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Proposing a Set of Improved Key Performance Indicators for Case Company

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Abstract

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The objective of the study is to propose a set of improved key performance indicators (KPIs) for the case company. In the production processes, the organization is struggling with having a clear picture of the process performance since there is a lack of good KPIs. Getting the KPIs into usable and value adding form demands a great deal of manual work. The quality of the data used for the KPIs is also at a poor level since it is affected by how the personnel is using the systems collecting the data.

The research approach of the study is design research, and the study includes four stages. The first stage is a literature review of existing knowledge and best practices related to how to analyze KPIs, the findings are compiled into the conceptual framework. The second stage is a current state analysis gathering the strengths and weaknesses of the current KPIs and data collection processes. In the third stage the initial proposal is co-created utilizing the outcomes from previous stages. The fourth and last stage is a validation round of the initial proposal of improved set of KPIs, providing feedback to build the final proposal.

Several process strengths and weaknesses were identified during the current state analysis. Five of the most critical weaknesses agreed were scoped for further development in this study.

The final proposal of improved set of KPIs includes a comprehensive set of KPIs with a balance between lagging and leading indicators, showing the outcome and highlighting the areas in the process where improvements are needed.

Keywords: Key performance indicator, Production process, Leading indicator, Lagging indicator, Process improvement, Data collection

Contents

List of Figures

Acronyms

CSF	Critical success factor
KPI	Key performance indicator
RI	Result indicator
PI	Performance indicator
KRI	Key result indicator
CSA	Current state analysis
DTM	Daily team management
CF	Conceptual framework
MTO	Make-to-order
BSC	Balanced scorecard
MES	Manufacturing execution system
WTRS	Working time registration system
ERP	Enterprise resource planning
MMS	Maintenance management system
SMS	Safety management system
TQM	Total quality management
OUI	Operator user interface
TPM	Total Productive Maintenance

1 Introduction

A starting point for any organization seeking outstanding performance is knowing what its critical success factors (CSFs) are. By clarifying these and communicating them within the organization, the individuals and teams can align their activities with the strategical goals. The CSFs and key performance indicators (KPIs) linked to them, are the only things that truly link daily activities in the workplace to the strategy of the organization. In an organization where this link is missing, it is often the thing that distinguishes it from a great performing organization. (Parmenter, 2019: 24-34)

In many organizations the used measures have been designed by personnel that have not received proper education, thus leading to wrong measures used resulting in poor or unwanted behaviour in the workplace. It is also common that monthly measures are considered to be KPIs rather than 24/7, daily or weekly measures that would be the real drivers in improving the daily decision-making process. (Parmenter, 2019: 24-34)

Performance measures are classified into two groups: result indicators (RIs) and performance indicators (PIs). RIs are measures that are affected by multiple teams input, and they are therefore not helpful in determining which teams are delivering the performance wanted and which teams are not. (Parmenter, 2019: 55-56)

PIs, on the other hand, are measures whose ownership lies in one or a cluster of teams working together towards a common goal. The responsibility for the performance can therefore be tied to one team, giving clarity and promoting ownership. With both RIs and PIs, some of them are more critical for the success of the organization, thus they are named key result indicators (KRIs) and KPIs. Many organizations are mistakenly using RIs as performance measures and it is therefore, no wonder, why reporting these measures has not improved the performance. (Parmenter, 2019: 55-56)

This study focuses on proposing a set of improved KPIs for the case company's cut & bend production processes that are linked with the strategy in a sound way.

1.1 Business Context

The case company is a leading manufacturer and distributor of reinforcement steel products in Finland, where it has two cut & bend plants and one mesh plant. At the time of writing this study the case company had approximately 140 employees working in sales, engineering, production, logistic and administration.

Most of the products produced in the cut & bend plants are make-to-order (MTO) with short delivery times. The work load in production can vary in time heavily, with normally higher volumes during spring and summer period, and lower during winter. Forecasting the level of customer demand has proven to be a difficult task for the case company, putting even more pressure on the performance of the supply chain and production processes.

The strategical guidelines for the case company include the implementation of daily team management (DTM), where every basic team must identify the main process deviations regarding their daily and weekly KPIs.

1.2 Business Challenge, Objective and Outcome

In the production processes the organization is struggling with having a clear picture of the process performance since there is a lack of good KPIs. The ones used at the moment of writing, are not working as a true driver for improving the performance since they are not showing what needs to be improved.

Getting the KPIs into usable and value adding form demands a great deal of manual work. The quality of the data used for the KPIs is also at a poor level since it is affected by how the personnel is using the systems collecting the data.

By solving the business challenge the case company can implement DTM mentioned in the strategical guidelines. Solving the business challenge is also critical since it will allow the case company to link their daily activities at the workplace with the strategy, thus having the opportunity to become a high performing organization.

Accordingly, the **objective** of this study is to propose a set of improved KPIs for the cut & bend processes, and the **outcome** is the proposed set of improved KPIs.

1.3 Scope and Outline

This study includes four stages to address the set business challenge discussed in the previous section. At the first stage relevant literature was searched to gain a deeper knowledge of KPIs and how to analyse them, the outcome of the literature search was the conceptual framework (CF) for the study.

After the literature search the current state of the KPIs used and the data collection process was analysed. As input to the current state analysis (CSA) a workshop and interviews with internal stakeholders was held. The outcome of the CSA was a list of strengths and weaknesses regarding the KPIs and data collection processes.

Following the CSA, a workshop and interviews with both internal and external stakeholders was held to co-create the initial proposal. The fourth and last stage was a validation round with both internal and external stakeholders of the initial proposal. Based on their feedback the final proposal was built.

The study consists of 7 sections. The introduction to the study is followed by section 2, which describes the project plan, chosen research approach, the research design and the data collection. Section 3 discusses relevant literature regarding how to analyse KPIs and outlines the CF of the study. Section 4 captures and summarizes the findings from the CSA. Section 5 introduces the

initial proposal for the improved set of KPIs. The initial proposal built in section 5 is validated in section 6. The final section of this thesis provides the conclusions with an executive summary along with a self-evaluation of the thesis and some final words.

This study does not include the implementation of the proposed set of improved KPIs. The study is limited to analysing the current state of the KPIs and the data collection process related to them, and proposing improvements to these. The following section describes the project plan, the chosen research and design approach and the data collection method.

2 Project Plan

In the previous section the business challenge, objective and outcome were introduced. In this section the chosen research approach and design is firstly described, followed by the data collection method.

2.1 Research Approach

Saunders et al. (2019) explains that one of the purposes of research is to expand the current knowledge of management and business processes. This type of research, which is not necessarily directed at solving a specific problem or addressing an individual opportunity, is referred to as basic, fundamental, or pure research. (Saunders, et al., 2019: 45)

According to Kothari (2004) applied research is a type of research that focuses on solving practical problems and addressing specific needs of an organization. The goal of applied research is to produce solutions that can be directly implemented or used to improve existing processes, products, or services. (Kothari, 2004: 3)

Design research, as described by Kananen (2013), involves combining development and research to produce practical and functional solutions that improve operations in organizations. This approach is closely aligned with the natural development work that organizations undertake as they seek to improve their operations. According to Kananen when development work is properly documented, uses appropriate scientific methods, and produces new knowledge, it can be considered a form of science. (Kananen, 2013: 20-22)

The research approach chosen for this study is design research, utilizing qualitative methods. Design research was selected as the most appropriate approach due to the study's focus on a particular organizational business problem and its objective of proposing process improvements.

The objective and outcome of this study does not involve implementing or evaluating the proposed solutions effect on the process. As a result, a qualitative data collection approach was selected instead of a quantitative approach.

2.2 Research Design

This study consists of four stages, which were designed in response to the business challenge and to achieve the desired outcome. Figure 1 shows the research design of the study.

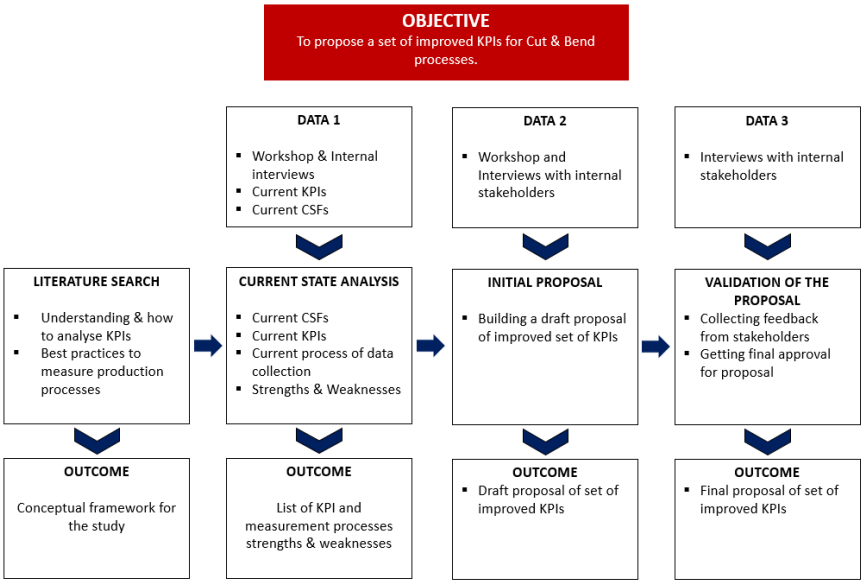

Figure 1. Research design of the study

In the first stage shown in Figure 1 deeper knowledge about understanding and analysing KPIs was gained by reviewing academic literature. The outcome of stage 1 was the CF for the study based on the learnings from the literature review.

After the literature review a CSA was conducted in stage 2 as shown in Figure 1. In the CSA interviews and a workshop with internal stakeholders was conducted to gain knowledge about the strengths and weaknesses of the current KPIs and data collection processes. Internal stakeholders who were interviewed and who participated in the workshop were selected to represent all

different levels in the processes analysed, ranging from operator level to production managers. The first level in the CSA was to identify the critical success factors of the organization which is the starting point according to Parmenter (2019). During the workshop and interviews the link between the CSFs and current KPIs was analysed. Findings regarding the strengths and weaknesses of current KPIs and their data collection processes, and the link between them and the CSFs was summarized as a list of strengths and weaknesses to form the outcome of the CSA.

In the third stage shown in Figure 1, a workshop and interviews with internal stakeholders were conducted. The learnings from these were used to build the initial proposal for an improved set of KPIs.

Following stage 3, the initial proposal was validated in stage 4. The initial proposal was presented to key internal stakeholders. The constructive feedback received was used to adjust the initial proposal forming the outcome of the fourth stage, the final proposal.

2.3 Data Collection and Analysis

The data for this study was obtained in three data collection rounds where interviews and workshops with internal stakeholders, and the current CSFs and KPIs were used as a data source. Table 1 shows the data collection for the CSA.

Table 1. Data 1 collection

	Content	Source	Participants/Role	Timing	Outcome
DATA 1 Current State Analysis	▪ Current CSFs ▪ Current KPIs ▪ Current process of data collection ▪ Strength & Weaknesses	▪ Workshops & Internal interviews ▪ Current CSFs ▪ Current KPIs	▪ Operators ▪ Work Foremen ▪ Production Planner ▪ Production Engineer ▪ Production Managers ▪ Safety Manager ▪ Maintenance Engineer ▪ Development Engineer	February -March 2023	▪ List of KPI and measurement processes strengths & weaknesses

To obtain needed knowledge for the CSA the Data 1 collection round was held. During Data 1 collection round, interviews and a workshop with internal

stakeholders were conducted. The current CSFs and KPIs were also used as a source for the CSA. As seen in Table 1, the outcome from the Data 1 collection was a list of KPI and measurement processes strengths and weaknesses. The second round of data collection, Data 2 for developing the initial proposal is presented in Table 2.

Table 2. Data 2 collection

	Content	Source	Participants/Role	Timing	Outcome
DATA 2 Developing the Initial Proposal	▪ Building a draft proposal of improved set of KPIs	▪ Workshops and Interviews with internal stakeholders	▪ Work Foremen ▪ Production Planner ▪ Production Engineer ▪ Production Managers ▪ Safety Manager ▪ Maintenance Engineer ▪ Development Engineer	April 2023	▪ Draft proposal of set of improved KPIs

As seen in Table 2, the initial proposal was developed based on data collected during a workshop and interviews with internal stakeholders in Data 2 collection round. The last data collection round, Data 3 for collecting feedback for the initial proposal is presented in Table 3.

Table 3. Data 3 collection

	Content	Source	Participants/Role	Timing	Outcome
DATA 3 Validation of the proposal	▪ Collecting feedback from stakeholders ▪ Getting final approval for proposal	▪ Interviews with internal stakeholders	▪ Work Foremen ▪ Production Planner ▪ Production Engineer ▪ Production Managers ▪ Safety Manager ▪ Maintenance Engineer ▪ Development Engineer	Maj 2023	▪ Final proposal of set of improved KPIs

To gather the constructive feedback on the initial proposal, interviews with internal stakeholders were conducted. The feedback was used to build the final proposal as can be seen in Table 3.

Thematic analysis was used to analyse the interviews, workshop and discussions in this study, identifying the most important weaknesses organized by importance ranking and refining them for further research with the conceptual framework.

The following section of this study presents findings from the literature search that was conducted to gain a deeper knowledge of KPIs and how to analyse them.

3 Existing Knowledge on Key Performance Indicators

In the previous section the project plan, the chosen research and design approach and the data collection method were introduced. This section presents findings from the literature search that was conducted to gain a deeper knowledge of KPIs and how to analyse them.

3.1 Basics of Performance Measurement

Performance measures are classified into two groups: result indicators (RIs) and performance indicators (PIs). RIs are useful in assessing teamwork, but it can be challenging for management to identify which teams are responsible for the results, whether negative or positive. In contrast, performance indicators are metrics that can be linked to either a team or a group of teams collaborating towards a shared objective. In this way, positive or negative performance can be tied to a single team or a cluster of teams, providing clarity and ownership. (Parmenter, 2019: 48)

To express the most important of these measures the word “key” is used, resulting in two measures for each group. Parmenter (2019: 48-49) describes the different performance measures as follows:

1. Key result indicators (KRIs) provide the board with an overall picture of the organization’s performance.

2. Result indicators (RIs) inform management about how teams collaborate to produce results.

3. Performance indicators (PIs) inform management about how well teams are performing.

4. Key performance indicators (KPIs) inform management how the organization is performing in their CSFs 24/7, daily or weekly.

Manufacturing operation management and continuous improvement (CI) heavily rely on KPIs. In today's manufacturing systems, KPIs refer to a collection of metrics that reflect operational performance, including efficiency, throughput, and availability, from the perspectives of productivity, quality, and maintenance. Continuously measuring and monitoring KPIs, provides valuable information of various aspects of operational activities that can be used for CI efforts. (Kang, et al., 2016: 6333)

KPIs are used by managers to evaluate the performance of their companies and to identify deviations from set objectives. Correctly chosen and built KPIs draw the attention to areas that need to be improved. The popular sayings “What gets measured gets done” and “if you cannot measure it, you cannot manage it” are commonly used to highlight the importance of metrics. However, many managers struggle to identify the essential metrics and instead gather and report easily measurable data that does not give real value. (Marr, 2014)

Selecting the correct measures is vital for managing, as it determines to a large extent how people within the organization behave and what they will focus on. Many managers focus on tracking standard industry approved measures which are useful in maintaining the status quo, but not helpful in taking the organization to the next level. For an organization to take their performance to the next level, focus on the measures that truly matters is a must. (Spitzer, 2007: 69)

A company’s success depends on how well the organization is able to create value for itself and its shareholders by delivering value to its customers. A well-executed strategy with the right performance measures in place to support it is key to achieving the desired operational performance, which ultimately generates value. (Spitzer, 2007: 74-75)

3.2 Characteristics for Winning KPIs

According to David Parmenter (2019: 50), KPIs are those that highlight the areas of organizational performance that are crucial for both present and future success of the organization. Parmenter (2019: 53-54) states he has during his extensive analysis and KPI workshops identified seven characteristics for winning KPIs:

1. **Non-financial:** Although financial measures are important for the business, they are solely outcome indicators and not indicative of potential changes.

2. **Timely:** KPIs should be monitored regularly, such as daily or weekly. If measures are only checked on a monthly or less frequent basis, they cannot be considered key performance indicators.

3. **CEO Focus:** All KPIs should be significant enough to capture the CEO's attention and make a significant impact on the business.

4. **Simplicity:** KPIs should reveal the necessary actions to be taken, and not require complex analysis to understand.

5. **Team-based:** Every KPI should be tied to a specific team, meaning someone should be owning the KPI.

6. **Significant impact:** KPIs should influence one or more critical success factors and not be irrelevant to the business.

7. **Limited dark side:** KPIs must not result in unwanted behaviour, such as prioritizing one area of the business at the expense of others.

According to Parmenter (2019), when the characteristics of KPIs are considered, the measures are rare and many organizations can function effectively with no more than ten KPIs. (Parmenter, 2019: 57)

3.3 Critical Success Factors of the Organization

Before developing any measures, an organization must understand what is crucial to get right day in, day out. Any organization seeking operational excellence must know and have its CSFs communicated with staff members. When the CSFs are known and communicated, staff members will be able to match their daily tasks with the organization's strategic direction. (Parmenter, 2019: 26)

The traditional balanced scorecard (BSC) approach monitors the implementation of strategic initiatives through performance measures, which are typically cascaded down from top-level organizational measures such as return on capital employed. This cascading of measures leading to hundreds of measures being monitored will frequently result in chaos within the organization. (Parmenter, 2019: 130)

Getting employees to prioritize their daily activities in accordance with the organization's CSFs is the "El Dorado" of management. Thus, instead of basing measures on strategy, it would be important to first define the organization's CSFs and then determine which measures would result in alignment with these. (Parmenter, 2019: 130)

3.3.1 Characteristics of Critical Success Factors

Parmenter (2019) states that CSFs and their corresponding KPIs are the only things that connect daily workplace activities to the organization's strategy. Parmenter states further that getting the CSFs right, enables an organization to easily find its winning KPIs. According to Parmenter, CSFs have the following characteristics: (Parmenter, 2019: 26,131)

1. Requires daily focus from all employees.

2. Employees focusing daily on the CSFs leads to operational success.

3. Worded in a way that is relevant to the activities employees should focus on, and avoiding use of empty words such as optimization and maximization.

4. Describes the activity.

5. Already talked about as success factors by management and the board, thus not a surprise to them.

6. Are organizational in nature and should not be divided into department CSFs.

7. Few in number, five to eight CSFs are enough.

8. Have a positive impact on other success factors.

Parmenter (2019) emphasizes the importance of communicating the CSFs to the organization as well as measuring progress in them. Parmenter (2019) states further that performance measures that have no relation to or impact the CSFs are, by definition, unimportant and should be avoided. (Parmenter, 2019: 132)

3.3.2 Defining the Critical Success Factors

The process of defining the CSFs should start with an examination of the organization's strategic documents, followed by the extraction and development of the CSFs in collaboration with key stakeholders. The wording used should meet the SMART criteria described below. (Parmenter, 2019: 134-135)

- **Specific** – A statement that avoids using empty and meaningless words common in management terminology, such as effective and efficient.

- **Measurable** – A statement that is measurable.

- **Achievable** – A statement that is clear and concise.

- **Relevant** – Narrow enough in scope to be relevant to the organization's employees.

- **Time sensitive** – Concentrated on the present moment. E.g. "Timely departure and arrival of planes 24/7".

To determine the organization's CSFs, it is critical that experienced staff members define them; it is not a task for new employees. When the CSFs are correctly defined, they will transform performance by providing clarity and alignment. (Parmenter, 2019: 136,138)

3.4 Lagging and Leading KPIs

Kaplan and Norton (1996) divide performance measures into two categories: lagging measures, also known as outcome measures, and leading measures, also known as performance drivers. (Kaplan and Norton, 1996: 55-56)

Taylor and Ahmed-Kristensen (2016) argue that there must be a balance between lagging and leading KPIs. Lagging KPIs showing the outcome alone do not communicate how to achieve the wanted outcomes of a process, while leading KPIs monitoring the process metrics do not communicate if the wanted outcome was achieved or not. Leading KPIs are required to highlight the areas in the process where improvements are needed. (Taylor and Ahmed-Kristensen, 2016: 1616).

Smith and Mobley (2005) states leading KPIs are used to manage a part of the business, while lagging KPIs are used to assess how well one have managed. When a poor result is discovered, leading KPIs allow for a direct and immediate response. Organizations gain value from knowing how well they have performed by looking at the lagging KPIs, but need the support of leading KPIs to determine the root cause of the underperformance. One cannot manage the

results, only the processes that deliver the results can be managed. (Smith and Mobley, 2005: 89, 90)

3.5 Conceptual Framework of the Study

The findings from relevant existing literature related to KPIs are summarized in the CF for the study presented in Figure 2. The CF is divided into three sections: characteristics of critical success factors, characteristics of winning KPIs and leading and lagging KPIs.

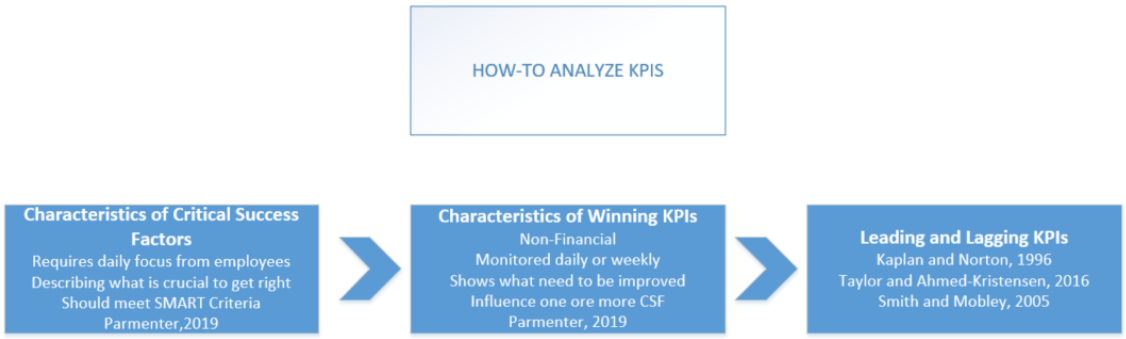

Figure 2. Conceptual framework of the study

The CF emphasizes that the first step is to clarify the CSFs of the organization, KPIs should then be linked to them. A key point is also that KPIs should be non-financial measures, followed up daily or weekly. There must be a balance between lagging and leading KPIs to be able to track both the outcome, and the process metrics highlighting where improvements are needed.

The CF is utilized to form the interview questions for the CSA described in the next section. The CF is used to recognize strengths and weaknesses in current KPIs and data collection processes related to them.

The following section of this study presents the findings from the CSA of the case company's KPIs and data collection processes.

4 Current State Analysis of KPIs and Data Collection Processes

In the previous section findings from the literature search that was conducted to gain a deeper knowledge of KPIs and how to analyse them was presented. This section describes the findings from the CSA and discusses the findings categorized into strengths and weaknesses.

4.1 Overview of the Current State Analysis

In the CSA interviews and a workshop with the internal stakeholders were conducted to gain knowledge about the strengths and weaknesses of the current KPIs and data collection process using the CF created in the previous section. The Internal stakeholders who were interviewed and who participated in the workshop were selected to represent all different levels in the processes analysed, ranging from operator level to production managers from both cut & bend plants, to gain input from all the stakeholders involved in the process.

In the manufacturing processes the case organization is struggling with having a clear picture of the process performance due to lack of good KPIs and quality of data used to build the KPIs. The quality of the data input is affected by how the personnel are using the data collection systems since the probability of human error is present. Extracting the data from the different systems and building the KPIs also involves risks of human error. The objective of proposing a set of improved KPIs is thus highly relevant for the case company since it will enable it to monitor and improve KPIs that truly matter and have an impact on achieving the strategic objectives.

The data collection started with an interview with the production managers of the cut & bend plants, where the focus was to identify the CSFs relevant to the production organization. During the interview with the production managers, the link between the CSFs and current KPIs was analysed.

A second interview was held with the production foremen, production planner, maintenance engineer, and development engineer to collect data on the KPIs used at their level. A workshop was conducted with this same group of participants, where the current data collection processes were mapped with the help of a flowchart. Operators were also interviewed in a more informal way during discussions in the workplace to get their input on the data collection processes and how they understand the KPIs used.

The interviews were conducted via Teams meetings using pre-prepared questions, but the stakeholders interviewed were also encouraged to bring forward their own experiences of the current state of the process analysed. The interview questions used had a focus on strategic objectives, currently used KPIs to measure the performance against the objectives, and how well they are answering what needs to be improved.

The findings were documented into written field notes which are presented as a summary in Appendix 1-3. The complete set of interview questions can be found in the Appendices.

The outcome of the CSA was a list of strengths and weaknesses of current KPIs and their data collection processes and it is summarized in Table 7.

4.2 Description and Analysis of the Current KPIs and Data Collection Processes

The first part of this section describes the findings from the first interview, focusing on the strategic objectives and used KPIs recognized during the interview with the production managers. It is followed by a section describing the findings from the second interview with line management; production foremen, production planner, maintenance engineer, development engineer, and operators. The third section describes the current data collection process used for building the existing KPIs.

4.2.1 Findings from the Interview with Production Managers

During the first interview with the production managers, the CSFs for the production organization were discussed by looking at the strategic objectives of the organization. The production managers were not familiar with the term critical success factor, instead, the normal procedure is to check the strategic objectives and align the activities according to them. In the case company, the strategic objectives are evaluated every year, and a 3-year plan is updated on the Nordic level. The strategic objectives for years 2023-2025 related to the production organization are presented in Table 4.

Table 4. Strategic objectives 2023-2025 for the production organization

No	Objective
1	Continue to strengthen our safety culture to reach target of 0 accidents
2	Make our management system part of our DNA
3	Improve competitiveness profitability by reducing cost and improved pricing
4	Improve Leadership and People Development
5	Reduce waste in our internal processes in order to increase efficiency (Master Order to Delivery)
6	Use digitalization and available data to create value
7	Secure competitive cost and decrease energy consumption
8	Define and deliver our Nordic Value proposition (Sustainability, Circularity and Services)

After the strategic objectives were recognized, the production managers were asked which KPIs they are using to evaluate the performance against the objectives. The current KPIs followed by the production managers are presented in Table 5.

Table 5. KPIs followed by the production managers

No	Indicator	Unit	Interval	Details	Data Source
1	Accident frequency Index	Accidents/MM hrs	Monthly	Lost time accidents per million working hours	SMS, WTRS
2	Safety Preventive Observation (OPS)	OPS/Month/Manager	Monthly	OPS per month per manager	SMS

3	Near Miss (NM)	NM/MM hrs	Monthly	Near misses per million working hours	SMS, WTRS
4	Hazard Notification (HN)	HN/MM hrs	Monthly	Hazards per million working hours	SMS, WTRS
5	5S	%	Monthly	5S Score from audits. Plant and area level	5S Audit Excel
6	Versatility index	%	Monthly	Level of how many different machines operators can operate	Operator register
7	Productivity	kg/mh	Monthly	Scorecard plant total, machine lines	MES 2, WTRS
8	Productivity	m/min	Monthly	Scorecard plant total, machine lines	MES 2, WTRS
9	Volume	tons	Monthly	Scorecard plant total, machine lines	MES 2
10	Average diameter	Average diameter	Monthly	Scorecard plant total, machine lines	MES 2
11	Weight/position	kg/pos	Monthly	Scorecard plant total, machine lines	MES 2
12	Bending amount	%	Monthly	Amount bended compared with total produced. Scorecard plant total	MES 2
13	Working hours	hours	Monthly	Scorecard plant total, machine lines	WTRS
14	Reference %	%	Daily	Reference time/working hours. Machine level	MES 1, WTRS
15	Overtime	hours	Monthly	Benchmarking	WTRS

16	Waste	%	Monthly	Amount of waste of raw material compared with total produced volume. Scorecard plant total	MES 2, ERP
17	Absenteeism	%	Monthly	Scorecard plant total	WTRS
18	Customer Claims	Pcs	Monthly	Scorecard plant total	Claims Excel
19	Delivery accuracy	%	Monthly	Scorecard plant total	MES 2, ERP
20	Other hours	%	Monthly	Scorecard plant total	WTRS
21	Personnel Satisfaction	eNPS	Yearly	Personnel Surveys 1-2 per year	Survey result
22	Management engagement	Engagement points	Yearly	Management engagement survey	Survey result

As can be seen in Table 5, the production managers follow many indicators. The indicators with a monthly interval are presented in the production organization scorecard that is communicated to the organization during the monthly meeting.

The reference % indicator is a relatively new indicator that has been in use in one of the cut & bend plants for a year. In the other cut & bend plant, the reference % indicator is currently being established.

The reference % indicator is comparing reference times calculated for each task with the total working hours. The reference times are calculated based on machine parameters given to the MES system which include loading times, weight of raw material of bundle/coil used, time for programming the machine, speed of the machine, time for cutting each bar, time per bending, waiting time between bars, bundling time, and time for transporting finished bundles with a crane.

When asked about the reference % indicator, the production managers stressed the importance as follows:

> *The reference % indicator is giving more value than the productivity kg/mh indicator since it is considering the mix of the production, thus helping us evaluate the performance in a better way.*
>
> *But the challenge with the reference % indicator is to get the correct machine parameters to the MES system, and getting the operators to log their time and production on the correct machine.*
>
> *Data 1: Interviewees, Production Managers*

When asked about how well the used KPIs are linked to the strategic objectives, the answer from the production managers was:

> *On a general level the used KPIs are linked with the strategic objectives in a good way. Measuring performance against management system, leadership and people development, digitalization and sustainability objectives is not easy.*
>
> *Data 1: Interviewees, Production Managers*

Continuing the question above and asking how well the used KPIs are answering the question of what needs to be improved and if they enable decision taking, the answer from the production managers was:

> *Used safety KPIs are good and enable decision taking. Indicators for productivity (kg/mh, m/min), waste %, delivery accuracy % and reference % does not give clear indication on what should be improved. We do not have the detailed information of which process metric is affecting the outcome negatively and what should be improved.*
>
> *Data 1: Interviewees, Production Managers*

During the interview, it was further highlighted how there is a lack of precise information regarding process metrics that impact the productivity, waste%,

delivery accuracy, and reference% indicators. According to the production managers:

> *If we would have information of machine downtime, loading/changeover times and bundling times it would be a game changer that would allow us to take the next step in daily management and improvement projects.*
>
> *Data 1: Interviewees, Production Managers*

The waste % indicator was seen as more difficult to gain more detailed information on, since this is highly affected by the shear line optimization done by the MES 1 system and the raw material available. The production volume is also highly affecting the waste % since, with a lower volume, the shear line optimizer has fewer available lengths to optimize to a shear line.

During the interview with the production managers, it was highlighted that the quality of the data used for building the productivity and reference % KPIs needs to be improved. The main challenge recognized as affecting the quality was the data input, which is affected by how well the operators are logging their time and how well production is logged on the correct machine. For total plant productivity, this is not an issue, but when looking at machine level or operator level, a better solution is needed.

4.2.2 Findings from the Interview with Line Management

The second interview was conducted via Teams meeting, where the production foremen, production planner, maintenance engineer, and development engineer attended. Feedback from the operators was gathered through informal discussions on the shop floor.

The attendees were first asked the question which KPI indicators they are following, the recognized KPIs are presented in Table 6 below.

Table 6. KPIs followed by the line management

No	Indicator	Unit	Interval	Details	Data Source
1	Accident frequency Index	Accidents/MM hrs	Monthly	Lost time accidents per million working hours	SMS, WTRS
2	Safety Preventive Observation (OPS)	OPS/Month/Manager	Monthly	OPS per month per manager	SMS
3	Near Miss (NM)	NM/MM hrs	Monthly	Near misses per million working hours	SMS, WTRS
4	Hazard Notification (HN)	HN/MM hrs	Monthly	Hazards per million working hours	SMS, WTRS
5	5S	%	Monthly	5S Score from audits. Plant and area level	5S Audit Excel
6	Versatility index	%	Monthly	Level of how many different machines operators can operate	Operator register
7	Productivity	kg/mh	Monthly	Scorecard plant total, machine lines	MES 2, WTRS
8	Productivity	kg/mh	Daily	Information from new MES system	MES 1, WTRS
9	Reference %	%	Daily	Reference time/working hours. Machine and operator level	MES 1, WTRS
10	Waste	%	Monthly	Amount of waste of raw material compared with total produced volume. Scorecard plant total	MES 2, ERP

11	Internal delivery accuracy	%	Monthly	Production ready compared with set targets per delivery zone.	MES 2, ERP
12	Pending production	kg or hours	Daily	Pending production kg or hours remaining per order and machine	MES 2

As can be seen in Table 6, when comparing it with Table 5, the amount of followed KPIs is smaller compared with the ones the production managers are following.

When asked which KPIs are truly followed by the attendees, the answer was:

> *Reference % indicator is the main one followed on a daily basis in one of the plants, where it is used during daily production meetings. In the other plant the machine parameters used for calculating the reference times are still under development. The other indicator that is followed is the pending production which is used for allocating resources to the correct machine. The other indicators are not really followed, they are more just communicated during monthly meetings with no follow-up after that.*
>
> *Data 1: Interviewees, Production foremen, Production planner*

Continuing the question about how well the truly followed KPIs are answering the question about what needs to be improved and if they enable decision taking, the answer was:

> *The reference % indicator is telling us more than the before normally used kg/mh, since it is considering the mix of the production. But it is hard to take decision on what we need to improve to get a better reference %. The pending production indicator is helpful in allocating resources to the correct machine, and estimating when orders will be finished to answer sales department.*
>
> *Data 1: Interviewees, Production foremen, Development Engineer*

During the interview, it was highlighted that there is no KPI related to maintenance. KPIs for machine downtime have been discussed, but the data for that is not available in the current systems. The maintenance engineer and production foremen stated during the interview:

> *We would like to have an indicator for preventive maintenance tasks to see if the planned tasks have been done or not. Unplanned machine downtime indicator would also help us in developing maintenance of the machines.*
>
> *Data 1: Interviewees, Production foremen, Maintenance Engineer*

The main challenge recognised during the interview was the quality of the data used for building the productivity and reference % KPIs. The attendees stated the following:

> *It is hard to get the operators to log their working time and production on the correct machine. Currently we are using two different MES systems to which the operators needs to log their production. Systems currently allows to log production on the wrong machine. We need to develop the systems towards automatic logging of production to improve the data quality.*
>
> *Data 1: Interviewees, Production foremen, Development Engineer*

> *Sometimes I forget to change my time to another machine if I change machine during the day. Sometimes I log my time by mistake on the wrong machine. The terminals for changing time registration between machines are always not near, so not always want to walk there to change time for a short period.*
>
> *I know I should not print a lot of tags at once and give feedback. But the operator UI is not so user friendly so sometimes easier to do it at once. Downloading / automatic feedback is better if it works correctly.*
>
> *Data 1: Interviewees, Operators*

4.3 Description and Analysis of the Current Data Collection Processes

The current data collection processes were mapped in a workshop where the production foremen, production planner, maintenance engineer, and development engineer attended. The process of data collection was drawn with the help of a flowchart that is presented below in Figure 3.

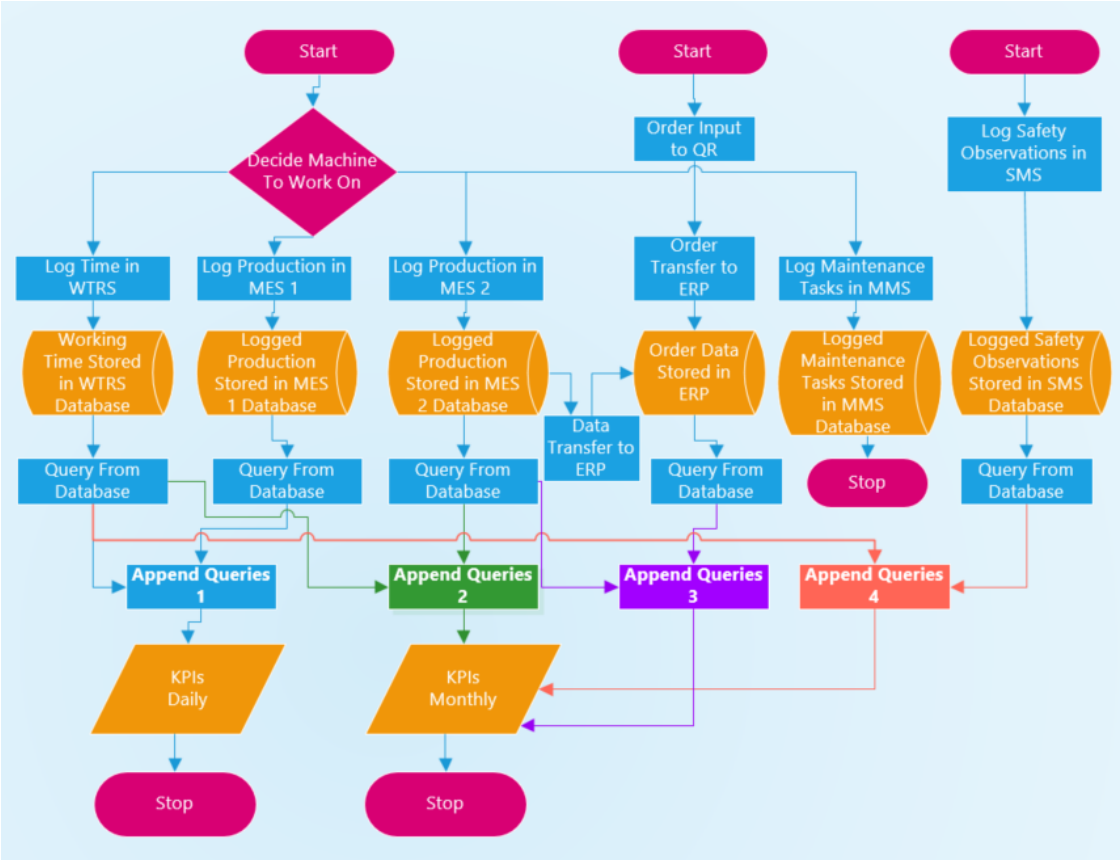

Figure 3. Data collection for KPIs

Data is collected from five different systems using five separate queries from databases with the help of MS Excel. The queries are appended with the help of four different append queries, as can be seen in Figure 3. The stakeholders who attended the workshop use mainly append queries 1 to get daily reference % and kg/mh KPIs. Append query 3 is used by the production planner to get the internal delivery accuracy KPI. Append queries 2 and 4 are used by the production managers to build the monthly KPIs shown in Table 5.

In production, operators log their working time in the working time registration system (WTRS) by choosing which machine they are working on; the decision on which machine to work on is made by the production planner or production foreman. Other hours, which include maintenance, cleaning, meetings, training, and TQM hours, are also logged in the WTRS system.

The production organization has at the time of writing two different manufacturing execution systems (MES) in use; MES 1 is a new one that is currently being implemented and is planned to replace MES 2 in the future. Further development is still needed, e.g., regarding traceability, before MES 2 can be completely replaced, but already MES 1 is the system used to control the production of most of the machines. The production data used to build the daily KPI indicators reference % and kg/mh is extracted from MES 1. Production data from MES 2 is still the source for building the monthly scorecard KPIs since not all machines are yet in the new MES 1 system.

As can be seen in Figure 3, operators log their production in both MES 1 and MES 2. MES 1 is, as explained earlier, the new system that is optimizing production and which the operators use to print tags and log finished production. The operators use the MES 1 system, with the operator user interface (OUI) running on tablets. When they start their work on a production machine, they choose which machine they are working on. In the next step, they print the desired tags and programme the production machine with the needed information to produce the bundles according to the printed tags. When a bundle is finished, the operator gives feedback via the MES 1 OUI by pressing ready for each task. On coil machines, one task is one bundle, while on machines that use bars as raw material, one task is one cutting task.

The operators can choose how many tags to print at a time; the first task gets a starting time when the tags have been printed. The finished time for the first task comes from when the operator gives feedback when the task is finished via the OUI. The starting time for the second task is the finished time for the first task, and the finished time comes from when the operator is giving ready

feedback. Normally, operators print many tags at a time and give feedback for all at once, which means the finished times for tasks are not correctly stored in the database. An example of production data extracted from the MES 1 database is shown in Figure 4 to better explain how the data is stored.

machine_task_nr	Starting Date	Starting time	Finished Date	Finished time	time_taken_h
1	7.3.2023	6.37.32	7.3.2023	6.40.44	0,026205625
1	7.3.2023	6.37.32	7.3.2023	6.40.44	0,027127709
2	7.3.2023	6.40.44	7.3.2023	6.40.47	0,000409463
2	7.3.2023	6.40.44	7.3.2023	6.40.47	0,00042387
3	7.3.2023	6.40.47	7.3.2023	6.40.50	0,000409463
3	7.3.2023	6.40.47	7.3.2023	6.40.50	0,00042387

Figure 4. Data of production with manual feedback extracted from MES 1 database

As can be seen in Figure 4, the time to produce each task is really short due to the earlier explained procedure of how the operators print tags and give feedback at once. If looking at the data per shift or day, this may not be an issue as long as the operator does not print more tags than he or she can finish during the shift.

At the moment of writing, one of the cut & bend plants has started to implement downloading features for tasks from the MES 1 system to the production machines. This also enables automatic feedback for finished tasks from the production machines to the MES 1 system.

During the interviews and workshop it was stated:

> *We have learned that implementing downloading and automatic feedback of tasks have resulted in tasks finished being logged at the correct times and on the correct machines, allowing us to get a more correct reference % indicator.*
>
> *Data 1: Interviewees, Production planner, Development Engineer*

Data extracted from MES 1 for a production machine using downloading and automatic feedback is shown in Figure 5 below.

machine_task_nr	Starting Date	Starting time	Finished Date	Finished time	time_taken_h
1	7.3.2023	17.15.29	7.3.2023	17.22.30	0,064513212
1	7.3.2023	17.15.29	7.3.2023	17.22.30	0,023121848
1	7.3.2023	17.15.29	7.3.2023	17.22.30	0,029309385
2	7.3.2023	17.22.30	7.3.2023	17.33.31	0,102143671
2	7.3.2023	17.22.30	7.3.2023	17.33.31	0,058780305
2	7.3.2023	17.22.30	7.3.2023	17.33.31	0,022687135
3	7.3.2023	17.33.31	7.3.2023	17.34.39	0,010507972
3	7.3.2023	17.33.31	7.3.2023	17.34.39	0,006046991
3	7.3.2023	17.33.31	7.3.2023	17.34.39	0,002333926

Figure 5. Data of production with automatic feedback extracted from MES 1 database

When comparing Figure 5 with Figure 4, it is easy to see that the finished time for each task is more accurate since the machine is giving feedback when each task is finished, not the operator.

The reference % indicator used on a shift or daily basis is calculated by comparing the time logged in the WTRS system with the reference time for the tasks produced during one shift or day. Each task in the MES 1 system has a reference time that is calculated based on the machine parameters given to the system, as explained earlier.

As can be seen in Figure 3, data on logged maintenance tasks is stored in the maintenance management system (MMS) database. This system is still under development at the time of writing, thus no KPI is built based on the collected data. As was mentioned in the findings from the second interview, the production foremen and maintenance engineer would benefit from an unplanned machine downtime indicator and an indicator for preventive maintenance to help develop the maintenance of the machines, which would again improve the reference % indicator and the productivity indicators.

The internal delivery accuracy % indicator is built based on data from the MES 2 and ERP system. The organization has targets for when production should be ready based on delivery zones to enable the logistic department to plan the deliveries in the best possible way.

During the workshop the production planner stated:

> *If we could get the data needed for building the internal delivery accuracy indicator directly from MES 1 system, it would save us a lot of time and we could follow this up on a daily basis instead of monthly as now.*
>
> *Data 1: Interviewees, Production planner*

4.4 Summary of the Identified Strengths & Weaknesses

The findings from the CSA, categorized into strengths and weaknesses, are presented in Table 7. The strengths are shown in green font, while the weaknesses are shown in red font. Additionally, the sources of the findings are listed in the source column. As can be seen in Table 7, a total of 16 findings were discovered. The findings are classified into five strengths and eleven weaknesses.

Table 7. Summary of Strengths and Weaknesses

No	Strength or Weakness	Source
1	Strategic objectives are recognized, and there are KPIs linked to some of them	Interviews, Current KPIs
2	Safety KPIs are on a good level allowing action taking	Interviews, Current KPIs
3	Reference % indicator is giving more value since taking into count the mix of the production	Interviews
4	Pending production indicator allows allocating resources to the correct machine and enables estimating when orders are finished	Interviews
5	Downloading of tasks to production machine and automatic feedback of finished tasks allows getting the finished time of tasks correct and production logged on the correct machine	Interviews, Data from MES 1
6	The CSFs are not worded, thus there are a lot of indicators that is not giving more value.	Interviews
7	Most of KPIs used are followed up on a monthly interval, thus cannot be counted as KPIs.	Interviews, Current KPIs
8	There is a lack of detailed process metrics showing what is affecting the used KPIs negatively and what should be improved.	Interviews, Current KPIs
9	Unreliable data due to human error in logging working time and production feedback when done manually by operator	Interviews, Current KPIs, CSA Workshop
10	No KPIs related to maintenance in use	Interviews, Current KPIs
11	No clear KPI indicator for Leadership and People development in use	Interviews, Current KPIs
12	No clear KPI indicator for Sustainability and Circularity strategic objectives	Interviews, Current KPIs
13	No clear KPI indicator for Management System strategic objective	Interviews, Current KPIs
14	Many different systems in use, data extraction is manual work and therefore timeconsuming and human error in data queries is possible	Interviews, CSA Workshop
15	Parameters for calculating reference times for tasks is not correctly in place on all machines	Interviews
16	Two different MES systems in use, the data used is not always the same which can lead to KPIs followed showing different values depending of source used	Interviews, CSA Workshop

When reviewing the findings summarized in Table 7, it is worth noting that the identified weaknesses are distributed throughout the process. What is seen as

rather alarming is that the CSFs are not worded, thus the starting point before developing any measure is not in place.

Based on the findings from the CSA, the following points was seen as the most critical needed to be developed, and was agreed to be scoped for further development in this study:

1. Critical success factors are not worded.

2. Most of the used indicators are followed up on a monthly basis, thus cannot be counted as a KPI.

3. Lack of process metrics showing what should be improved.

4. Quality of the data used for building the KPIs.

5. No indicators related to maintenance.

This concludes the CSA stage of this study. The following section presents the creation of the initial proposal.

5 Creation of the Initial Proposal

In the previous section the CSA was described. This section combines the findings from the CSA and the conceptual framework into creation of the initial proposal. This section provides an overview of the stage, a list of initial proposal of set of improved KPIs and description of the creation process.

5.1 Overview of the Proposal Creation

The initial proposal was co-created in a one-day workshop with internal stakeholders from different levels in the organization as presented in Table 2 in section 2 of this study. The participants in the workshop were selected from within the production organization from both cut & bend plants and technical department. The workshop started with an introduction of the business challenge, the objective and the outcome. The introduction was followed by reviewing the findings from the literature search and the CSA.

A key weakness identified during the CSA was that the CSFs were not worded which is the starting point before developing any measures. Therefore, the second part after the introduction in the workshop was to co-create the CSFs of the organization. After the CSFs were identified, the workshop moved over to the third part of selecting the winning KPIs linked to the CSFs. The selection of the KPIs was done for each identified CSF one by one, focusing on tackling the weaknesses scoped to be developed.

The participants in the workshop were active and provided their ideas as well as gave feedback and evaluated suggestions for KPIs that came from other participants in the workshop. The selected participants represented both production plants to get feedback from all the stakeholders being part of the process under improvement in this study. The workshop was arranged as a face-to-face event to minimize the risk of technical issues and to get a better engagement from all the participants.

The conceptual framework was used as a guideline when building the initial proposal of improved set of KPIs utilizing the field notes documented during the workshop. The proposal is focused on tackling the key weaknesses identified in the CSA to achieve the objective and the expected outcome of this study.

In the following subsections, the CSFs developed during the workshop are presented, followed by introducing the initial proposal of improved set of KPIs linked to them.

5.2 The Critical Success Factors of the Organization

The critical success factors were derived from the strategic objectives presented in Table 4 in section 4 of this study. The findings from the literature search were used as guidelines when defining the CSFs. The following CSFs were defined during the workshop:

1. Continue to strengthen our safety culture to reach a target of 0 accidents, maintaining a healthy and safe workplace (safety always comes first).

2. Delivery in full, on time, to all customers 98% of deliveries.

3. Promote cost effectiveness by maintaining correct machine and people capacity utilization.

4. We develop exceptional people and teams who have the ability to undertake all core activities in-house.

5. We understand our key customers' needs, gain their trust and develop new services to benefit them.

6. Be a learning organization through relentless reflection and continuous improvement.

7. Reduce waste in our internal processes in order to increase efficiency.

The above presented CSFs were defined in collaboration with key stakeholders participating in the workshop who all were experienced staff members. Defining the CSFs with the selected team in the workshop was quite straight forward, even if there had not been worded CSFs before.

5.3 Preliminary Proposal for Improved set of KPIs

After the CSFs were defined each one of them were discussed during the workshop with the focus on defining KPIs linked to them. The proposed set of improved KPIs for each CSF are presented in the following subsections.

5.3.1 Preliminary Proposal for Safety KPIs

During the CSA the participants stated that safety related indicators are on a good level, however since they are only followed at a monthly interval they cannot be counted as KPIs and thus improved KPIs related to safety are proposed. This subsection describes proposed set of improved KPIs linked with the following CSF:

1. *Continue to strengthen our safety culture to reach a target of 0 accidents, maintaining a healthy and safe workplace (safety always comes first).*

Proposal

Proposed set of improved KPIs related to safety are presented in Table 8 below.

Table 8. Proposed set of improved safety KPIs

No	Indicator	Unit	Interval	Category
1	Safety Preventive Observation (OPS)	OPS/Manager	Weekly	Leading
2	Hazard Notification (HN)	HN/MM hrs	Weekly	Lagging
3	Manual bending percentage	%	Weekly	Leading
4	Ratio of hazards to corrective actions	N/A	Weekly	Lagging
5	Average time to resolution of risks and issues	Days	Weekly	Lagging

The safety preventive observation and hazard notification indicators are proposed to be followed-up on a weekly interval instead of the current monthly interval. The safety preventive observation indicator is an important leading indicator and a weekly follow-up instead of monthly would assist the organization to boost the safety culture by focusing on the safety behavior of the employees.

Identifying any potential risk to the health and safety of employees or equipment in the workplace is a crucial part of the case company's safety strategy. Following-up hazard reporting on a weekly basis instead of monthly would help the organization to identify potential risks faster and have a better opportunity to prevent incidents or accidents to occur.

During the initial proposal-building workshop, the participants stated that accidents related to hand injuries are the most common in the case company, due to the high amount of manual work in the processes. By reducing the amount of manual bending, risks related to hand injuries could be reduced. The manual bending percentage indicator is proposed to support the organization in reducing the amount of products produced in manual bending, and thus lowering the risk of hand injuries.

The ratio of hazards to corrective actions indicator is proposed to give insight into the quality of the hazard reporting. If reported hazards do not result in any corrective actions, they may reoccur and turn into incidents or accidents. By tracking this indicator, the organization can make sure that corrective actions are taken based on the risks identified.

The average time to resolution of risks and issues indicator is proposed to follow-up how effectively the organization is resolving identified risks at the workplace. Measuring the average resolution time is important to make sure identified risks are corrected before they turn into more severe events.

All the safety related indicators are proposed to be followed-up with a weekly interval to highlight the importance and to allow the organization to react faster.

The manual bending percentage, ratio of hazards to corrective actions and average time to resolution indicators are proposed as new indicators.

5.3.2 Preliminary Proposal for Delivery Accuracy KPIs

Most of the products produced in the cut & bend plants are MTO with short delivery times. Forecasting the level of customer demand is a challenge, making it difficult to match resources with the level of orders. During the CSA it was stated that the internal delivery accuracy indicator is based on data from MES 2 and ERP systems, and that getting accurate data on the internal delivery accuracy on a daily or weekly level is too time consuming.

This subsection describes proposed set of improved KPIs linked with the following CSF:

2. *Delivery in full, on time, to all customers 98% of deliveries.*

Proposal

Proposed set of improved KPIs related to delivery accuracy are presented in Table 9 below.

Table 9. Proposed set of improved KPIs related to delivery accuracy

No	Indicator	Unit	Interval	Category
1	Internal delivery accuracy	%	Weekly	Lagging
2	Ref %	%	Shift, Daily, Weekly	Lagging
3	Production schedule attainment	%	Daily, Weekly	Leading
4	Estimated production schedule attainment, next 3 days	%	Daily	Leading
5	Machine downtime	hrs:min	Daily, Weekly	Leading
6	Preventive maintenance compliance (PMC)	%	Daily, Weekly	Leading
7	Maintenance work orders per status	pcs	Weekly	Lagging
8	Mean waiting time (MWT)	hrs:min	Weekly	Lagging
9	Mean time to restoration (MTTR)	hrs:min	Weekly	Lagging
10	Mean time between failure (MTBF)	hrs:min	Weekly	Lagging

As was stated in the CSA the internal delivery accuracy indicator is showing the level of production ready compared with set targets per delivery zone. Each delivery zone has a target when products need to be finished in order for the products to reach the customer on time. Data used to build the internal delivery accuracy indicator is proposed to be gathered from the new MES 1 system, which would allow the organization to follow-up the internal delivery accuracy on a weekly interval.

The ref % indicator is calculated by comparing time logged in the WTRS system with the reference time for the tasks produced as was stated in the CSA. During the CSA it was also stated that the quality of the data used to build the ref % indicator is of low quality. The main reason for the low data quality was stated to be human error when logging the working time. To improve the quality of working time registration, it is proposed to start registering working time via MES 1 system instead. The proposed solution would block printing of tags, downloading of tasks to production machines and giving feedback when tasks are finished if the user has not logged his time on the machine he is operating via MES 1. The proposed solution of using MES 1 for logging working time would prevent operators from logging their working time on the wrong machine; as a result the ref % indicator would be more accurate.

The ref % indicator is important to follow-up since it is showing if the organization is able to produce according to reference times. The production planning done by MES 1 system is using reference times when optimizing the production, and it is therefore crucial for the organization to produce according to reference times to be able to follow the schedule.

The production schedule attainment indicator is proposed to show how well the organization is producing orders compared with the schedule. Having a daily follow-up on this indicator, would provide information if the daily production plan is met or not. Low schedule attainment would indicate there is some form of waste in production that needs to be reacted upon. Data to build this KPI is proposed to be gathered from the new MES 1 system.

The estimated production schedule attainment, next 3 days indicator is proposed to show the estimated schedule attainment the following 3 days. It would allow the organization to react beforehand with prioritizing orders, with overtime and by allocating resources to the correct machines. . Data to build this KPI is proposed to be gathered from the new MES 1 system.

The machine downtime indicator is proposed to show amount of downtime on the machines. For the case company it is crucial to reduce the amount of downtime due to the short delivery times. Data regarding downtime is proposed to be gathered from MES 1 system. The proposed solution is based on the reference times, if a task is exceeding the reference time by a set amount of time the system would ask the operator the reason for this. Available options for categorizing downtimes is proposed to be machine breakdown, lack of material, unable to produce due to wrongly listed order, waiting for crane and waiting for logistics to empty finished bundles.

The preventive maintenance compliance (PMC) indicator is proposed to show how well the organization is executing the preventive maintenance schedule. To reduce the amount of downtime due to machine breakdowns, it is essential for the organization to make sure the preventive maintenance schedule is followed. Data to build this KPI is proposed to be gathered from the maintenance management system.

The maintenance work orders per status is proposed to keep track of all reported work orders, and to improve the planning of maintenance work. A large amount of outstanding work orders would indicate the need to hire more employees, no backlog on the other hand, could indicate it would be possible to reduce workforce. Data to build this KPI is proposed to be gathered from the maintenance management system.

Mean waiting time (MWT) indicator is proposed to show the average time that it takes for maintenance to react on requested work orders. Data to build this KPI is proposed to be gathered from the maintenance management system. The

MWT indicator would support in assessing the capacity of the maintenance organization, showing if there is room for preventive maintenance or if the staff is overloaded.

Mean time to restoration (MTTR) is proposed to show the average time it takes for maintenance organization to repair a machine. It is the average time from repair started to repair finished, showing possible inefficiencies in maintenance processes. Data to build this KPI is proposed to be gathered from the maintenance management system.

Mean time between failure (MTBF) indicator is proposed to show the average time until a machine fails since the last repair. Increasing the MTBF is essential to help the organization increase the productivity, and to optimize the preventive maintenance that both would support meeting the production schedule.

5.3.3 Preliminary Proposal for Cost Effectiveness KPIs

In the CSA it was stated that one of the strategic objectives was to improve competitiveness profitability by reducing cost and improved pricing. During the initial proposal workshop this objective was reworded to the below CSF to which this subsection describes a proposed set of improved KPIs:

3. *Promote cost effectiveness by maintaining correct machine and people capacity utilization*

Proposed indicators to follow-up the cost effectiveness are presented in Table 10 below. The chosen indicators are mainly the same as the indicators chosen related to delivery accuracy with additional two indicators, capacity utilization indicator and productivity indicator.

Table 10. Proposed set of improved KPIs related to cost effectiveness

No	Indicator	Unit	Interval	Category
1	Capacity Utilization	%	Weekly	Lagging
2	Productivity	Kg/mh	Weekly	Lagging

3	Ref %	%	Shift,Daily,Weekly	Lagging
4	Machine downtime	hrs:min	Daily, Weekly	Leading
5	Preventive Maintenance Compliance (PMC)	%	Daily, Weekly	Leading
6	Maintenance work orders per status	pcs	Weekly	Lagging
7	Mean waiting time (MWT)	hrs:min	Weekly	Lagging
8	Mean time to restoration (MTTR)	hrs:min	Weekly	Lagging
9	Mean time between failure (MTBF)	hrs:min	Weekly	Lagging

The capacity utilization indicator is proposed to follow-up the degree of the manufacturing capacity that is currently being utilized. The indicator is tracking how much of the manufacturing potential output is being met, taking into count machinery capacity and available resource utilization. This indicator is essential for the case company to follow-up to understand how efficient in terms of using its available resources the organization is, and pinpointing areas where the production is wasteful.

The productivity indicator is proposed to assess the efficiency of the case company's production processes, showing if the desired outcome is achieved or not. The case company is selling its products in tons, why a productivity indicator measuring the output in kilogram per man-hour is proposed.

The ref % indicator is important to follow-up since it is showing if the organization is able to produce according to reference times. Tracking this would allow the organization to recognize were time is lost in the production.

The machine downtime indicator is proposed to show were downtime is occurring, thus causing costly events. As was explained in the previous subsection, to reduce the amount of downtime due to machine breakdowns, it is essential for the organization to make sure the preventive maintenance schedule is followed. To show how well the preventive maintenance schedule is followed, the preventive maintenance compliance indicator is proposed.

The rest of the proposed indicators for tracking the cost effectiveness were explained in the previous subsection.

5.3.4 Preliminary Proposal for People Development KPIs

In the CSA it was stated that one of the strategic objectives was to improve leadership and people development. During the initial proposal workshop this objective was reworded to the below CSF to which this subsection describes a proposed set of improved KPIs:

4. *We develop exceptional people and teams who have the ability to undertake all core activities in-house.*

Proposed indicator for tracking people development is presented in Table 11 below.

Table 11. Proposed set of improved KPIs related to people development

No	Indicator	Unit	Interval	Category
1	Ref %	%	Shift,Daily,Weekly	Lagging

During the initial proposal workshop the ref % indicator was seen as the main indicator showing how well an operator is performing compared with the reference times. Tracking the ref % indicator on operator level would give valuable information of where additional training is needed. The versatility index indicator the organization is tracking, and which is showing the level of how many different machines operators can operate was not seen to give any more value if followed on a weekly or daily level.

5.3.5 Preliminary Proposal for Customer Satisfaction KPIs

This subsection describes proposed set of improved KPIs linked with the following CSF that was established during the initial proposal workshop:

5. *We understand our key customers' needs, gain their trust and develop new services to benefit them.*

Proposed indicators for following-up customer satisfaction are presented in Table 12 below.

Table 12. Proposed set of improved KPIs related to customers' needs

No	Indicator	Unit	Interval	Category
1	Internal delivery accuracy	%	Weekly	Lagging
2	Rejected products	Kg, mh	Daily, Weekly	Lagging
3	Production throughput	Kg/workday	Weekly	Lagging

During the initial proposal workshop the main customer needs recognized was on time deliveries, quality of delivered products and short delivery times.

The internal delivery accuracy indicator explained in subsection 5.3.2 is proposed to track on time deliveries.

The rejected products indicator is proposed to track the amount of rejected products in internal processes. Reducing the amount of rejected products in internal processes will reduce the amount of wrongly delivered products to customers. The proposed solution is to develop the possibility to reject products via MES 1 system, allowing operators to reject products they produce them self that is not according to requirements, as well as the possibility to reject products in the following process. Tracking the amount of rejected products will allow the organization to recognize which processes have quality deviations, and take corrective actions to improve the quality of produced products.

The production throughput indicator is proposed to track the amount of material the organization is able to produce during a set time period. Improving the throughput means increased output, which allows for shorter delivery times.

5.3.6 Preliminary Proposal for Continuous Improvement KPIs

This subsection describes proposed set of improved KPIs linked with the following CSF that was established during the initial proposal workshop:

6. *Be a learning organization through relentless reflection and continuous improvement.*

Proposed indicators for tracking continuous improvement are presented in table 13 below.

Table 13. Proposed set of improved KPIs related to continuous improvement

No	Indicator	Unit	Interval	Category
1	Amount of completed SCRA	pcs	Weekly	Leading
2	Amount of improvement suggestions	pcs	Weekly	Leading

During the initial proposal workshop, it was recognized that it is essential for the case company to empower the people to be involved in continuous improvement.

The amount of completed SCRA indicator is proposed to track the amount of SCRA the organization is closing. SCRA is intended to be used as a problem solving tool in the case company to systematically solve problems that occur. The SCRA tool includes a systematic root-cause analysis which helps the organization to learn from deviations, and take corrective actions to prevent the deviation to reoccur. The amount of completed SCRA is proposed to be tracked via the quality management system of the case company.

The amount of improvement suggestions indicator is proposed to track the amount of improvement suggestions reported. The amount of improvement suggestions is proposed to be tracked via the maintenance management system, since the operators are already familiar with using this system for reporting.

5.3.7 Preliminary Proposal for Waste KPIs

This subsection describes proposed set of improved KPIs linked with the following CSF that was established during the initial proposal workshop:

7. *Reduce waste in our internal processes in order to increase efficiency.*

Proposed indicators for tracking waste in internal processes are presented in Table 14 below.

Table 14. Proposed set of improved KPIs related to waste in internal processes

No	Indicator	Unit	Interval	Category
1	Ref %	%	Shift,Daily,Weekly	Lagging
2	Machine downtime	hrs:min	Daily, Weekly	Leading
3	Scrap %	%	Daily, Weekly	Lagging
4	Preventive Maintenance Compliance (PMC)	%	Daily, Weekly	Leading
5	Rejected products	Kg, mh	Daily, Weekly	Lagging
6	Mean waiting time (MWT)	hrs:min	Weekly	Lagging
7	Mean time to restoration (MTTR)	hrs:min	Weekly	Lagging
8	Mean time between failure (MTBF)	hrs:min	Weekly	Lagging

During the workshop the main causes of waste in the production was agreed to be machine downtime, waiting time, rejected products causing rework and scrap amount.

The ref % indicator is proposed to be tracked to show if the organization is able to produce according to set reference times. A low ref % is indicating some

waste is occurring in the processes. To get more detailed information of the waste occurring, the machine downtime indicator is proposed to show machine downtime including waste related to machine breakdowns and waiting time.

The scrap % indicator is proposed to be tracked to show the amount of scrap the organization is producing. A high amount of scrap is indicating the MES 1 system is optimizing poorly, and corrective actions are needed to improve the optimizer.

The preventive maintenance compliance indicator and maintenance indicators MWT, MTTR and MTBF proposed are seen as important indicators to track to reduce the amount of waste in maintenance processes and waste caused by machine breakdowns. These indicators is explained earlier in subsection 5.3.2.

The rejected products indicator is proposed to track the amount of rejected products in internal processes. Reducing the amount of rejected products in internal processes will reduce the amount of rework needed, thus reducing waste. The rejected products indicator is explained earlier in subsection 5.3.5.

5.4 Summary of the Preliminary KPI Proposals

The preliminary proposed KPIs introduced in the previous subsections were based on the key weaknesses identified in the CSA, with utilizing the existing knowledge from the literature. The proposed indicators were co-created during a workshop with key internal stakeholders from both cut & bend plants and technical department.

Based on the findings from the CSA, the following points were seen as the most critical needed to be addressed:

1. Critical success factors are not worded.

2. Most of the used indicators are followed up on a monthly basis, thus cannot be counted as a KPI.

3. Lack of process metrics showing what should be improved.

4. Quality of the data used for building the KPIs.

5. No indicators related to maintenance.

Co-creation of the initial proposal covering the identified key weaknesses identified in the CSA was performed successfully with active collaboration from the stakeholders.

The CSFs were worded and proposed KPIs are to be followed up on a daily or weekly basis. The proposal has a balance between lagging and leading indicators showing the outcome and highlighting the areas in the process where improvements are needed. The proposal includes KPIs related to maintenance that was one of the key weaknesses identified in the CSA.

The proposal also includes development to data collection processes resulting in needed improvement to the quality of the data used for building the KPIs. Main proposed improvement to data collection is to start registering working time via MES 1 system that would drastically improve the quality of logged working time, enabling a more accurate ref % indicator. Data used to build proposed KPIs is proposed to be gathered from MES 1, maintenance management system, safety management system and quality management system. Gathering data related to production KPIs from only MES 1 will enable the organization to have the KPIs updated automatically on chosen intervals.

For the case company it is crucial to reduce the amount of downtime due to the short delivery times. Proposed machine downtime indicator including machine breakdowns and waiting times, will be a game changer enabling the organization to recognize the waste in the production, and take needed actions.

A summary of the preliminary proposal of set of improved KPIs are presented in Table 15 below.

Table 15. Summary of the preliminary proposal of set of improved KPIs

No	Indicator	Unit	Interval	Category
1	Safety Preventive Observation (OPS)	OPS/Manager	Weekly	Leading
2	Hazard Notification (HN)	HN/MM hrs	Weekly	Lagging
3	Manual bending percentage	%	Weekly	Leading
4	Ratio of hazards to corrective actions	N/A	Weekly	Lagging
5	Average time to resolution of risks and issues	Days	Weekly	Lagging
6	Internal delivery accuracy	%	Weekly	Lagging
7	Ref %	%	Shift, Daily, Weekly	Lagging
8	Production schedule attainment	%	Daily, Weekly	Leading
9	Estimated production schedule attainment, next 3 days	%	Daily	Leading
10	Machine downtime	hrs:min	Daily, Weekly	Leading
11	Preventive maintenance compliance (PMC)	%	Daily, Weekly	Leading
12	Maintenance work orders per status	pcs	Weekly	Lagging
13	Mean waiting time (MWT)	hrs:min	Weekly	Lagging
14	Mean time to restoration (MTTR)	hrs:min	Weekly	Lagging
15	Mean time between failure (MTBF)	hrs:min	Weekly	Lagging
16	Capacity Utilization	%	Weekly	Lagging
17	Productivity	Kg/mh	Weekly	Lagging
18	Rejected products	Kg, mh	Daily, Weekly	Lagging
19	Production throughput	Kg/workday	Weekly	Lagging
20	Amount of completed SCRA	pcs	Weekly	Leading
21	Amount of improvement suggestions	pcs	Weekly	Leading
22	Scrap %	%	Daily, Weekly	Lagging

As can be seen from Table 15, the proposal includes a total of 22 KPIs that will fulfill the needs of all the stakeholders, and give insight to the areas that needs to be improved.

The following section of this study describes the validation of the co-created initial proposal.

6 Validation of the Proposal

In the previous section the co-created initial proposal was described. This section first describes the validation process in general, followed by presenting the feedback received from the stakeholders and adjustments made to the initial proposal. Finally the outcome of the study, the final proposal of improved set of KPIs is presented.

6.1 Overview of the Validation of the Proposal

The validation of the proposal was performed by presenting the proposal to the selected stakeholders of the case company and receiving their feedback. The feedback was required to evaluate if the proposed KPIs was relevant to the organization, and if they would solve the business challenge described in section 1 of this study.

The validation was executed in two different online Teams meetings, to get a better engagement from all the participants. In the first meeting production planner, production engineer, maintenance engineer and development engineer participated, representing both cut & bend plants. In the second meeting production managers and work foremen from both cut & bend plants took part. Both meetings followed the same structure starting with an introduction to the objective of the study, followed by a summary of the findings from the CSA and an overview of the conceptual framework. The initial proposal of improved set of KPIs was presented next by presenting proposed KPIs linked to each of the CSFs that was established at the beginning of the initial proposal workshop, one by one. After each CSF the proposed KPIs were discussed, assessed and given feedback on by the participants, generating Data 3 of this study. The initial proposal of improved set of KPIs was adjusted based on Data 3 to form the outcome of the study, the final proposal of improved set of KPIs.

6.2 Feedback Received on the Initial Proposal

The feedback provided on the initial proposal by the participants in the validation meetings was very positive in general. The introduction to the study and the work done so far received compliments. In addition, the initial proposal covering KPIs related to all of the CSFs was seen as a strong point:

> *The initial proposal including KPIs connected to all of the established CSFs is very important to the case company.*
>
> *Data 3: Participant, Production Manager*

Proposed safety KPIs was the first KPIs discussed in the validation process. The proposed hazard notification indicator proposed as a frequency rate indicator was seen difficult to track on a weekly level since data of working time hours for all personnel would be needed. It was seen enough to only track the amount of reported hazards, reducing the amount of systems to fetch data from, and thus saving costs.

> *The proposed hazard notification indicator is hard to present as an frequency rate indicator on a weekly level. This would need data on the working time hours from the WTRS system, since working hours for all personnel is included in this indicator. It would be enough to only track the amount of reported hazards, the target could be adjusted based on the amount of personnel. Tracking only the amount of hazards would save cost of building this KPI since only need to fetch data from the safety management system.*
>
> *Data 3: Participant, Production Manager*

The proposed manual bending percentage indicator was not seen to give any more value to follow on a weekly level. It was stated that it is enough to follow this indicator on a monthly level since it is the MES 1 system that is controlling the routing in the production. The routing is based on parameters in the MES 1 system, which can be changed but it was seen that a monthly level follow-up would be enough to track the effects of made changes.

> *The proposed manual bending percentage indicator would be enough to track on a monthly level. The effects made to the parameters in MES 1 controlling the routing is not seen on weekly level.*
>
> *Data 3: Participant, Production planner*

The proposed ratio of hazards to corrective actions indicator was not seen to show the quality of the hazard reporting culture, since corrective actions are not established for all reported hazards in the safety management system. For many of the reported hazards immediate actions are taken and reported in the system, but they are not opened as corrective actions that would allow data of the amount of corrective actions to be fetched from the system.

> *For many of the reported hazards immediate actions are taken but only reported in the safety management system as a text field. All actions would need to be opened as a corrective action in the action module of the safety management system for us to get the data on amount of opened corrective actions. This would only generate more work, since many hazards can be corrected with an immediate action in the field.*
>
> *Data 3: Participant, Production foremen*

The proposed average time to resolution of risks and issues was not seen as an indicator to track on a weekly level. It was seen enough to track this on a monthly level to indicate how effectively the organization is closing opened actions.

> *The proposed average time to resolution of risks and issues is enough to track on a monthly level to indicate how effectively we are closing opened actions.*
>
> *Data 3: Participant, Production managers*

After the proposed safety KPIs had been assessed, the proposed KPIs for tracking the delivery accuracy was discussed. The participants from both meetings agreed on the proposed indicators, and they were seen highly

relevant for the organization. Especially the proposed indicator for machine downtime was given compliments:

> *The proposed machine downtime indicator would be a game changer for the organization. The proposed solution of tracking this via MES 1 system based on the reference times is genius, and would not need any investments in automated downtime detection equipment. It would still be a mix of tracked times with operators reporting the reasons for exceeding the reference times, giving us important data on both the downtime and the reason behind it.*
>
> *Data 3: Participant, Production managers*

The proposed solution for improving the quality of the ref % indicator was also seen as a working solution that would greatly improve the quality of logged time in production:

> *The proposed solution to improve the quality of the working time registration would greatly improve the quality of the logged working time. At the moment the operators quite often log their working time on the wrong machine, by moving over to registering the working time via MES 1 system that would force the operators to log time on the machine they are working on would fix this issue.*
>
> *Data 3: Participant, Production foremen*

The proposed production schedule attainment and estimated production schedule attainment for the next 3 days KPIs were also seen as indicators that would support the organization to comply with the agreed delivery times:

> *Tracking the production schedule attainment and estimated production schedule attainment the following 3 days would give us data to support decision taking related to prioritizing orders and reacting with overtime where needed.*
>
> *Data 3: Participant, Production foremen, Production planner*

The proposed preventive maintenance compliance KPI was seen as a good indicator to track how well the preventive maintenance schedule is followed. At

the moment there is no indicator showing this, and since it is essential for the case company to have a working preventive maintenance to reduce downtime this indicator was seen to add value:

> *Tracking the compliance with the preventive maintenance schedule would give us data on how well we are following the preventive maintenance schedule. Due to the short delivery times it is essential for us to reduce downtime on the machines, tracking this indicator would help us improve the compliance with the preventive maintenance schedule, and thus support us in reducing downtime on the machines.*
>
> *Data 3: Participant, Production foremen, Maintenance engineer*

The proposed maintenance work orders per status, mean waiting time, mean time to restoration and mean time between failure KPIs was seen as potential KPIs to follow. There were stated a concern regarding the quality of the data used to build these KPIs:

> *We have just implemented a new maintenance management system, and I am not sure if we are able to get data of good quality from the system. At the moment we might use the system in the wrong way, causing low quality on the data needed.*
>
> *Data 3: Participant, Maintenance engineer*

The quality of the data in the maintenance management system was discussed, and it was agreed that starting to follow these KPIs would put focus on the users to use the system in the correct ways. Since the indicators was seen as good indicators assessing the capacity and efficiency of the maintenance organization, it was decided that adjustments to proposed KPIs were not needed.

After the proposed delivery accuracy KPIs had been assessed, the proposed KPIs related to cost effectiveness was discussed. The participants from both meetings agreed on the proposed indicators, and they were seen relevant for

the organization. The proposed capacity utilization indicator was seen as an important indicator showing how efficiently the organization is using its available resources:

> *The capacity utilization indicator would support us in understanding how efficient we are in using our available resources, and support us in improving our output by pinpointing areas of the production suffering from waste.*
>
> *Data 3: Participant, Production managers*

The proposed productivity KPI was seen as a good indicator showing if the desired output is achieved or not:

> *There are proposed a great number of new leading KPIs showing us what to improve. The proposed productivity KPI would show us if improving the leading KPIs is giving the desired outcome or not.*
>
> *Data 3: Participant, Production managers*

The rest of the proposed KPIs for tracking the cost effectiveness are the same indicators proposed to track the delivery accuracy. The participants of the validating process agreed that all the proposed KPIs are important to track to be able to improve cost effectiveness. Since they were already validated when assessing the KPIs related to delivery accuracy, no additional discussion where needed at this stage.

After the proposed KPIs related to cost effectiveness had been assessed, the proposed KPIs related to people development was discussed. The participants from both meetings agreed that the proposed ref % KPI was enough to track people development in production:

> *We do not have any development programs that could be followed to track people development. The ref % indicator on operator level could give us valuable information of where additional training is needed.*
>
> *Data 3: Participant, Production managers*

After the proposed KPIs related to people development had been assessed, the proposed KPIs related to customer satisfaction was discussed. The participants from both meetings agreed that the proposed indicators are relevant. The proposed internal delivery accuracy KPI was already validated when assessing KPIs related to delivery accuracy, therefore the focus at this stage was on the proposed rejected products and production throughput KPIs.

The rejected products KPI was seen as a great KPI to track that would show the amount of rejected products, and enable the organization to see which processes are suffering from quality deviations. The proposed solution of developing the possibility to report rejected products via MES 1 system was given compliments:

> *There have been discussions earlier that we would like to track the amount of rejected products, but we have not been able to find a digital solution. The proposed solution of developing the possibility to reject products directly in the MES 1 system is brilliant.*
>
> *Data 3: Participant, Development engineer, production foremen*

The production throughput indicator was seen as a good indicator to use to increase the output that would allow for shorter delivery times:

> *The throughput KPI would help us identifying and minimizing the weakest link in the production process. It would support us in improving the production flow, resulting in higher output and therefore more satisfied customers.*
>
> *Data 3: Participant, Production managers*

After the proposed KPIs related to customer satisfaction had been assessed, the proposed KPIs related to continuous improvement was discussed. The proposed amount of completed SCRA KPI was not seen as an indicator to be followed on a weekly level:

> *The amount of completed SCRA KPI would not give any value if tracked on a weekly level, it is enough if we follow this on a monthly level or during improvement projects where SCRA is used.*
>
> *Data 3: Participant, Production foremen, production planner*

The amount of improvement suggestions KPI was agreed to be a good indicator for tracking the amount of improvement suggestions reported:

> *We want our staff to take an active role in building the continuous improvement culture. By tracking the amount of reported improvement suggestions we believe we would get more suggestions and therefore more opportunities to learn.*
>
> *Data 3: Participant, Production foremen*

After the proposed KPIs related to continuous improvement had been assessed, the proposed KPIs related to waste was discussed. The participants from both meetings agreed that the proposed KPIs are highly relevant in tracking waste in the processes:

> *Getting information of the machine downtime including breakdowns and waiting times will give needed data to start improving our processes. This lack of data has been the main reason why earlier improvement efforts have failed.*
>
> *Data 3: Participant, Production managers*

During the validation meetings, the proposed KPIs were assessed with a critical mind-set. The received feedback was used to adjust the initial proposal; the adjustments made are presented in the following subsection.

6.3 Adjustments to the Initial Proposal

Based on the feedback from the validation, four initially proposed KPIs were removed and one KPI was adjusted. The hazard notification indicator was adjusted from showing hazard notification frequency rate to show amount of

hazards reported. The manual bending percentage, ratio of hazards to corrective actions, average time to resolution of risks and issues and amount of completed SCRA KPIs were removed from the proposal.

6.4 Final Proposal

As a result of the extensive collaboration of the stakeholders during the previous stages, the initial proposal presented in the validation meetings was already polished and feasible.

The final proposal, the improved set of KPIs are presented in Table 16 below. The initial proposal can be found in Table 14 found in section 5.4.

Table 16. Summary of the final proposal

No	Indicator	Unit	Interval	Category
1	Safety Preventive Observation (OPS)	OPS/Manager	Weekly	Leading
2	Hazard Notification (HN)	pcs	Weekly	Lagging
3	Internal delivery accuracy	%	Weekly	Lagging
4	Ref %	%	Shift, Daily, Weekly	Lagging
5	Production schedule attainment	%	Daily, Weekly	Leading
6	Estimated production schedule attainment, next 3 days	%	Daily	Leading
7	Machine downtime	hrs:min	Daily, Weekly	Leading
8	Preventive maintenance compliance (PMC)	%	Daily, Weekly	Leading
9	Maintenance work orders per status	pcs	Weekly	Lagging
10	Mean waiting time (MWT)	hrs:min	Weekly	Lagging
11	Mean time to restoration (MTTR)	hrs:min	Weekly	Lagging
12	Mean time between failure (MTBF)	hrs:min	Weekly	Lagging
13	Capacity Utilization	%	Weekly	Lagging
14	Productivity	Kg/mh	Weekly	Lagging
15	Rejected products	Kg, mh	Daily, Weekly	Lagging
16	Production throughput	Kg/workday	Weekly	Lagging
17	Amount of improvement suggestions	pcs	Weekly	Leading
18	Scrap %	%	Daily, Weekly	Lagging

The seventh and the final section of the study summarizes the work, recommends the next steps towards the implementation of the improved set of KPIs and provides a self-evaluation of the study.

The final section of this thesis provides the conclusions with an executive summary along with a self-evaluation of the thesis and some final words.

7 Conclusions

The final section of this study includes an executive summary, recommendations for next steps, a self-evaluation of the study and its results and finally some closing words.

7.1 Executive Summary

The objective of the study was to propose a set of improved KPIs for the cut & bend processes of the case company, and the outcome of the study is the proposed set of improved KPIs. The outcome of the study allows the case company to have a clear picture of the process performance and to link their daily activities at the workplace with the strategy, thus having the opportunity to become a high performing organization.

The research approach of the study was design research, utilizing qualitative methods. The study included four stages. The first stage was a literature review to gain deeper knowledge about understanding and analysing KPIs, providing a conceptual framework for the study. The second stage was a current state analysis providing the strengths and weaknesses of the current KPIs and data collection processes. In the third stage, the initial proposal of improved set of KPIs was co-created with key stakeholders. The fourth and last stage was a validation round of the initial proposal, gathering feedback from the key stakeholders and generating the outcome of the study, the final proposal of improved set of KPIs.

The current state analysis consisted of interviews and a workshop with key internal stakeholders. The findings were scoped down to the five most critical points needed to be developed. The first critical point identified was that the critical success factors were not worded, the second critical point was that most KPIs were followed on a monthly interval, thus not counted as a KPI. The third identified critical point was the lack of process metrics showing what should be improved, the fourth critical point was the low quality of the data used for

building the KPIs and the fifth critical point was that there were no indicators related to maintenance.

The initial proposal was co-created in a one-day workshop with internal stakeholders from different levels in the organization. The participants in the workshop were selected from within the production organization from both cut & bend plants and technical department. The workshop started with an introduction of the business challenge, the objective and the outcome. The introduction was followed by reviewing the findings from the literature search compiled to the conceptual framework, and the findings from the current state analysis. The conceptual framework was used as a guideline when building the initial proposal utilizing the field notes documented during the workshop. The initial proposal was focused on tackling the key weaknesses identified in the current state analysis to achieve the objective and the expected outcome of the study.

The initial proposal included a total of 22 KPIs identified to fulfil the needs of all the stakeholders. The proposal included a balance between lagging and leading indicators showing the outcome and highlighting the areas in the process where improvements are needed. The main new proposed indicator for tracking waste in the production processes was the machine downtime KPI including waste related to machine breakdowns and waiting times in the production. The proposal also included new KPIs for maintenance that was identified as a weakness in the current state analysis. Development to the data collection processes was also included, the main proposed development was to start registering the working time via MES 1 system that was seen to drastically improve the quality of logged working time, enabling a more accurate ref % KPI.

The validation of the initial proposal was performed by presenting the proposal to the selected stakeholders of the case company and receiving their feedback. The validation was executed in two different online Teams meetings, to get a better engagement from all the participants. In the first meeting the production planner, production engineer, maintenance engineer and development engineer

participated, representing both cut & bend plants. In the second meeting production managers and work foremen from both cut & bend plants took part.

Both meetings followed the same structure starting with an introduction to the objective of the study, followed by a summary of the findings from the current state analysis and an overview of the conceptual framework. The initial proposal of improved set of KPIs was presented next by presenting proposed KPIs linked to each of the critical success factors that was established at the beginning of the initial proposal workshop, one by one. The proposed KPIs were discussed, assessed and given feedback on by the participants, generating Data 3 of this study.

The feedback provided on the initial proposal was very positive in general. Four KPIs from the initial proposal was removed and one KPI was adjusted based on the validation feedback received to form the outcome of the study, the final proposal of improved set of KPIs.

The final proposal of improved set of KPIs includes a comprehensive set of KPIs with a balance between lagging and leading indicators, showing the outcome and highlighting the areas in the process where improvements are needed.

7.2 Recommendations for Next Steps

For the case company to be able to have a clear picture of the process performance and to link their daily activities at the workplace with the strategy, the final proposal of improved set of KPIs are recommended to be implemented. The first step in the implementation phase should be to communicate the critical success factors presented in section 5.2 of this study and the final proposal of improved set of KPIs found in section 6.4 of this study, within the organization.

In order for the organization to be able to implement the proposed KPIs with the quality needed, the following points needs to be solved:

- Develop a working time registration module in MES 1 system to improve the quality of the working time data used for building the ref % KPI. The proposed solution would block printing of tags, downloading of tasks to production machines and giving feedback when tasks are finished if the user has not logged his time on the machine he is operating via MES 1.

- Fine tune parameters in MES 1 used to calculate reference times to get accurate reference times used in building the ref % KPI.

- Implement downloading feature and auto feedback of tasks on all machines where it is technically possible. This will give accurate data on time taken for each task, enabling accurate calculation of the ref % indicator.

- Develop reporting possibility of machine downtime via MES 1 system. The proposed solution is based on the reference times, if time taken to produce a task is exceeding the reference time by a set amount of time, the system would ask the operator the reason for this. Available options for categorizing downtimes is proposed to be machine breakdown, lack of material, unable to produce due to wrongly listed order, waiting for crane and waiting for logistics to empty finished bundles.

- Develop possibility to reject products via MES 1 system. The proposed solution is to allow operators to reject products they produce them self that is not according to requirements, as well as the possibility to reject products in the following process.

- Develop database connection to maintenance management system, to be able to extract needed data to build proposed maintenance indicators and data regarding amount of reported improvement suggestions.

- Develop Scrap % tracking via MES 1 system, to be able to track the KPI on a weekly level.

- Develop internal delivery accuracy tracking via MES 1 system, to be able to track internal delivery accuracy on a weekly level.

- Develop calculation of production schedule attainment, estimated production schedule attainment the following 3 days and production throughput in MES 1 system.

- Decide on targets for all proposed KPIs.

- Develop a KPI dashboard that extracts data on wanted intervals from needed system and visualizes the data.

The points above are presented in prioritized ordering. Fine tuning parameters in MES 1 used to calculate reference times and deciding on targets for the KPIs are tasks for the case company. Rest of the needed actions are tasks for software developer from external party.

7.3 Self-Evaluation of the Study

The initial business challenge was that the case company was struggling with having a clear picture of the process performance since there was a lack of good KPIs showing what needs to be improved. The objective to propose a set of improved KPIs was set based on the business challenge. The outcome of this study, presented in Section 6, is a set of improved KPIs that has been validated by key stakeholders at the case company. Therefore, the objective of the study is achieved in full.

The proposed set of improved KPIs are designed to tackle the identified key weaknesses. One may question if all the weaknesses were identified or if the chosen key weaknesses to tackle were chosen correctly. Even though a large amount of key stakeholders from different levels of the organization participated

in the CSA, there is no guarantee that all the weaknesses were identified, or that the key weaknesses chosen to be tackled was the correct ones. However considering the fact that a large amount of the same weaknesses were identified and agreed upon by key stakeholders from various levels of the process, supports the statement that the objective of this study is achieved.

The author of this study is a member of the production organization working in the process under review. Personal knowledge and experience of the process under review was a major advantage since it was highly motivating to achieve the objective since it is affecting the authors working days. Personal knowhow of the process reduced the possibility for the stakeholders to leave something out of their feedback, and helped in identifying the weaknesses and proposing solutions to tackle them. All data input was gathered from the stakeholders while the author being one stakeholder among the others with no additional weight on the decisions.

During the literature part, it turned out to be a challenge to find literature directly related to the type of process and environment of the case company, which had an effect on building the conceptual framework. The literature did not give any straight answers on suitable KPIs for the case company, however valuable aspects to what should be taken into count when building KPIs was provided by the literature search.

7.3.1 Validity

Taylor (2013) defines validity as an adjective that is always related with claims such as the validity of conclusions drawn from study data. The fact that these statements are sound, justified, logical, and supported by evidence aids in determining the item's validity. (Taylor, 2013: 1, 2).

The term internal validity refers to researchers must use both logical justifications and empirical data to support their claims that the findings of their research are due to the anticipated correlations among the variables they have found. (Taylor, 2013: 11)

Shenton (2004) advocates triangulation as a means of increasing the credibility and reliability of a study. Triangulation is defined as the use of several methods for acquiring evidence, using a wide range of informants and sources, and using diverse informants and sources (Shenton, 2004: 63-66).

Triangulation was used to ensure credibility and internal validity in this study. In the CSA Data 1 was gathered by utilising a variety of approaches and sources. Data 1 was gathered through analysing current KPIs, organizing interviews and conducting a workshop with stakeholders from both cut & bend plants. Data 2 was compiled during the co-creation stage of the initial proposal by conducting a one day workshop with stakeholders from both cut & bend plants. Data 3 was gathered during the validation of the initial proposal by conducting two meetings where the initial proposal was validated.

The informants for Data 1, Data 2 and Data 3 were selected to represent all different levels in the production organization ranging from operator level to production manager from both cut & bend plants.

7.4 Closing Words

Development and implementation of KPIs have a profound impact on measuring and managing organizational performance. Through careful selection and alignment with strategic objectives, KPIs provide valuable insights, enable better decision making and drive continuous improvement. By regularly monitoring and evaluating KPIs, organizations can optimize their operations, enhance their competitive advantage and achieve their desired outcomes.

This thesis concentrated on proposing a set of improved KPIs for the cut & bend processes of the case company. The first steps in selecting the winning KPIs are now taken with this study; next step is to implement the proposed KPIs.

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Appendix 1 Summary of Field Notes from Interview with Production Managers

Question	Answer	Participants	Date	Platform
What are the strategic objective of your organization?	1. Continue to strengthen our safety culture to reach target of 0 accidents. 2. Make our management system part of our DNA 3. Competitiveness profitability by reducing cost and improved pricing. 4. Improve Leadership and People Development 5. Reduce waste in our internal processes in order to increase efficiency (Master Order to Delivery) 6. Use digitalization and available data to create value 7. Work as a Nordic Team to gain competitive advantage 8. Secure competitive cost and decrease energy consumption 9. Define and deliver our Nordic VP (Sustainability, Circularity and Services).	Production Managers Cut & Bend Plants	8.3.2023	Teams Interview
How are you today measuring your performance against the strategic objectives? List of KPI indicators used	1. Safety (Accident Frequency Index, OPS, Near Miss, Hazards) 2. 5S audit results, Versatility Index 3. Productivity Scorecard; kg/mh, m/min, tons, average diameter, weight/pos, bending amount %, working hours, overtime, waste %, absenteeism %, customer claims, delivery accuracy, other hours % 4. Versatility Index, Personnel Survey, Management Engagement Survey, No other indicator that is followed. 5. Reference % 6. - 7. - 8. Use of energy only on higher level, not really followed. 9. Waste % used in production. GHG emissions followed on a higher level since production processes does not generate any bigger amount of GHG emissions.	Production Managers Cut & Bend Plants	8.3.2023	Teams Interview
How well are the used KPI indicators linked to the strategy in your opinion?	On a general level used KPI are linked to the strategy. Measuring performance against management system, leadership and people development, digitalization and sustainability objectives not easy.	Production Managers Cut & Bend Plants	8.3.2023	Teams Interview
Does the used KPI give the answer what needs to be improved and enable decision taking in your opinion?	Used safety KPIs are good and enable decision taking. Indicators for productivity (kg/mh, m/min), waste %, delivery accuracy % and reference % does not give clear indication on what should be improved. We do not have the detailed information of which process metric is affecting the outcome negatively and what should be improved. The reference % indicator is giving more value than the productivity kg/mh indicator since it is considering the mix of the production, thus helping us evaluate the performance in a better way. But the challenge with the reference % indicator is to get the correct machine parameters to the MES system, and getting the operators to log their time and production on the correct machine.	Production Managers Cut & Bend Plants	8.3.2023	Teams Interview
What KPI do you think you are missing, if any in your opinion?	If we would have information of machine downtime, loading/changeover times and bundling times it would be a game changer that would allow us to take the next step in daily management and improvement projects. Waste % indicator difficult to get more information of what is affecting it, since this is highly affected by optimization done by MES system and available raw material. Production volume also affects this alot since lower volume gives less options for optimizing shear lines in a good way.	Production Managers Cut & Bend Plants	8.3.2023	Teams Interview
Free word	Quality of the data input used for building productivity and reference % indicators needs to be improved. The data quality is affected by how the operators logs their time in WTRS system, and if they logs finished production on the correct machine. Not an issue for total plant productivity, but we want to track this on machine/operator level.	Production Managers Cut & Bend Plants	8.3.2023	Teams Interview

Appendix 2 Summary of Field Notes from Interview with Line Management

Question	Answer	Respondent	Date	Platform
Which KPI indicators do you follow in your work?	Accident frequency Index, OPS, Near Miss, Hazard Notification, 5S, Versatility Index, Reference %, Productivity kg/mh monthly, kg/mh daily,Internal delivery accuracy %, Waste %, Pending production (kg remaining per order and machine per day)	Production Foremen, Production Planner, Maintenance Engineer, Development Engineer, Operators	15.3.2023	Teams Interview, Operators on Shop Floor
Which KPIs are you truly following of the mentioned ones?	Reference % indicator is the main one followed on a daily basis in one of the plants, where it is used during daily production meetings. In the other plant the machine parameters used for calculating the reference times are still under development. The other indicator that is followed is the pending production which is used for allocating resources to the correct machine. The other indicators are not really followed, they are more just communicated during monthly meetings with no follow-up after that.	Production Foremen, Production Planner	15.3.2023	Teams Interview
Does the truly followed KPIs give the answer what needs to be improved and enable decision taking in your opinion?	The reference % indicator is telling us more than the before normally used kg/mh, since it is considering the mix of the production. But it is hard to take decision on what we need to improve to get a better reference %. The pending production indicator is helpful in allocating resources to the correct machine, and estimating when orders will be finished to answer sales department.	Production foremen, Development Engineer	15.3.2023	Teams Interview
What are the main challenge of used KPIs and data collecting processes?	It is hard to get the operators to log their working time and production on the correct machine. Currently we are using two different MES systems to which the operators needs to log their production. Systems currently allows to log production on the wrong machine. We need to develop the systems towards automatic logging of production to improve the data quality.	Production forement, Development Engineer	15.3.2023	Teams Interview
Why is it hard to log the working time correctly?	Sometimes I forget to change my time to another machine if I change machine during the day. Sometimes I log my time by mistake on the wrong machine. The terminals for changing timeregistration between machines are always not near, so not always want to walk there to change time for a short period.	Operators	15.3.2023	Shop Floor discussion
Why is it hard to log the production correctly?	I know I should not print a lot of tags at once and give feedback. But the operator UI is not so userfriendly so sometimes easier to do it at once. Downloading / automatic feedback is better if it works correctly.	Operators	15.3.2023	Shop Floor discussion
Free word	We would like to have an indicator for preventive maintenance tasks to see if the planned tasks have been done or not. Unplanned machine downtime indicator would also help us in developing maintenance of the machines.	Production foremen, Maintenance Engineer	15.3.2023	Teams Interview

Appendix 3 Summary of Field Notes from CSA Workshop

Observations	Respondent	Date	Platform
There are a lot of different systems collecting data that can be affected by human error.	Development Engineer, Production foremen, Production planner.	16.3.2023	Teams Interview
Data extraction from databases is manual work and timeconsuming in excel. Human error in queries is possible	Development Engineer, Production foremen, Production planner.	16.3.2023	Teams Interview
Operators need to manually log their working time, and finished production in two different MES systems if not downloading / automatic feedback in use.	Development Engineer, Production foremen, Production planner.	16.3.2023	Teams Interview
Data source for monthly kg/mh and daily kg/mh is not the same.	Development Engineer, Production foremen, Production planner.	16.3.2023	Teams Interview
Data in WTRS and MES 1 and MES 2 is not named the same way. In WTRS operators full name is used while in MES systems only initials, machines are also named differently in WTRS and MES systems. There is a need of manual editing of queries from databases when new operators are starting at the company	Development Engineer	16.3.2023	Teams Interview
Parameters for calculating reference times for tasks is not correctly in place on all machines	Development Engineer, Production foremen, Production planner.	16.3.2023	Teams Interview
Data of maintenance tasks are stored in maintenance system database. But still not used for building KPIs. System is under development.	Production foremen, Maintenance Engineer	16.3.2023	Teams Interview