Throughput and the above-mentioned production rate are similar but not exactly the same, as throughput refers to the rate at which products are being produced and leaving the production system, while production rate typically refers to the rate at which products are being manufactured within the production system.

Throughput takes into account not only the speed at which products are being produced, but also any delays or bottlenecks that may be present in the system. For example, if a production line is producing 100 units per hour, but there is a bottleneck that prevents some units from leaving the system, the actual throughput may be lower than 100 units per hour.

Production rate, on the other hand, typically refers to the rate at which products are being manufactured within the system, regardless of whether they are leaving the system or not. As explained above, production rate may be measured in units per hour, or it may be measured in terms of the capacity of the production system.

In general, it is important to track both throughput and production rate in order to gain a complete understanding of how efficiently the production system is operating. By monitoring both metrics, manufacturers can identify bottlenecks and other inefficiencies that may be limiting production and throughput and take steps to address them.

2.3.2.4 Cycle time

Cycle time is the time required to complete one unit of production. While throughput, as described above, is the number of units produced in a given time period. The relationship between cycle time and throughput can therefore be expressed mathematically as:

Throughput = 1 / cycle time

This means that as cycle time decreases (i.e., it takes less time to produce one unit), throughput increases (i.e., more units can be produced in the same amount of time). Conversely, as cycle time increases, throughput decreases. For example, if the cycle time for a particular production process is 1 hour, then the throughput is 1 unit per hour. If the cycle time is reduced to 30 minutes, then the throughput increases to 2 units per hour.

2.3.2.5 Lead time

This metric measures the time it takes for an order to be fulfilled, from receipt of the order to delivery of the finished product.

Lead time is a measure of the time taken for a product or service to be delivered to a customer from the moment an order is placed. It is an important performance indicator for businesses as it impacts customer satisfaction and can affect their competitiveness in the market. Lead time can be broken down into different components such as processing time, waiting time, and delivery time. Gunasekaran et al. define lead time or order lead time in the broadest sense possible involving all processes and departments involved as: the time which elapses between the receipt of the customer's order and the delivery of the goods. They go on by saying that the following elements are included:

Total order cycle time = Order entry time (through forecasts/direct order from the customer)

+ Order planning time (design, communication, scheduling time)

+ Order sourcing, assembly, and follow-up time

+ Finished goods delivery time. (Gunasekaran & al., 2001, pp. 73-74)

Figure 19 below shows this process in its entirety:

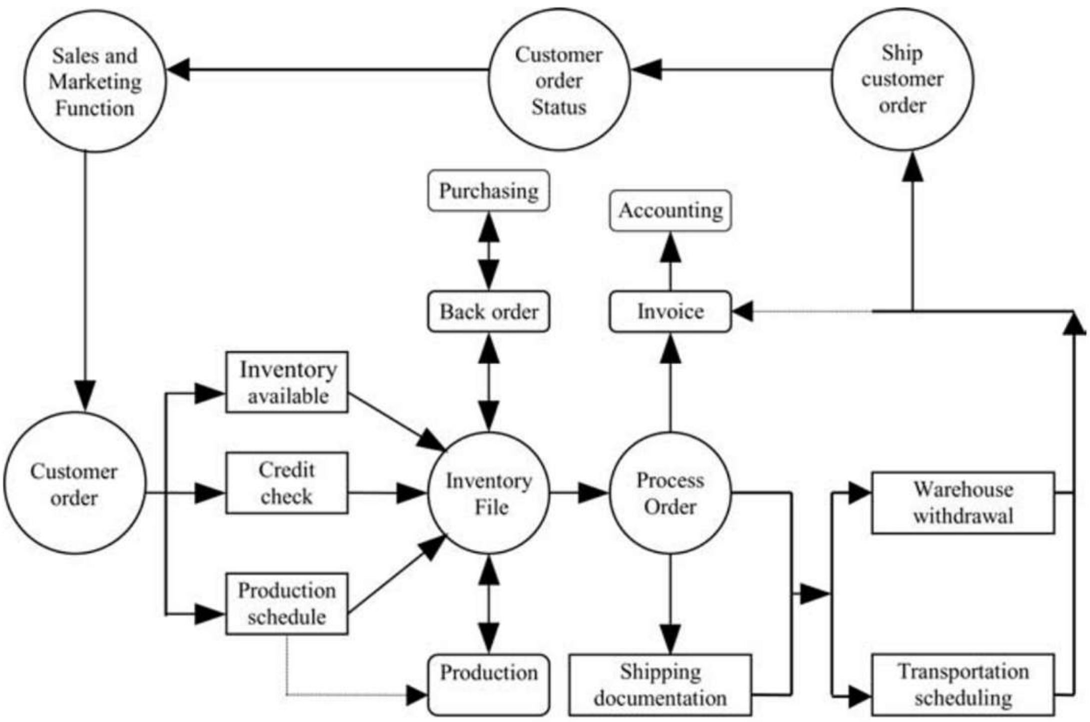


Figure 19: Order lead time (Gunasekaran & al., 2001, p. 74)

Clearly, lead time can also be defined as an internal process limited in its scope to production in the shop floor only, starting when the internal order is placed internally for production until the product exits the shop floor.

2.3.2.6 Inventory turnover

This metric measures the rate at which inventory is used and replenished, usually measured as the ratio of cost of goods sold to average inventory. In other words, it is a financial metric that measures how quickly a company is able to sell and replace its inventory over a certain period of time. Specifically, it measures the number of times a company's inventory is sold and replaced during a particular period, such as a year or a quarter.

The formula for calculating inventory turnover is as follows:

Inventory Turnover = Cost of Goods Sold / Average Inventory

Cost of Goods Sold (COGS) is the total cost of producing or purchasing the goods that were sold during the period. Average Inventory is the average value of inventory that a company held during the period, calculated by adding the value of inventory at the beginning and end of the period and dividing by two.

For example, if a company had a COGS of €500.000 and an average inventory of €100.000, its inventory turnover for the period would be 5. This means that the company sold and replaced its inventory 5 times during the period.

A high inventory turnover ratio is generally seen as a positive indicator, as it suggests that a company is efficiently managing its inventory and selling products quickly. This can result in increased cash flow and profitability. However, a very high inventory turnover ratio may also indicate that a company is understocked and may risk running out of inventory.

On the other hand, a low inventory turnover ratio may indicate that a company is not effectively managing its inventory, resulting in excessive or outdated stock that is difficult to sell. This can lead to higher costs and lower profitability.

Overall, inventory turnover is an important metric for businesses to monitor as it can provide insights into how well they are managing their inventory and whether there are opportunities to improve their operations.

2.3.2.7 Defect rate

Defect rate is typically defined as the percentage or proportion of defective or non-conforming products within a given sample or batch. It is a measure of the quality of a product or service and is calculated by dividing the number of defective items by the total number of items in the sample or batch. The defect rate can be used to evaluate and monitor the performance of a manufacturing process, and to identify areas for improvement.

2.3.2.8 Downtime

This metric measures the amount of time that a machine or production line is not in operation, usually measured in minutes or hours. As already described above, downtime is part of OEE calculation as a component or potential loss in the availability factor of the OEE formula. It is to be decided case by case if for the specific problem at hand, downtime by itself is worth measuring or tracking as an individual KPI. To be clear, downtime is not an alternative to OEE, but part of it. Also mentioned above it is part of the production rate calculation, reducing the time equipment is available for production.

While it is fairly easy to measure and keep track of equipment downtime, Liu et al underline that assigning and measuring the true cost of each event of system downtime in a multi-stage manufacturing process is not a simple task at all. Typically, a multi-stage manufacturing process involves a set of workstations that are separated by finite buffers, and a sequence of operations are performed on a product based on a predetermined order. When a particular stage encounters downtime, it can lead to blockage and starvation, causing the downtime to propagate quickly to the adjacent upstream and downstream workstations if not repaired in a timely manner. As a result, Liu et al. summarize that the cost of downtime must consider not only the indirect maintenance expenses (such as maintenance personnel wages and spare parts cost) and direct operating expenses (such as equipment depreciation and operator wages) during the downtime but also the associated costs of inactivity forced upon the surrounding stations. Although the allocation of maintenance and operating expenses during downtime may seem straightforward and the duration of the downtime incident appears to be a convenient choice for allocation, this approach may only work for fully synchronized manufacturing systems where a downtime event at one stage results in a system-wide shut down, such as a group of manual workstations along a shared conveyor. In all other cases, Liu et al. believe that collateral costs must be calculated using more complex methods to avoid losing accuracy. (Liu & al., 2012, p. 1)

2.3.2.9 Scrap rate

This metric measures the amount of material that is wasted during the production process, usually measured as a percentage of total material used. It can be used to identify areas where process improvements or quality control measures are needed to reduce waste and improve efficiency. Manufacturers can use a variety of techniques to minimize scrap rates, including implementing lean manufacturing practices, improving process control and automation, and investing in quality management systems and training for employees. By reducing scrap rates, manufacturers can increase their profitability, improve customer satisfaction, and minimize their environmental impact by reducing waste.

Shokri explains that the scrap rate is a frequent component of the cost associated with poor quality, and it can arise due to high levels of defects and variability in any manufacturing process. This rate has the potential to adversely affect the process cycle time, leading to additional costs and increased uncertainty in the supply of products. (Shokri, 2019, p. 106).

2.3.2.10 Employee turnover

Employee turnover refers to the number or percentage of employees who leave a company and are replaced by new hires within a specific period of time, typically on an annual basis. It can be calculated by dividing the number of employees who leave by the total number of employees at the beginning of the period. Employee turnover can be voluntary, such as when an employee resigns or retires, or involuntary, such as when an employee is terminated or laid off. High employee turnover can indicate problems with employee engagement, job satisfaction, or the overall work environment, and can lead to increased costs associated with recruiting, hiring, and training new employees.

High turnover rates among shop floor workers can lead to decreased productivity, increased training costs, and reduced quality control, all of which can have a negative impact on the company's bottom line.

2.3.2.11 Safety incidents

Safety incidents are unplanned events that result in injuries or damage to equipment, property, or the environment. They can occur in any workplace, but they are particularly common in manufacturing and industrial settings where there are potential hazards such as heavy machinery, hazardous materials, and working at heights. Safety incidents can range from minor incidents like slips, trips, and falls to more serious incidents like chemical spills, fires, and explosions. Employed as a metric, it measures the number of safety incidents that occur on the shop floor, usually measured as the ratio of incidents to total hours worked.

A different and more differentiated way to calculate is the total recordable incident rate (TRIR) as described in the following. TRIR measures the number of recordable incidents (i.e., incidents that result in medical treatment beyond first aid, lost work time, or job transfer) per 100 full-time employees per year. This metric allows organizations to track their safety performance over time and benchmark their performance against industry standards. (Tims, 2023)

Organizations use a variety of strategies to prevent safety incidents, including employee training, safety audits, hazard assessments, and the use of personal protective equipment (PPE). Continuous improvement and regular review of safety policies and procedures are also important for maintaining a safe working environment. In conclusion, safety incidents are a critical aspect of workplace safety and should be closely monitored by organizations to ensure the well-being of their employees and the environment. The use of metrics like TRIR and IR can help organizations identify potential hazards and implement effective safety measures.

2.3.2.12 Summary of alternative KPIs on the shop floor

These are some of the most widely used KPIs in shop floor management alongside OEE, but there may be other KPIs that are more relevant the specific organization or industry. The key is to select the KPIs that align with the chosen goals and objectives, and consistent and proper usage of them consistently to track and improve performance over time.

3 Case Study: Shop floor management at Rosendahl Nextrom

This case study was carried out to examine a real-life situation in an Austrian medium-sized equipment manufacturing company. In order to retrieve information about shop floor management methods and systems a qualitative interview was conducted by the author of this thesis with the plant manager overseeing production and shop floor KPI dashboards of that company. Some of the figures in the following analysis that will depict dashboards of key metrics and indicators are taken from Rosendahl Nextrom's Business Intelligence Software Suite fed by the MES/ERP System, that the company has implemented deeply in the company's processes. Names have were from those figures to allow for sufficient degree of privacy.

3.1 A brief overview of Rosendahl Nextrom

Rosendahl Nextrom is a medium sized company manufacturing equipment for the for the cable and wire, fiber optics and battery industry. Based in Austria, with headquarters in Pischelsdorf am Kulm, Styria, Rosendahl Nextrom has delivered more than 5000 projects to more than 1200 customers in 73 countries and operates with approximately 760 employees. Its biggest business group, under the brand name Rosendahl- covers the cable and wire industry supplying manufacturing solutions for cable makers dealing in almost any application such as: low voltage power cables, medium and high voltage cables, automotive cables, metal communication cables, fiber optic cables, steel ropes and shock tubes.

Rosendahl Nextrom is a leading supplier of machinery and equipment for the wire and cable industry, with a global presence and a reputation for innovation and quality it has a vital impact on this niche market of cable and wire industry. Despite the company's success, Rosendahl Nextrom is not a household name, and many people may not be aware of their contributions to the wire and cable industry. However, their customers and industry insiders recognize the company's expertise and the value of their products and services. Rosendahl Nextrom's therefore can be considered a a hidden champion, testament to their commitment to excellence and their ability to stay ahead of the competition in a highly specialized field.

As for their shop floor, Rosendahl Nextrom's production facilities are equipped with state-of-the-art machinery and technology to ensure the highest level of quality and efficiency in their production processes. The company enjoys low turnover rates, employees are highly trained and specialized in their area of work. The company's manufacturing processes are automated wherever possible, with many of their machines featuring advanced software and control systems. Additionally, the production floor is designed to maximize safety and efficiency, with clear lines of sight, designated walkways, and safety equipment located throughout the facility.

Rosendahl Nextrom has committed to lean processes and is running several tools and shop floor management systems that enable cost-effective, high-quality production The following figure represents a global view of the approach Rosendahl Nextrom is taking. Figure 20 indicates that continuous improvement is over-arching the process map with a strong customer focus and clear definition of roles and duties of departments and staff functions.

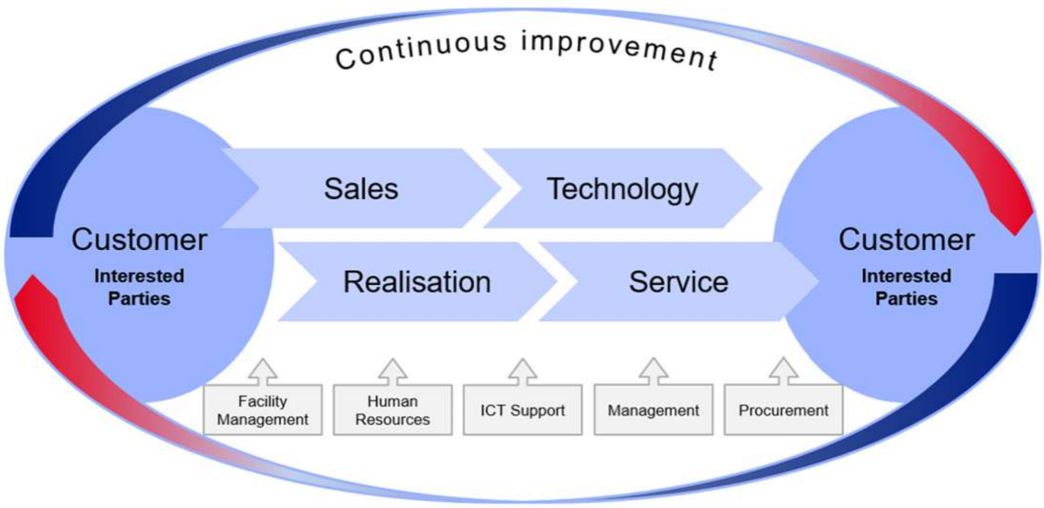


Figure 20: Process Map Overview (continuous improvement) at Rosendahl Nextrom (Rosendahl Nextrom GmbH, 2023)

Going one step deeper in the realization part from the figure above we can see the sub-units of realization (or production unit) in Figure 21 below. In below chapters the departments and sub-units mentioned will be steel work & mechanical manufacturing, varnishing, mechanical and electrical assembly. Commissioning will be omitted because other circumstances apply, as commissioning mostly takes place at the customer's premises and just in rare cases or to a certain extend at Rosendahl Nextrom's shop floor.

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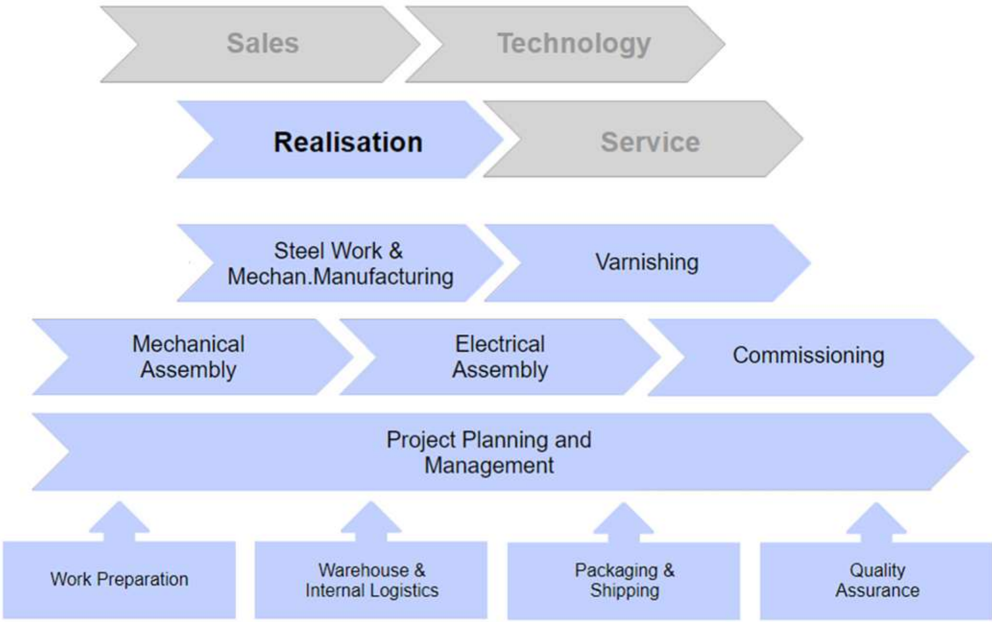

Figure 21: Process Map Overview: Realization (Production) at Rosendahl Nextrom (Rosendahl Nextrom GmbH, 2023)

3.2 An insight in Rosendahl Nextrom's shop floor management systems

According to the plant manager, the main challenges the company is facing in its production unit are due to the nature of the special machinery business and its need to react quickly to changes on very short notice. This is opposed to a line production that has a clearer flow, less variables and thus reduced need for short-term reaction to unforeseen changes. In short, this can be summarized as a lack of transparency as stated by the plant manager.

Alongside missing transparency, it is the human factor that keeps the production management team busy. A pleasant work environment support by human resources management, trainings and the possibility for everyone to trigger improvements projects are used to keep staff motivated on the hand and continuously improve processes on the other hand. (Plant Manager, 2023)

3.2.1 Regular communication patterns are key to quick solutions

Rosendahl Nextrom's plant manager states the regular and continuous communication patterns in German called "Regelkommunikation" as the most vital part of a smooth-running production. All departments and sub-units that are part of realization (production) stick to so called daily "standings" where any problem hat can be solved within one to three days will be discussed. Standings are meetings of defined working groups or teams that require participants to stand during these meetings rather than sitting down at a table to keep the meetings short and as effective as possible, hence the term standing is derived from "to stand" as opposed to "to sit". For bigger problems, a project will be set up and treated by a designated team. Every worker is encouraged to give input and report problems on the shop floor. Even seemingly insignificant things that can be changed and improved will be taken into account and are reported in the CIP dashboard as can be seen in the figure below. (Plant Manager, 2023)

The status of each project and idea is covered in a weekly continuous improvement project (CIP) meeting. The figure below depicts the CIP dashboard that is the basis for this meeting. It is a simple tool to keep track and follow-up on projects and ideas. Their status (reported, in process, execued, stopped) as well as start and end date and also the reporting department and person is availbale in the overview of this dashboard as can be seen in Figure 22 below:

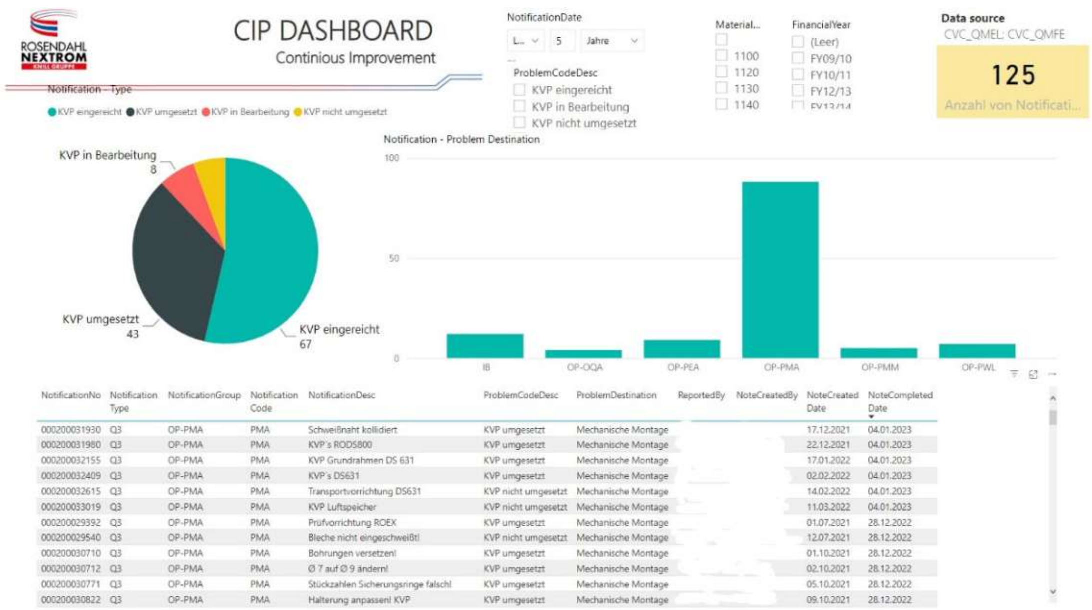

Figure 22:CIP Dashboard (Rosendahl Nextrom GmbH, 2023)

3.2.2 Capacity planning

As for continuous improvement also capacity planning is reviewed on a weekly basis. The plant manager considers capacity planning as an essential factor that has direct influence on cost of goods sold and thus financial success of the company.

For mechanical and electrical assembly departments there is a capacity based on available and planned resources which can be seen in the dark blue curve in Figure 23 below. Current and future need of capacity due to customer projects and projects in the pipeline are represented by the blue columns. This simple tool provides the plant manager with a quite good overall overview of capacity planning. The same is true for the departments of steel work & mechanical manufacturing and varnishing, but due to their more complex nature and the bigger variety of machines used in the production process, the capacity dashboard for this department can be drilled down to machine level. For each product or semi-finished product (PSP-element) the need of capacity, current status and necessary information such as apartment affected are displayed. The aggregated need of capacity for each week can then be compared to the available capacity. The main gal is to avoid underutilization of available capacities. The production manager at Rosendahl Nextrom is, roughly speaking, targeting 100 to 110% utilization of available capacity to have optimum results. By moving and shifting products while respecting delivery times this can be levelled. In case of overcapacity short term measures such as adding extra hours, implementing extra shifts, or adding short term personnel hired. (Plant Manager, 2023)

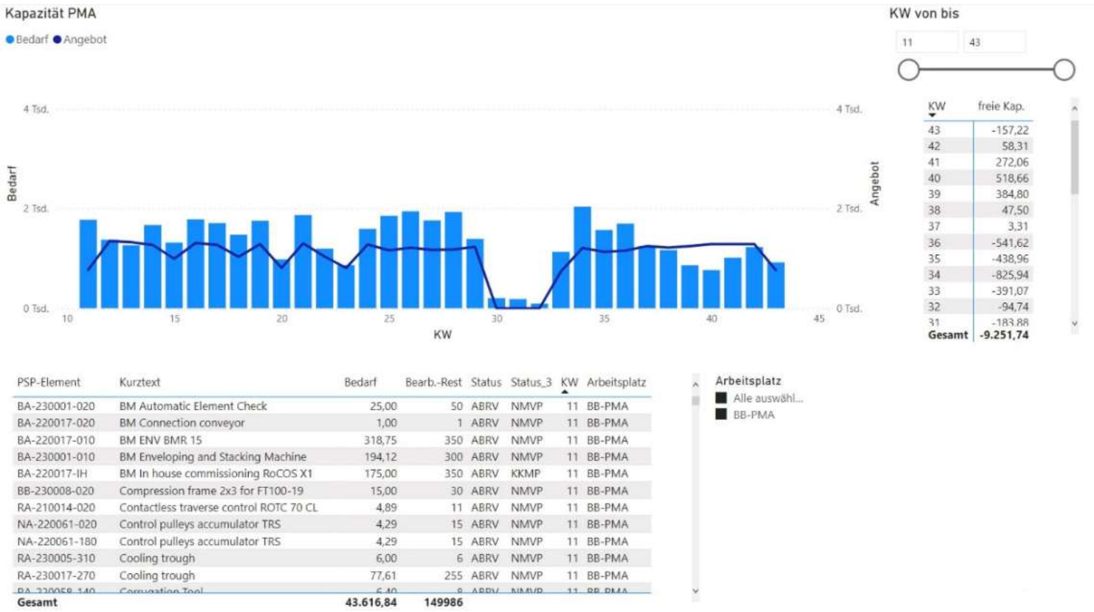

Figure 23: Capacity Dashboard (Rosendahl Nextrom GmbH, 2023)

3.2.3 The role of Overall Equipment Effectiveness at Rosendahl Nextrom

The plant manager agrees with literature that OEE is the gold standard of KPIs in shop floor management. Although he believes that in the case of Rosendahl Nextrom OEE would be an interesting figure to check and track, he suggests that it is aggregating data to a high degree and that OEE lacks detail which is essential in the special machine building industry. He states that in automotive industry, where he has experience for former assignments, OEE is heavily used, but he does not see the same need for OEE tracking in Rosendahl Nextrom's business. Also, OEE can be cheated by workers on the shop floor, and he suggests that just implementing OEE for the sake of it is not a helping anyone unless there is full commitment and a clear view on how OEE can be used in the company. (Plant Manager, 2023)

Despite that, Rosendahl Nextrom is working on establishing a dashboard displaying Overall Equipment Effectiveness. The figure below shows this draft, which is not operational, but still work in progress. OEE is supposed to be used in the future to track long term developments and help steering. Execution is very difficult as OEE requires every machine to be part of the system. Due to some operators working with 2 machines in parallel or products that take longer than a shift to be finished at a single production step or machine makes the detailed execution of OEE implementation resources intense and time consuming. So far, the numbers shown in this OEE dashboard draft are not yet reliable and show mistakes. The plant manager even states that in most cases where problems arise on the shop floor, OEE would not help to solve the issue, but it needs detailed information on a micro level to sort things out.

OEE will not be a problem-solving tool, but a very high-level monitoring and steering tool which can never replace detailed communication practices and continuous improvement process as described in chapter 3.2.1 above. (Plant Manager, 2023)

Figure 24: Draft of OEE Dashboard (Rosendahl Nextrom GmbH, 2023)

Figure 24 above shows that in the future this dashboard is supposed to give target and actual OEE for each machine or working cell within any given time period. The plant manager describes that the way to define and set the target OEE by working cell or machine is a very difficult yet important work that has to be done with utmost attention and thoughtfulness. Rosendahl Nextrom chose to use a calculated benchmarking approach to set the best possible targets and by that avoiding using experience or empirical values to take biased or influenced values out of the process.

3.2.4 Quality Dashboard

The KPI that covers quality at Rosendahl Nextrom is the number of failures, meaning number of parts that are out of their specification and cannot be used or need extra treatment to re-enter the production process. Each part -no matter if it is sourced or manufactured in-house- that is used in a final product will undergo quality assurance processes. This is either specifically done at the quality assurance laboratory or for some parts done by the worker in the shop floor by general visual inspection during assembly or manufacturing process. The amount of failures is given by department where it occurred. The different departments are represented by the differently coloured bars of the bar chart in Figure 25 below. The reporting worker follows a defined process on how to deal with different kinds of failures and the worker also attaches a description to each failure which can give a hint on how to avoid it in the future. It can be also noted that a CIP process as described in chapter 3.2.1 has been started.

The plant manager notes that the high amount of failures deteced in the mechanical manufcatruign departemnt can be traced down to a very common failure that is very hard to permamently solve or cope with namely insuficient deburring of flash removal of threads. It is a recurring failure that seems to be unavoidable even though many measures have been taken in order to try and solve the issues. The plant maager adds that in the time beofre this quality dashboard was introduced and every failure was captured, one was not aware of the route causes of delas and all the consequences this failures are triggering. Just the capability to see the kinds of failures and the departements where failures occur gives another, much greater level of transparnecy that has tremendous potential for quality improvements in Rosendahl Nextrom’s production processes. (Plant Manager, 2023)

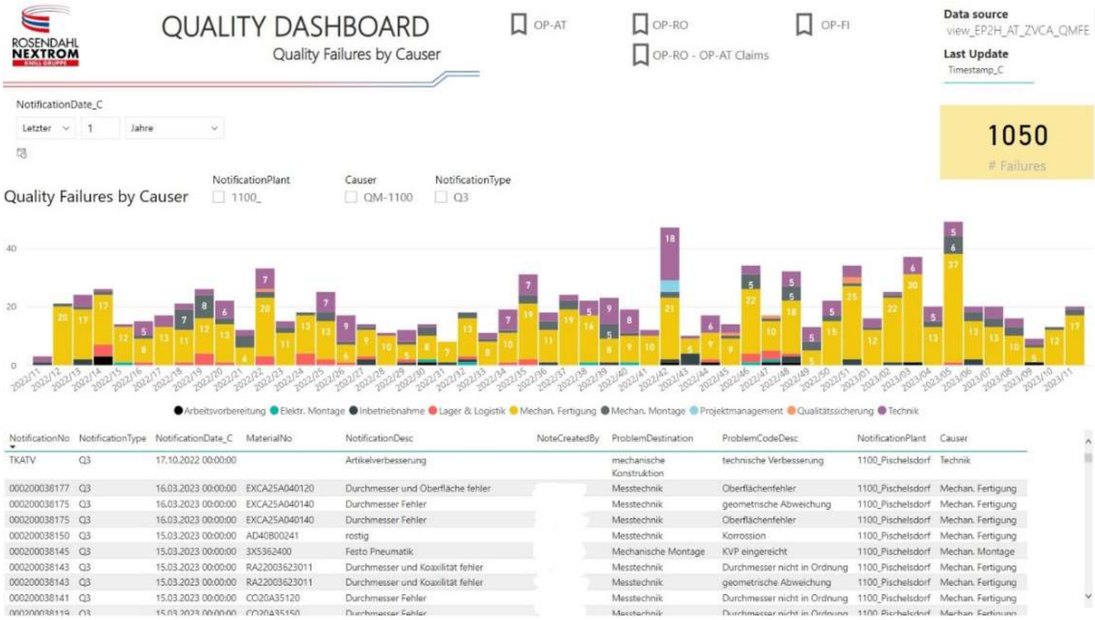

Figure 25: Quality Dashboard (Rosendahl Nextrom GmbH, 2023)

3.2.5 5S at Rosendahl Nextrom

As introduced in chapter 2.1.3 the 5S methodology has become a standard in modern production facilities worldwide. Also, Rosendahl Nextrom is working with the goal to respect the 5S methodology. Workers are regularly trained and each work group on the shop floor appoints a 5S leader among them who takes care of regular training and awareness of colleagues and makes sure that 5S is always kept on top of workers' minds. Rosendahl Nextrom has also developed a 12-page, ease-to-read brochure that helps workers understand the methodology and its benefits in their daily working lives. The plant manager underlines that it is the regularity of trainings and awareness sessions that are key for 5S to be permanently at the desired level. Too easily it seems that sorting materials, tools and workpieces as well as keeping the shop floor and individual workplaces clean gets forgotten or workers start jogtrotting. He states that 5S works once it has become a routine and workers feel the benefit of it. (Plant Manager, 2023). Figure 26 below depicts 2 pages of the 5S guideline brochure of Rosendahl Nextrom. The company has slightly adapted to 5S key words in German language to its own needs and translated the sort, stabilize, shine, standardize and sustain somewhat similar as shown in Figure 9 of chapter 2.1.3 as explained above.

Figure 26: 5S Guideline (Rosendahl Nextrom GmbH, 2023)

The brochure also shows some examples of DOs and DON'Ts and some best practice examples. Visualization seems to be a key for easy understanding and increased workers' acceptance.

3.2.6 Health and Safety at Rosendahl Nextrom

During the interview, the plant manager mentions health and safety as one of the main topics that are tightly tracked and looked at by Rosendahl Nextrom's management. The management team has implemented several dashboards covering health and safety and believes that health and safety measures that directly improve their indicators that can be seen in the dashboards, but also positively influence several other important metrics. It might be hard to measure these indirect effects and it seems even more difficult to put a discrete number to it, but this perception seems to be widely accepted at Rosendahl Nextrom and therefore any improvement in Health and Safety is highly appreciated for its main and indirect benefits. Figure 27 below depicts the Health and Safety Dashboard categorizing events into unsafe situation, near miss and accidents. The amount of these event is tracked by the affected persons' status, such as permanent staff, external persons such as visitors, suppliers etc.), apprentices and contract workers. The plant manager mentions that a lot of time is invested in best possible trainings and awareness session to reduce events to a minimum.

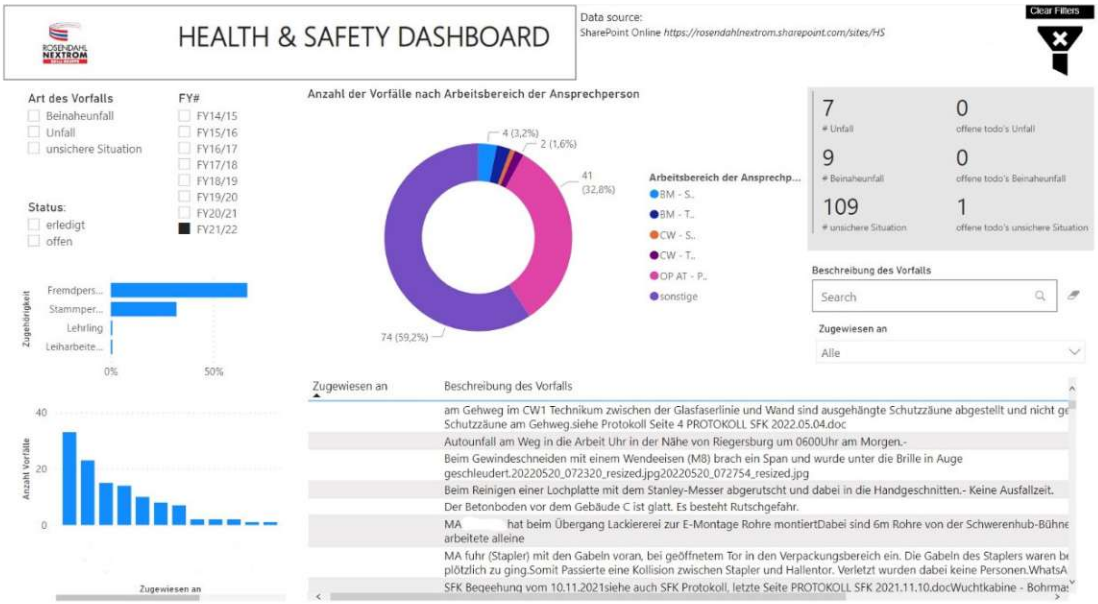

Figure 27:Health and Safety Dashboard (Rosendahl Nextrom GmbH, 2023)

In the weekly Friday standings, special safety minutes of events that recently occurred are discussed and -in severe cases- are communicated throughout the company describing the event or accident with potential solutions on how to avoid similar events in the future. Not only does this educate Rosendahl Nextrom's staff, but it also creates awareness and calls to caution. Figure 28 below shows such a safety minute that was communicated to every Rosendahl Nextrom employee a few days after the event occurred was thoroughly analyzed and potential counter measures were developed.

Figure 28: Safety Minute (Rosendahl Nextrom GmbH, 2022)

3.2.7 Summary of case study

This case study examines a medium-sized equipment manufacturing company in Austria called Rosendahl Nextrom, which specializes in producing machinery and equipment for the wire and cable industry. The study aims to retrieve information about shop floor management methods and systems, and the author conducted a qualitative interview with the plant manager overseeing production and shop floor KPI dashboards.

Rosendahl Nextrom operates globally and has delivered more than 5000 projects to over 1200 customers in 73 countries. Its production facilities are equipped with state-of-the-art machinery and technology to ensure the highest level of quality and efficiency in their production processes. The company is committed to lean processes and runs several tools and shop floor management systems that enable cost-effective, high-quality production.

According to the plant manager, the main challenges the company faces in its production unit are due to the nature of the special machinery business and its need to react quickly to changes on truly short notice. This is opposed to a line production that has a clearer flow, fewer variables, and thus reduced need for short-term reaction to unforeseen changes. In short, this can be summarized as a lack of transparency as stated by the plant manager.

Alongside missing transparency, it is the human factor that keeps the production management team busy. A pleasant work environment supported by human resources management, training, and the possibility for everyone to trigger improvement projects are used to keep staff motivated on the one hand and continuously improve processes on the other hand.

The plant manager emphasizes that regular and continuous communication patterns are the most vital part of a smooth-running production at Rosendahl Nextrom. All departments and sub-units that are part of realization (production) stick to so-called daily or weekly "standings" where any problem that can be solved within one to three days will be discussed. For bigger problems, a project will be set up and treated by a designated team. Every worker is encouraged to give input and report problems on the shop floor, and even seemingly unimportant things that can be changed and improved will be taken into account and reported in the CIP dashboard.

The CIP dashboard is a simple tool to keep track and follow-up on projects and ideas. Its status (reported, in process, executed, stopped), start and end date, and also the reporting department and person are available in the dashboard. The status of each project and idea is covered in a weekly continuous improvement project (CIP) meeting.

The plant manager explains that he considers capacity planning as a crucial factor for financial success and reviews it on a weekly basis. The mechanical and electrical assembly departments have a capacity based on available and planned resources, while the steel work & mechanical manufacturing and varnishing departments have a more complex capacity dashboard that can be drilled down to the machine level. The main goal is to avoid underutilization of available capacities and achieve 100 to 110% utilization of available capacity through product shifting while respecting delivery times. In case of overcapacity, short-term measures such as adding extra hours, implementing extra shifts, or hiring short-term personnel are implemented.

Although the plant manager of Rosendahl Nextrom agrees that Overall Equipment Effectiveness (OEE) is a valuable KPI for shop floor management, he believes that OEE lacks detail essential in special machine building industry and has the potential to be manipulated by workers on the shop floor. Despite this, the company is working on establishing an OEE dashboard to track long-term developments and help in steering. However, the detailed execution of OEE implementation is difficult and time-consuming due to factors such as some operators working with multiple machines in parallel or products taking longer than a shift to be finished. The plant manager states that OEE will not be a problem-solving tool but a high-level monitoring and steering tool that cannot replace detailed communication practices and continuous improvement processes. The company is using a calculated benchmarking approach to set targets for each machine or working cell within a given time period.

The primary KPI for quality at Rosendahl Nextrom is the number of failures, which includes parts that are out of specification or require extra treatment to re-enter production. Quality assurance processes are conducted for all parts used in final products, and failures are reported by department and described in detail to identify root causes and potential solutions. A common issue in the mechanical manufacturing department is insufficient deburring or flash removal of threads, which is difficult to permanently solve. The plant manager notes that the quality dashboard has provided greater transparency and potential for quality improvement in the production processes.

The 5S methodology is a standard practice in modern production facilities, and Rosendahl Nextrom also aims to respect this methodology. Workers are trained regularly, and each work group appoints a 5S leader who ensures that the methodology is always on workers' minds. Rosendahl Nextrom has also created an easy-to-read brochure that helps workers understand the methodology and its benefits. The plant manager emphasizes the importance of regular training and awareness sessions for 5S to be permanently at the desired level. The company has slightly adapted the key words in German to its own needs and translated them similarly to the original 5S methodology.

The plant manager at Rosendahl Nextrom emphasizes the importance of health and safety in the workplace and states that the company tracks and looks at several dashboards covering health and safety. The company believes that any improvement in health and safety not only directly improves their indicators seen in the dashboards, but also positively influences several other important metrics. The Health and Safety Dashboard categorizes events into unsafe situations, near misses, and accidents, and the amount of these events is tracked by the affected persons' status. The company invests a lot of time in providing the best possible training and awareness sessions to reduce events to a minimum. In the weekly Friday standings, special safety minutes of events that recently occurred are discussed, and in severe cases, they are communicated throughout the company with potential solutions on how to avoid similar events in the future.

In conclusion, Rosendahl Nextrom's success can be attributed to its commitment to excellence and its ability to stay ahead of the competition in a highly specialized field. The company's shop floor management systems are designed to maximize efficiency, quality, and safety, while also encouraging regular communication, employee input, and continuous improvement.

In conclusion, the case study of Rosendahl Nextrom, a medium-sized equipment manufacturing company in Austria, has revealed that the company has a strong commitment to lean processes and runs several tools and shop floor management systems that enable cost-effective, high-quality production. The company's production facilities are equipped with state-of-the-art machinery and technology to ensure the highest level of quality and efficiency in their production processes. The plant manager identifies the main challenges the company faces as lack of transparency due to the nature of the special machinery business and the need to react quickly to changes on very short notice. Communication patterns are considered the most vital part of a smooth-running production at Rosendahl Nextrom, with all departments and sub-units that are part of realization (production) sticking to so-called daily or weekly “standings” where any problem that can be solved within one to three days will be discussed. The company is using various dashboards, such as the CIP dashboard, to keep track and follow-up on projects and ideas, as well as health and safety dashboards to reduce events to a minimum. The plant manager notes that OEE will not be a problem-solving tool but a high-level monitoring and steering tool that cannot replace detailed communication practices and continuous improvement processes. Overall, Rosendahl Nextrom's is highly aware of existing theories and practices of shop floor methods tools and strategies and due its distinctive nature of business choses the KPIs that are most valuable and goal oriented. Together with a strong focus on transparency, communication, and continuous improvement processes this setup has enabled the company to achieve cost-effective, high-quality production, and to maintain a pleasant work environment for its staff.

4 Conclusion an Outlook

The thesis discussed some of the main principles, methods, strategies, and tools that have been developed and find application in the field of shop floor management and manufacturing. The research question focused on the reasons for choosing Key Performance Indicators (KPIs) in manufacturing.

The author conducted a literature review describing and defining some of the most common tools, strategies, and methods to manage a shop floor of a manufacturing company, followed by definition of potential KPIs to be used. The case study, which examined the shop floor practices of a medium-sized equipment manufacturing company in Austria called Rosendahl Nextrom, was based on a qualitative interview with the company's production manager and supported by research in the company's Business Intelligence Software and its dashboards currently implemented and dashboards in development.

Relating to the research question, it has to be said that in essence, there is no clear answer to the research question which factors are decisive to choose for one or the other metric or KPI to keep track of. On the contrary, it is highly depending on historic development of companies, the nature of the business and individual choices of the manufacturing company's management. This statement is strongly underlined by the findings of the case study and the statements made by the production manager interviewed.

This work contributes to the vast amount of scholars' work that has been done in the field of shop floor management, lean manufacturing and process driven production in a sense that it creates a connection of theory and a single practical case of application. The author's goals were to find out whether the state-of-the-art methods, tools and strategies find application in a modern and successful manufacturing company, which partly was the case. The reasons for or against were given, and mainly stem from the nature of the business and the need for great detail in everyday work and problem-solving on the shop floor.

The future will bring along even more refined and tailored strategies, tools, and methods to tackle shop floor management problems and improve performance. Big Data, Smart Manufacturing, Industry 4.0, 5,0 and following, as well as Machine to Machine (M2M) communication are keywords that are being discussed and already find application and will find even more application in the field of manufacturing in the future. Still, the degree of implementation and success of these practices in real-life industry and manufacturing companies around the globe will depend on individual choices, human factors and will always demonstrate the imperfections of reality versus theory and literature.

IV List of figures

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