CHALMERS
UNIVERSITY OF TECHNOLOGY

Exploring the Potential Use of Key Performance Indicators

A Case Study in Operations with Outsourced Production

Master's thesis in Quality and Operations Management

ARNES PALALIJA

SAR APPEL JONSSON

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF SERVICE MANAGEMENT AND LOGISTICS

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2023
www.chalmers.se

Report No. E2023:038

Report No. E2023:038

Exploring the Potential Use of Key Performance Indicators

A Case Study in Operations with Outsourced Production

ARNES PALALIJA
SAR APPEL JONSSON

Department Of Technology Management and Economics
Division of Service Management and Logistics
Chalmers University of Technology
Gothenburg, Sweden 2023

Exploring the Potential Use of Key Performance Indicators
A Case Study in Operations with Outsourced Production
ARNES PALALIJA
SAR APPEL JONSSON

Supervisor and examiner: Bo Bergman,
Department Of Technology Management and Economics

Report No. E2023:038
Department Of Technology Management and Economics
Division of Service Management and Logistics
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

Cover: The KPI dashboard that was implemented in the case organisation with anonymised product names and numbers.

Gothenburg, Sweden 2023

Exploring the Potential Use of Key Performance Indicators
A Case Study in Operations with Outsourced Production
ARNES PALALIJA
SAR APPEL JONSSON
Department Of Technology Management and Economics
Chalmers University of Technology

Abstract

Although outsourcing has been providing many benefits to organisations since its inception, the issues with limited control and insight still remain. One resource that can be used to overcome these issues is by the help of metrics such as key performance indicators (KPIs), that allow a company to monitor the performance of its subcontractors. A company that has been experiencing obstacles with limited control and insight in its subcontractors' performance, is CPAC Systems AB. The company only uses a few metrics to evaluate the performance of their subcontractors and these metrics are only collected once a month. CPAC reached out the authors of this thesis, for help with developing and implementing new KPIs to mitigate the issues. Therefore, with the assistance of the case organisation, the thesis aims to answer the questions: firstly, how the operational needs of an organisation with outsourced production remain unsatisfied, and secondly, what KPIs are suitable to enable operational improvement aligned with these needs.

To answer the questions, the thesis combines a hybrid approach of qualitative and quantitative elements. The qualitative part entailed exploring literature on the subject of KPIs, visual management, and outsourcing to get acquainted with the subject. Then interviews were conducted with the case organisation to find the needs of the Operations function at CPAC, from which the KPIs should derive. As for the quantitative part of the thesis, a KPI dashboard was constructed that could act as a proof of concept for how a visual display of KPIs might be implemented.

The thesis found multiple needs present at the departments of the Operations function that could be linked to the outsourcing dilemma. Also, the thesis presents multiple KPIs that could be valuable to CPAC, and discusses whether these are suitable to implement. Furthermore, the process of creating the dashboard is explained and discussed in detail. Finally, the thesis ends with concluding remarks about recommending the case organisation to look into a database solution, and addressing the gap between what is learned in university versus the reality of industry.

Keywords: Key performance indicators, Critical success factors, Outsourcing, Visual management, KPI-visualisation.

Acknowledgements

First and foremost, we would like to thank the case organisation, CPAC Systems AB, for providing us with the opportunity to write our thesis within their organisation. The thesis has given us insight into a firm in a field of cutting edge technology and has been a great opportunity to learn new skills. We greatly appreciate all the kind employees, everyone from the janitor to the CEO, that have expressed an interest in the thesis since the first day we arrived, and taken their time in helping us whenever issues occurred. A particular thank you is directed towards the group of people that agreed to be interviewed. Their valuable input and insights were the foundational stones upon which the entire thesis rests. We would also like to express gratitude to our co-workers who included us in meetings with customers and suppliers, allowed us to operate wheel loaders and excavators, and engaged us in other activities that went beyond the scope of the thesis. While these activities were not directly related to the thesis, they provided us with valuable and educational experiences.

We would like to direct special thanks to some notable individuals that have been decisive for the outcome of this thesis. First, thank you to Daniel Andersson, our supervisor at CPAC Systems, for always being committed, helping us without hesitation and guiding our work throughout the entire process. Finally, we would like to express our deepest appreciation for our supervisor and examiner from Chalmers University of Technology, Bo Bergman. It has been an honor to be supervised by someone like Bo, who possesses a remarkable legacy within the quality domain. His extensive experience has elevated the thesis to higher levels than it would have reached otherwise.

Arnes Palalija, Gothenburg, May 2023

Sar Appel Jonsson, Gothenburg, May 2023

Contents

List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

DP	Delivery Precision
FPY	First Pass Yield
FTP	File Transfer Protocol
ICT	In-circuit testing
KPI	Key Performance Indicator
MDT	Mean Down Time
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
NFF	No Fault Found
OEE	Overall Equipment Effectiveness
PPM	Parts Per Million Defectives
QIR	Quality Inspection Reports
SFTT	Supplier First Time Through
SLT	Supplier Lead Time
VM	Visual Management

List of Figures

List of Tables

1

Introduction

For many decades, outsourcing has been a major sourcing method for companies all around the globe [11]. While giving rise to multiple benefits, many organisations now stand with a production structure in which they by definition have limited control and insight.

It has long since been concluded that quantitative metrics for performance can be a very useful resource for monitor and control of the organisation's performance but that it needs to be implemented with care and consideration [10]. When looking to implement quantitative metrics for performance it is therefore important to consider the behavioral consequences of such metrics [25].

Finding and implementing the optimal quantitative metric is, on the other hand, not always as straightforward as it might seem. Previous research has concluded that while key performance indicators (KPI) are commonly utilised at the corporate and site levels, KPIs can be noticeably absent when it comes to supporting the production network as a whole [32]. This type of quantitative metric spanning across multiple suppliers, customers, and the organisation itself, can therefore be crucial for achieving organisational alignment [22]. Since a KPI of the customer or supplier is not necessarily a KPI for the organisation, and vice versa, it is important to differentiate between different KPIs.

Due to limited research on the matter of KPIs for outsourced production, organisations looking to increase their control and insight into the production of their subcontractors find themselves in a position where they might be fumbling in the dark. This can make it difficult for organisations to incorporate KPIs that span the whole supply chain.

1.1 Purpose

The purpose of the thesis is to explore the implementation and use of performance indicators in organisations with outsourced production through a case study. The final product of the thesis is a suggestion of KPIs for a case organisation based on the organisations needs. As a proof of concept, the thesis integrates performance indicators into a visualisation tool that can be utilised in everyday operations, follow-

ups, and long-term planning.

1.2 Research questions

To achieve the purpose of the thesis, the following two questions are deemed necessary to answer. The first question aims to identify the underlying operational needs for improvements that justify the implementation of certain metrics. In this context, operational needs refer to the needs of the Operations function within an organization, which are preferably fulfilled to enable a high work performance, such as a need for performance metrics. The second question highlights the issue regarding what specific metrics should be used to enable improvement.

- *RQ 1:* What operational needs are not satisfied in an organisation with outsourced production?
- *RQ 2:* What Key Performance Indicators are suitable for facilitating operational improvement, considering the operational needs of an organization that utilizes outsourced production?

In addition to these questions and to further examine how to incorporate metrics in the daily work of the case organisation, the thesis also aims to evaluate how an organisation with outsourced production in practice can implement and use KPIs to monitor the performance of their operations.

1.3 Limitations

A constraint of the thesis is that it is limited to the case organisation and its Operations function, which includes Production, Purchasing, Logistics, and Quality. These departments are the most intertwined with the manufacturing and logistics of the products while other parts of the organisation mainly work with R&D or have supporting functions. The objective of proposing and developing new KPIs focused primarily on addressing the needs of the Operations function, without taking into account the optimal perspective from an R&D, supplier, or customer standpoint.

In the scientific literature studied in this thesis, there is a consensus regarding the term KPI. According to this consensus, KPIs should strictly be used for organization-wide metrics that encompass all departments and are critical for the overall success of the organization. However, in the industry, the term KPI is generally used to include metrics that the scientific community would classify as performance indicators or simply metrics. Due to this difference in interpretation, this thesis will use the term KPI to refer to metrics or performance indicators that are critical to the success of a department as well. Since the KPIs in the case organization were partially or entirely derived from the metrics of the suppliers or customers, there is a significant

overlap. However, in this thesis, the use of KPI specifically refers to the metrics used by the case organisation, while the metrics used by suppliers or customers will be referred to as metrics. By using the term KPI at the department level, the intention is to emphasize the importance of these metrics, even if they would otherwise be considered performance indicators according to the scientific consensus.

2

Theory

In the following section, a theoretical framework will be presented to the reader. The theory section will include a background on what academia has previously found on the topic of KPIs. KPIs will be examined through multiple perspectives such as how they should align with organisational strategy, how they should be implemented, and visualised. Theory will also be provided on the concept of outsourcing, and how it relates to performance metrics. Lastly, the theory section will exemplify some metrics from literature.

2.1 KPI background

Key performance indicators are a set of metrics that are meant to reflect the dimensions of organisational performance that are of most importance for the organisation [22]. KPIs display several characteristics that distinguish them from other performance metrics. First, they are non-financial metrics that could potentially be assigned the responsibility of a team. Second, KPIs should indicate what actions are required of the team or department to maintain or improve performance. KPIs allow for the storage of historical data in databases that can help in forecasting future trends that can further help the organisation to improve. Third, the measuring frequency should be either around the clock, daily, or weekly. Lastly, as KPIs are the most important metric of organisational performance, they should be closely related to the strategic goals, objectives, and improvement activities of the organisation [32].

Because key performance indicators are tied to the organisation's strategic goals and objectives, they are the most useful when developed with the organisation's needs in consideration [14]. There is not a specific set of KPIs that any organisation can simply adopt to their context, rather each metric needs to be carefully chosen and integrated into the organisational context. Likewise, the problem does not lie within finding KPIs as there are dozens to choose from [15], but standardised definitions of KPIs should be used as to not let the operational definition slide over time [6]. Therefore, standardised definitions of KPIs will be further examined in Section 2.4. Nevertheless, the recommendation is for an organisation to use about ten KPIs [22]. Having more metrics than necessary makes it difficult for the user of the metric to understand what information is critical [17], [18]. Meanwhile, having fewer KPIs

than necessary can impact the user's ability to take an informed decision, as they may be lacking critical information [17].

One step toward finding relevant key performance indicators is to identify the relevant critical success factors (CSF) at the organisation [22]. As the name suggests, CSFs are the primary activities of an organisation and determine their ability to be competitive in the market and satisfy their customers' needs. When the CSFs have been identified, suitable KPIs can be used to to satisfy, maintain, or improve upon the CSFs. Without mapping the CSFs, performance metrics have limited or even detrimental use as they may entice aimless efforts that do not help in maintaining or improving the performance of the organisation. Likewise, if there is no agreement with what the CSFs should be, stakeholders might prioritise differently regarding what they think are the true CSFs [17].

The use of KPIs is justified in multiple dimensions. Metrics in general are important because if you cannot measure a process, you can not manage, control, or improve it either [21]. KPIs specifically are indicators that provide the organisation with an opportunity to improve their operations continuously [17]. A KPI can help stakeholders monitor the performance of the process as the KPI serves as an indicator when the results deviate from the target which in turn instigates a search for the root cause of the deviation and following corrective actions [21]. Apart from deviations, a KPI can give an indication on where there are opportunities to run improvement efforts.

Once an improvement effort has been carried out, the KPI can also be used to evaluate the return on the investment in terms of performance increase in relation to the cost of the project. KPIs can be an important metric for the organisation to be able to benchmark themselves with competing organisations in their industry as well as their internal performance over time, between different plants, departments, or teams [13].

2.2 Strategy, Management & KPIs

For an organisation to reap the benefits of using KPIs in daily operations, the KPIs must be grounded and in line with the organisation's overall strategy [22]. By implementing and using KPIs in an organisation, the fundamental idea is to reduce uncertainty and align the organisation in its strive toward strategic goals [18]. The KPIs should be used throughout the organisation in both short and long-term strategic work, and the everyday monitoring to get an understanding of the standings of the organisation. Since strategic goals can sometimes seem abstract in terms of everyday operations, KPIs can serve as a valuable tool for raising awareness of these goals. They can be utilized to identify potential bottlenecks and problems in critical operations and highlight areas for improvement. By utilising good and aligned KPIs, an organisation can condense the vision, mission, and strategy into a few graspable, quantifiable metrics for which clear goals can be set and a plan for

fulfillment more easily can be incorporated in the everyday operations [22]. If the KPIs cause contradictions, there is a risk that they thwart the goals the organisation seeks to achieve through the implementation [22]. To achieve alignment and non-conflicting goal achievement, stakeholders of the organisation must be identified and taken into consideration.

For KPIs to be successfully incorporated, an organisation's management team must be approving the implementation [22]. Some of the organisation's stakeholders are likely to be part of the management of the organisation but might also be found outside of the management team. The importance of management involvement is further discussed in subsequent chapters.

KPIs can be utilized as a management tool to distribute responsibility from the management closer to the operations of the organization [18]. This can be achieved by allowing management to set overall targets and assigning a person or department in the organization that is responsible for ensuring that the organization reaches a specific level of performance. With its characteristics, KPIs provide the possibility for benchmarking and comparison to competitors, suppliers, and customers, as well as internal goals and development. Through the use of KPIs, organisations get more accessible data and an increased understanding of their performance [22]. This can make it easier to follow internal performance and development over time and compare current with previous performance. KPIs can efficiently be used to indicate what progress has been made in projects in terms of targets, goals, and objectives [17]. Due to these characteristics, KPIs can also be efficiently used as a tool for presenting and visualizing the current status, changes over time, and issues in the operations of an organization [22].

2.3 Outsourcing and KPIs

Outsourcing is when an organisation decides to move a process or business function located internally within the organisation to instead be the responsibility of an external party [24]. The processes or business functions that get outsourced can be strongly linked to the core value creation of the organisation, or they have less important supportive activities. Regardless, outsourcing may be used because the activity is too expensive to perform internally at the organisation, or it may allow for greater flexibility as the organisation can concentrate on its most important value-making processes. Another reason why an organisation may opt to outsource a process or a business function to an external party is to get access to specialised knowledge, which the organisation does not possess internally [12].

Because of the increased geographical distance and distribution of responsibility that outsourcing entails, control of the outsourced processes becomes more difficult. One way to counter this issue is for the organisation that has outsourced their process or business function to use performance metrics, to continuously monitor the performance of the subcontractor [24]. Some researchers mention different types

of performance metrics that can be used to monitor and evaluate outsourced operations. The performance metrics can be divided into strategic metrics, financial metrics, and quality metrics. Likewise, other dimensions of outsourcing performance include customer satisfaction, cost savings, and cycle times [9]. Alongside strategic, financial and quality metrics, sustainability and environmental performance reporting is becoming increasingly important [26]. Generally, the performance metrics should be quantifiable, objective, inexpensive to collect, and could be used as a benchmark for comparison with other organisations. However, there is the possibility to measure processes based on subjective information parallel to using objective information [23]. While objective metrics can be metrics such as number of errors or completions times, subjective metrics are perceptions about the strengths and shortcomings of the process. Alongside the objective information, the subjective metrics help gain a deeper understanding of the state and capabilities of the process.

The success of the outsourced operations is however only partially achieved by the use of performance metrics, and there are other factors involved as well. One of the most important factors is that the communication between the organisation and its outsourced production is efficient [9]. Naturally, performance metrics can be part of that communication, but the main point is that organisations need to frequently update each other on the state of production, issues, and future plans. Additionally, top management commitment is crucial if an organisation wants to be successful in using an outsourced operation [23]. Uncommitted top management may result in ambiguous milestones and deliverables, that usually results in the execution of the outsourced operations not reaching expectations.

2.4 Standardisation of KPIs

As has been stated above, the issue with KPIs is not to find them but rather to find those that are of relevance to the organisational context. A criterion that is used for distinguishing between good and bad KPIs, is if the KPI is standardised or not [14]. Standardisation of KPIs is important because there should be no ambiguity regarding what the KPI represents and how it should be measured. There is also no possible way of setting a baseline for improvements if the KPI is not standardised, because the measurements may have been taken under different circumstances. Nevertheless, there are industry standards that can be used as a source of inspiration to see what is commonly used in the type of industry where the organisation operates. The International Organisation for Standardization has created its standards regarding KPIs for manufacturing operations. The first standard called ISO 22400-1:2014 defines the characteristics of a KPI, the criteria for constructing KPIs, and describes how a KPI can be used [14]. The other part of the standard named ISO 22400-2:2014 is instead concerned with exemplifying different standard KPIs for manufacturing operations and how they can be calculated [15].

Table 2.1 appears in ISO 22400-1:2014 as a way to precisely define a KPI in a concise manner [14]. The name of the KPI and a unique ID should be given for quick iden-

tification of the metric. Consequently, a short description of what the KPI measures should be done, while the scope connects the KPI to a work unit, work center, product, or unit. The formula explains how the KPI should be calculated, while the unit of measure specifies if the KPI is measured in percentages, monetary units, SI units, or something else. Range denotes the lower and upper logical limits of the metric and the trend states if a higher or lower value of the metric is better. Regarding context information, timing states the frequency of measurement, and the audience should specify the user group such as operators, supervisors, or management. The production methodology explains if the production is set to discrete, batch, or continuous production, while the effect model diagram should specify the location of a schematic which depicts the interdependencies between the KPIs. Lastly, the row about notes is for any further information that could be useful.

Table 2.1: Table for creation of standardised KPIs from ISO 22400-1:2014 [14].

KPI description	
Content:	
Name	Name of the KPI.
ID	Unique ID for quick identifaction of KPI.
Description	Short description of what the KPI measures.
Scope	Connects KPI to a work unit.
Formula	How to calculate KPI.
Unit of measure	Specifies KPI unit
Range	Logical limits of the KPI.
Trend	Defines if higher or lower value of KPI is better or worse.
Context:	
Timing	Frequency of measurements.
Audience	To whom the KPI is concerned.
Production methodology	Discrete, Batch, or Continuous production.
Effect model diagram	Location of Effect Model Diagram.
Notes	

2.5 Conditions for establishing KPIs

There are both enabling factors and barriers that may help or harm the implementation of performance metrics in an organisation. In an example from a study of logistics performance metrics, the authors found that the most important internal enablers are upper management support and availability of resources at the department level [16]. Meanwhile, internal barriers were mostly concerned with the availability of information. For external logistics metrics, upper management support was again the most important enabler combined with trust between supply chain actors. The major external barrier would be the compatibility of IT systems between organisations, and the resources available to maintain the metrics. Accuracy of information was perceived to be an external enabler as frequently as an

external barrier toward logistic performance metrics.

Fundamental requirements for implementing performance metrics of a process are process stability and the use of multiple measurements [23]. Having stable processes is a necessity if one is to implement performance metrics. Otherwise, a process that cannot consistently produce products of equal quality will result in equally chaotic measurements because the metrics are essentially not being measured under the same circumstances. Implementing multiple measurements is another requirement, as a single measurement is unlikely to provide a holistic perspective of the process. If the single measurement is wrong or faulty, there is also no other way to assess the process.

Establishing KPIs can itself be seen from a process perspective. Even though someone might spend significant time developing standardized definitions of KPIs, collecting data, and prioritising the most important KPIs, they still might not succeed in finding the right metrics for the organisation. To reach a full set of effective KPIs they must also be tested in practice, and adjusted after the resulting behavior and performance have been observed [8]. Moreover, viewing the established metrics from a process perspective implies that a KPI is an indicator of the amount of progress toward an objective, not a performance target. They might indicate how adjacent one is to meet the target, but the KPI is not the target by definition [17]. Thus, it is important not to be blinded by the KPI itself, but rather see it as a tool to achieve a target in the process of continuous improvement.

2.6 Visual Management

The problem of organisations communicating over long distances has mostly been resolved through the development of information technology. Meanwhile, the issue of achieving effective internal communication is still persistent. The methods that organisations choose to deploy are often not increasing operational performance. One example would be work manuals that contain how an operator should conduct their work. But, the workshop manual is typically heavy on text and has complex descriptions, while also often not being in close reach of the operator [30]. To overcome the issue, many organisations use visual management (VM) practices. VM is a method, often associated with Lean and Toyota Production Systems when it comes to modern production systems, where directions and guidelines for employees are set by visual cues and allow for better understanding of processes and performance [7]. Therefore, all tools used in VM can commonly be described as providing instant information to the user at the moment they need it, and the user should be able to assess the information from a glance at the tool. Additional characteristics of VM tools are that the user can gain the needed information themselves without having to ask someone and that the information provided is nonverbal and contains none or only a small amount of text [30].

However, the reasons for using VM practices do not stop at simplifying information

flows. By providing the information at the exact geographical point where it is needed, there is less handling and transfer of the information from one person to another, which itself is non-value-adding work [7]. Consequently, if the information is provided directly to the employees that will need to act on it, the employees will be empowered and get the chance to take ownership of their processes and participate in the decision-making process. In turn, the decision-making process is more effective by decisions being made where the process and the knowledge is located. Also, by using the VM tools, transparency is emphasized, and communication at the workplace is more open, which acts as a countermeasure against poor practices being concealed. At the same time, the VM tool should be able to entice an intended behavior in the employees, which supports them in making a habit of following the correct procedures. For example, by linking the visual management tool to a continuous improvement program, opportunities for continuous improvements and a continuous improvement culture will likely be established. Lastly, visual management tools help in promoting management by facts and taking decisions on metrics rather than on emotions and can support continuous improvement initiatives by setting the baseline from which the initiatives can set out.

2.7 KPI Visualisation

After KPIs have been developed for the organisation, the information that they convey needs to be communicated effectively. One approach is to visualise the performance metrics in a dashboard. Among the benefits of using dashboards is the possibility to track trends in the metrics and correct them if needed, measure the efficiency or inefficiency of the operations, and make informed decisions, and gain total visibility of the operation's processes [17]. However, producing an effective dashboard is far from a simple task. Before starting the thought process about what kind of charts should be used, the designer must gain an understanding of the end-user needs and how they would like to use the dashboard to determine what information should be displayed [17], [8]. Then the designer has to handle how information will be managed, such as how the measurements will be collected, how frequently they will be collected, and how often the dashboard should be updated. Regardless, the consensus seems to be that all of the information should be able to fit on a single screen and the user should be able to acquire and process all necessary information from a glance at the dashboard for it to be effective [8], [17], [31].

Furthermore, there are some design principles that the designer should adhere to. The dashboard should not contain more performance metrics than is necessary, and the metrics in turn are preferably ones that are easy to keep in the short-term memory [17]. Likewise, the designer must not use an excessive amount of colors to not distract the user from the information that is meant to be conveyed. The placement of the information on the dashboard is of importance as well. Users tend to start viewing information from the top left, and then shifting their focus to the top right, bottom left, and bottom right subsequently [8], [31]. Thus, the

most important KPI should be displayed at the top left, while the least important is placed in the lower right corner of the dashboard.

It can be difficult to create a dashboard that is of equal relevance to all potential users. Important to note is however that the dashboard can be unsuitable for certain users, and the dashboard should consequently not be mandatory for these stakeholders to use [17]. For example, it is unlikely for management to be as interested in the same metrics as the personnel on the workshop floor [31]. To counter the issue, tabs in the dashboard can be used to display user-specific information that allows someone with a given role to easily access information that is not necessary to display for all.

2.8 Metrics from literature

As was mentioned in the first section of this chapter, there is an abundance of KPIs and the aim of the thesis is not to describe every single one of these. Rather, this section aims to provide an overview of what is said in the literature regarding specific metrics that could be useful for CPAC to consider.

2.8.1 ISO 22400-2:2014 metrics

First, in the ISO 22400-2:2014 standard, First Pass Yield (FPY) is described as a metric that relates the number of products that full fill the quality demands to the total amount of produced products. The first pass aspect of the name comes from the requirement that the metric must only consider the first run of the process without any reworks [15]. In practice, this means that a product cannot fail any stage of the test and still be considered as part of the good quantity after it has been reworked and passed the test. A high value of the FPY is preferred. Partially, this is due to a high FPY means that less time is spent on non-value-adding work such as reworking products because they are not meeting quality standards. A high FPY and fewer reworks also ensure that more products are ready to be shipped to customers, which affects the Delivery Precision (DP) of the operations. Another metric mentioned in the ISO 22400-2:2014 standard is that of the Mean Time Between Failures (MTBF). MTBF is a metric that, as the name suggests, measures the average time between a machine failing once again after it has been repaired because of a previous failure [15]. The MTBF is ideally as high as possible because this means that the up-time of the machinery is maximized.

Scrap ratio and Mean Time To Repair (MTTR) are metrics that provide additional perspectives on manufacturing performance, as compared to the metrics in the paragraph above. The Scrap ratio measures the number of products that need to be scrapped in relation to the total amount of produced products. Meanwhile, MTTR measures the average time it takes to fix manufacturing equipment after a breakdown [15]. Monitoring and evaluating the scrap ratio can help the organisation

achieve effectiveness in its production while minimising MTTR helps in maintaining efficiency in production.

Inventory turnover is a logistics metric that is described in the ISO 22400-2:2014 standard. Inventory turnover is meant to describe how efficient an organisation is with its inventory, and how many times the inventory has been replenished or turned over a period of time. The reason for measuring the inventory turnover is that if the stock is not frequently replenished, the quality of goods might become worse if they are left on the shelves for longer periods [15]. Additionally, inventory is always associated with an opportunity cost. The money that is tied up in inventory is money that could have been spent elsewhere, and therefore you do not want to keep inventory for a longer time than is necessary [27].

2.8.2 Lean Six Sigma and related metrics

Six Sigma is an improvement methodology used in industry to solve issues in production, reduce variation in product quality, and lower production costs. Emphasis is placed on using statistical methods and metrics to determine the root cause of the issues and variation in product quality [2], [3].

An important tool within Six Sigma is the control chart. Control charts are used to study variation over time, where measurements on the produced products are taken at regular time intervals [2]. The process mean, standard deviation, control limits or specification limits, and amount of non-conforming units can then be deduced from the control chart. Therefore, the control chart can act as an alarm bell if the production process starts to drift and produces non-conforming products. The control chart's primary purpose is however to help the organisation's continuous improvement efforts, as the result of implemented improvements should become visible in the control charts. The control chart should in the best case become proof for both producer and customer that the process is stable and that it can be trusted. An illustration of a control chart is given below, that shows a set of measurements, and the resulting mean and control limits of the process. If a measurement slips outside of the control limits, or the measurement form a specific pattern, it is likely due to a cause of unnatural variation.

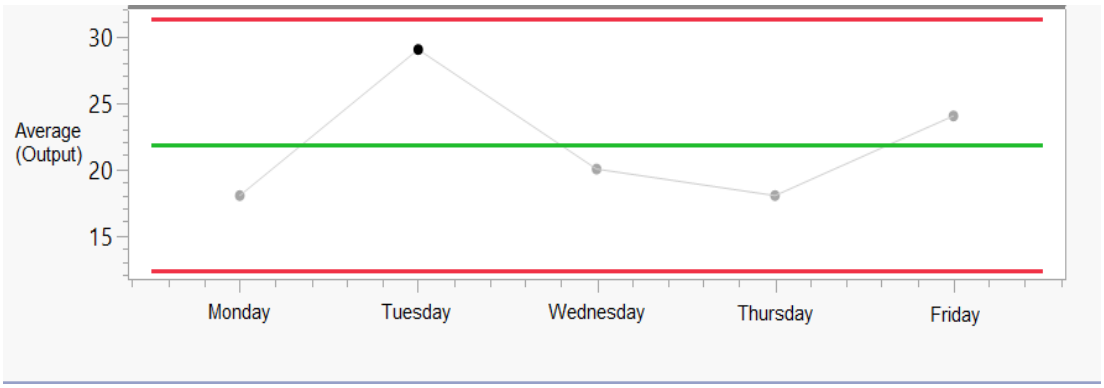


Figure 2.1: Illustration of a control chart with dummy data.

Additional metrics used in Lean Six Sigma that could prove useful for an organisation that is trying to evaluate the performance of its outsourced production are process capability metrics. Process capability metrics are widely used in Lean Six Sigma as a tool for evaluating how well a process can consistently produce products within a set of tolerance limits [2]. The capability of the process will often be approximately normally distributed as the units that fall between the set of tolerance limits are considered to be cases of natural variation, as every process will never achieve the same result every time. To measure how well our process can produce products that only exhibit cases of natural variation, the metric C_p is used. A large value of C_p is to be understood as that the process will produce many products within the specification limits, given that the process is well centered around the target specification. Otherwise, if C_p is small, plenty of products fall outside of the tolerance requirements. However, C_p as a metric can only explain the dispersion of the process, and not if the process is centered.

To counter the issue with C_p only being able to give information about the dispersion of the process and not its centering, another process capability metric is used. C_{pk} is a metric that can handle both the dispersion and the centering of the process at the same time [2]. However, C_{pk} does take into account if the mean value of the process differs from the target value, and thus the metric assumes that the process is stable and the mean is not shifting over time. To instead study the variation of longer time intervals, P_{pk} is used.

One additional Six Sigma metric is that of Mean Down Time (MDT). This metric is for measuring the average time the manufacturing equipment is out of commission [28]. MDT may appear to be simple to measure. However, particular consideration is needed when deciding what is defined as the start of the downtime, again highlighting the importance of operational definitions [6]. For example, if the manufacturing equipment breaks down when the machine is idle, should the downtime start at the time of break down or when an alarm is signaled. There is no right answer to the posed question, but the organisation needs to decide a standard for how MDT should be measured in all instances. Otherwise, if there is no standard, the metric can not be used for improvements or comparison with MDT of other manufacturing equipment.

2.8.3 Overall Equipment Effectiveness

Other than measuring process capabilities, Overall Equipment Effectiveness (OEE) is a metric for measuring the overall performance of the manufacturing equipment. The metric considers three different aspects of equipment efficiency [29]. The first aspect is availability, which measures the time that the manufacturing equipment is available for production. The second aspect is related to performance, and it measures how effective the machine is in its throughput. And, the last aspect is related to quality. This last measurement is based on how many of the produced products have to be scrapped or reworked in relation to the total amount produced, i.e., yield. Each of these three measurements are measured as percentages, and by

multiplying the percentages the OEE can be calculated. The OEE helps in setting a baseline for improvements, to identify production losses, and finding opportunities for improving product quality [15].

A low value of OEE can give several indications of issues with the manufacturing equipment [5]. Frequent breakdowns and long set-up times for the machines will affect the availability aspect of the OEE. Excessive reworks will impact the quality measurement as a large amount of the tested products do not, at least initially, conform to the quality standards. Low values of OEE may also indicate issues such as over-capacity, poor production planning, and standards that are inaccurate.

3

Methods

In this study, a hybrid of a qualitative and quantitative research strategy was used. Qualitative research can be explained as being concerned with meaning rather than numbers. Specifically, the research strategy emphasises exploring the different viewpoints of individuals and the outcomes of interactions between individuals. Meanwhile, quantitative research is more concerned with the collection and study of quantifiable data [1]. The first step towards realizing the qualitative part of the research strategy was by exploring literature on the subject, to get acquainted with what academia had already explored about KPIs and outsourcing. Afterward, a case study was conducted through interviews with internal participants to understand the needs of the case organisation, the metrics they use, and the organisation in general. As part of the quantitative element of the research strategy, production data were collected to create a dashboard pilot that could act as proof of concept showing how CPAC can implement the KPIs to monitor the performance of their operations. The details of the steps are further described in the following subchapters.

3.1 Theoretical framework

Exploring literature on the subject was the first step to realising the purpose of the thesis, and getting familiar with the subject of KPIs. Sources used were found through databases such as Chalmers Library, Google Scholar, and Scopus, and keywords used were key performance indicators, critical success factors, outsourcing manufacturing, visual management, and KPI visualisation. The literature for the theoretical framework was reviewed by the principles of conducting a narrative review. A narrative review entails that the researcher uses the literature to gain an initial understanding of the research topic [1]. This type of review is useful when the research approach is inductive, such as in this thesis, as the new theory is the outcome of the research rather than the testing of the previous theory by using deductive methods. Likewise, the narrative review also allows the researcher to be less specific about the criteria for inclusion or exclusion of literature than in a systematic review, which in turn allows for the researcher to gradually revise their frame of reference.

The literature that was eventually chosen for the research was a mixture of scientific papers and textbooks. However, more textbooks were used than scientific articles

as many scientific articles on the subject were often about KPIs in special cases, while the textbooks were more applicable to general situations. Each potentially interesting source of information was first logged in a file with a brief description of the source, and graded on how relevant it might be for the thesis on a scale of one to five. The grading was based on how well the source was perceived to aid in answering the research questions and the sources with the best perceived grade were used for the thesis.

3.2 Case study

The purpose of the thesis will be addressed through a single case study. A case study design involves an extensive examination of a single organisation, person, location or event and the researcher is concerned with highlighting the specific features of the case [1]. The case study was carried out in cooperation with CPAC Systems AB (hereinafter referred to as CPAC). CPAC reached out to the authors of this thesis with a request to investigate the current literature on the subject of KPI usage in organisations with outsourced production and the practicalities of implementation in the organisation. The organisation is used as a case study to investigate the needs of an organisation with outsourced production in terms of performance indicators and implementation of KPIs. With outsourced production comes challenges with insight into the production and overall information sharing. This forces organisations to put their trust in the manufacturers' abilities as they not have full control of their production. Another difficulty is that the manufacturers measure the data in different ways, which makes comparison between the manufacturers inappropriate. The degree of complexity is prone to increase with geographical distance as visits to the production site become more challenging.

Organisations that operate in the automotive industry also have regulatory requirements for data handling and need to be able to monitor and control their production and find fixes to issues relatively fast to guarantee the safety of their products. With respect to these issues, CPAC is a suitable case for studying the potential use of key performance indicators.

3.2.1 Case study structure

The thesis follows a mildly unconventional structure as it incorporates the mindset of the DMAIC methodology [5]. The thesis is based on a conventional case study but has an additional chapter, Chapter 6: *Implementation of KPIs*, that incorporates parts of the theory, results and discussion of the case study in an implementation project in the case organisation. The purpose of including this additional chapter was to highlight the implementation work of the thesis, which would not have fit well within conventional chapters and therefore risked going undocumented. In likeness to the Define phase in the DMAIC methodology, the natural step after examin-

ing literature in the field was to thoroughly evaluate the needs in the organisation through a case study. The additional chapter of the thesis reflected the latter stages of DMAIC, with incorporation of the metrics in the organisation through a KPI dashboard in likeness to the Measure, Analysis, Improve and Control phases. With the help of the implemented KPI dashboard, the ambition is for the organisation to keep the situation under closer control.

3.2.2 About CPAC Systems

CPAC is an electronics developer and manufacturer for the automotive industry. The hardware production is outsourced to multiple factories in several countries. The suppliers have several KPIs that are measured locally on the production site and handled within the factories but only the yield is summarised and shared with CPAC once per month. The performance of CPAC is in turn assessed by the customers through multiple KPIs. Instead of yield, the customers measure Supplier First Time Through (SFTT), Quality Inspection Reports (QIR) Parts Per Million defects (PPM), Delivery Precision (DP), and Supplier Lead Time (SLT). CPAC experience that these KPIs are not completely representative of its performance and that they in some cases even are inappropriate for measuring the production quality of an electronics supplier. Because of these factors, CPAC has encountered challenges in assessing its performance and has identified the need for improved insight into its production, as well as additional complementary information beyond the KPIs of customers and suppliers. To satisfy these needs, CPAC sought to investigate what KPIs would be suitable to develop and implement to measure and track the performance of the organisation's operations in both the daily work and the long-term strategic work.

Furthermore, CPAC has not had any easily accessible tool for visualisation of performance which in turn greatly diminishes the usefulness of KPIs. Therefore, for the new KPIs to be useful they need to utilise a visually pleasing and intuitive presentation that can be used in everyday work. The thesis has therefore created a KPI dashboard that can act as a proof of concept for how the KPIs might be implemented. The dashboard was created using Python, and the details of the steps taken to create the dashboard are explained in Chapter 6.

To gain an understanding of the organisational structure of CPAC, and specifically the locations of the departments in the operations functions, the following illustration of a simplified organisational chart of CPAC is provided in *Figure 3.1*.

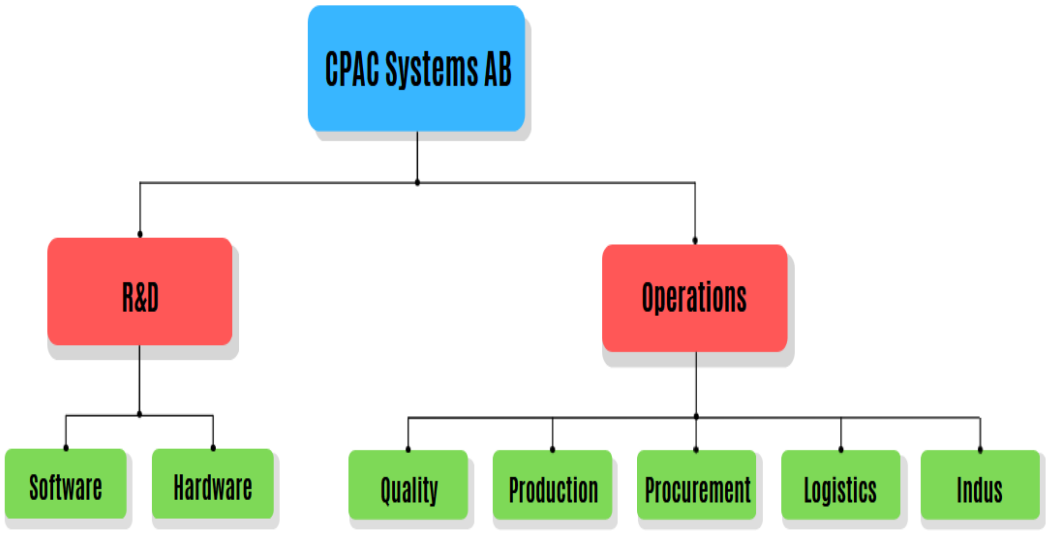


Figure 3.1: Simplified version of CPAC's organisation

3.3 Choice of interviewees

To find relevant interviewees for the thesis, a snowball sampling approach was used. Snowball sampling entails establishing contact with a first group of individuals that are of interest to the study, and which can, in turn, refer to other potential participants. This type of sampling is useful when relationships and connections are of interest to the researcher [1]. KPIs are not metrics that can be captured in isolation but should rather give a holistic view of the performance of the organisation [22]. Accordingly, the use of snowball sampling is appropriate when exploring what KPIs are useful for an organisation.

The participants were chosen based on several criteria. The first criteria for the internal participants were a requirement that they worked for one of the departments in the Operations function at CPAC. Secondly, a mixture of employees at both managerial positions and non-managerial positions was selected from the departments. The intention behind the criteria was that all departments in the Operations function would be represented, and cover viewpoints from different levels of the organisational hierarchy. By covering all different departments, most of the CSFs were expected to be uncovered, that in turn could be matched to suitable KPIs. Top management was also of particular interest, to get an understanding of how they view the Operations function and to learn more about CPAC's strategy and goals. In total, 11 interview subjects were found and used as candidates for the interviews. The respondents, their role, and the date for the interviews are specified in *Table 3.1*.

Table 3.1: Information about each interview occasion.

Respondent	Role	Date
1	Quality Assurance Engineer 1	2/2-2023
2	Quality Assurance Engineer 2	16/2-2023
3	Industrialisation, Quality, and Production Manager	9/2-2023
4	Supplier Quality Assurance	22/2-2023
5	Production Engineer	9/2-2023
6	Supply Chain Specialist	9/2-2023
7	Supply Chain Manager	3/3-2023
8	Strategic Buyer 1	13/2-2023
9	Strategic Buyer 2	24/2-2023
10	Top Management Representative 1	27/2-2023
11	Top Management Representative 2	3/3-2023

3.4 Interviews

Qualitative interviews have been used to explore the need for KPIs internally at CPAC. Qualitative interviews are useful when wanting to understand the lived experiences and different perspectives of individuals [19]. Developing KPIs includes a joint effort between management, employees, suppliers, and other key stakeholders [22]. Therefore, using qualitative interviewing is justified as individuals in these different positions likely have different perceptions of what KPIs should be measured, the CSFs of the organisation, and how the KPIs should relate to the overall organisational strategy.

Specifically, semi-structured interviews were used. Semi-structured interviews allow the interview to be based around certain key themes, rather than needing to ask predefined questions in a predefined sequence [1]. This type of interview thus allows for greater flexibility for both the interviewer and interviewee in pursuing interesting concepts that may be brought up during the interview. The length of the interviews was set to 45 minutes, while the location was held at CPAC or online using Microsoft Teams depending on the participant's preference.

Several sources were used as inspiration to construct the interview guides [1], [4], [20]. Two interview guides were constructed, one for the co-workers at the departments in the Operations function and one for the management team. The interview guides can be found in the appendices under *A* and *B* respectively. Different types of questions were used to stimulate diverse types of responses. Examples of these types are "feeling questions" to reveal the interviewee's feelings about performance measurement in general and "experience and behaviour questions" to reveal how they act during a typical situation, such as during a regular day at work [20] [1]. The intent of using different types of questions was not only to establish facts about what metrics the interviewees use and their responsibilities but also to capture their

feelings so that a holistic view of their needs could be established. Furthermore, a pilot interview was also run with a member of the quality department in accordance with [4]. This was done to ensure that the questions covered relevant areas of the subject and that the general flow of the interview was satisfying.

3.5 Analysis of interviews

After the interviews were conducted, the collected material was summarised and analysed in several steps. First, the interviews were transcribed using Microsoft Word's automatic transcription tool, where software can translate speech from an audio file into text. However, due to the tool sometimes lacking precision in its transcriptions, there was some manual labour involved in correcting the errors. Second, the material from the transcriptions was summarised into a one-pager for each of the interviewees. The one-pagers aimed to specify each of the interviewee's current problems or needs, the metrics that they use, the metrics they would like to use, and how they would like their metrics visualised. By using the same format for all of the one-pagers, the answers from the interviews could be compared. An example of a one-pager for the Quality Assurance Engineer #1 is given in Appendix C.

In the third step, a similar one-pager format was used once again, which can be seen in Appendix D. This time, the format was instead used to summarise the results at the department level. In practice, this meant combining the one-pagers from interviewees belonging to the same department. Then in the fourth and last step of the analysis, the one-pagers on the department level were compared to find common needs transcending the departments. The comparison was done through placing similar information from different departments into the same row in a grid-system. Each row would then represent a common need, which the departments shared. The result of this grid-system is presented in this thesis as *Figure 4.1*. The ambition was that by finding common themes regarding needs, metrics, and visualisation input, the resulting KPIs would be related to the CSFs and strategy of the organisation.

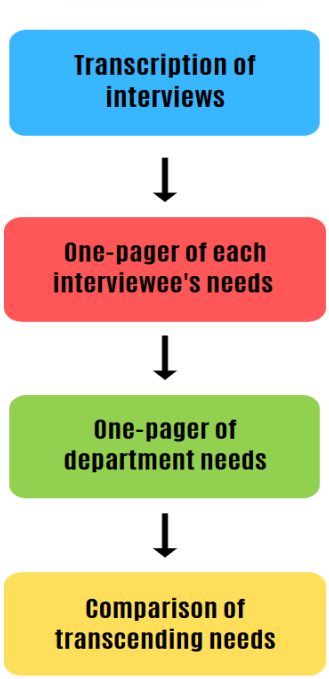


Figure 3.2: The process of analysing the interview material.

3.6 Reliability and validity of the study

The mixture of both qualitative and quantitative research designs demands great care taken into ensuring the reliability and validity of the study. Reliability for this research design can be difficult to establish, as it is unlikely that another researcher would experience the same conditions for their study at a different point in time because of the changing nature of social settings [1]. However, the case organisation used for this thesis is meant to be viewed as inspiration for how to implement KPIs at an organisation with outsourced production, given the contemporary data. The resulting KPIs and implementation could therefore be different if used in another organisation, or if the case organisation were to redo the study at a later point in time.

The validity of the research design provided some challenges that needed to be handled. The most important aspect when creating the dashboard pilot was to present accurate data. A dashboard is of no use if it is visually pleasing but not providing the user with information that they need to act on. To counter the issue, the values of the KPIs were continuously compared to manual calculations directly from the source of the data. The manual calculations were done by both the writers of the thesis, and by engineers that regularly do manual collections on the KPIs that were implemented into the dashboard. The difference between current manual calculations and new automated calculation was up to 0.5 percentage points. This was due to the manual calculations sometimes being inconsistent while the automated calculation did not have these inconsistencies.

3.7 Ethical considerations

Four types of ethical considerations are usually examined when conducting research and the thesis has thus considered harm to participants, lack of informed consent, invasion of privacy, and whether deception has been involved [1]. Harm to participants does not only concern physical harm as it can also be emotional harm afflicting participants or something that may hurt their social status at home or the workplace. Information about KPIs can be considered sensitive depending on the details of the information provided, and if it were made public it could hurt the participant or the organisation itself. Therefore, special care was taken into making the participants' names and profiles anonymized, so that others could not trace the information back to them. The interview questions that were used were also designed to specifically ask questions about their role at the company, what needs and issues they face, and about metrics in general, to not get into any personal details.

Furthermore, the issue of informed consent is about making sure that participants get as much information as possible for them to be able to make an informed decision about whether they want to participate in the study [1]. To counter the issue, emails were sent to the participants detailing the purpose and aim of the study. The intent was that by clearly stating the aim and purpose of the thesis in writing, the risk of the participant misinterpreting the reason for the study would be minimised.

The two final issues of intrusion of privacy and deception were also dealt with. The intrusion of privacy was easily avoidable by constructing interview questions as mentioned above and assuring that they were strictly about the subject, their duties at work, and their needs at the workplace. There was always a risk that the questions posed may lead the participant in answering with confidential information if they were asked during the interview session. Therefore, it was deemed better to provide the participants with the interview guide before the interview, so that they would not feel deceived in any way.

4

Results

The following chapter presents the results of the thesis and is divided into three sections. The first section treats the needs that have been identified in the evaluated departments in the case organisation. The second section shows a visualisation of the expressed needs in relation to the respective department and identified categories. The third and final section treats the metrics of the case organisation, both the currently utilised metrics and the proposed metrics obtained through the interviews.

4.1 Department needs

There is an abundance of metrics to choose from, but this does not imply that every metric is right for every organisation or every department. Therefore, a key aspect of the interviews was to examine the needs present at each of the departments in the Operations function at CPAC. These needs have been interpreted as the CSFs of the departments, and thus the most important factors that will help them succeed with maintaining and improving the operations of CPAC. The CSFs are accordingly the foundation stones that guided the work with finding the right KPIs for CPAC. The following subsections will highlight common themes that were found among the departments' needs. To find a summary of the needs for the different departments, refer to Figure 4.1 at the end of this section.

4.1.1 Spread awareness internally

One of the shared needs that all departments in the Operations function experienced was that they wanted to spread awareness internally about their own challenges and their contribution to CPAC's business. As the organisation is divided into R&D and Operations functions respectively, there was a feeling from the Operations function that R&D could be made more aware of the challenges that there are in producing, quality assuring, and moving the products that the R&D departments are developing. The R&D departments are mainly working in projects, and once the development in one project is done they move on developing other features in another project. The departments in the Operations function would like to make the R&D function more aware of the fact that the features they are developing will

eventually go into production and become a physical product. The ambition of the Operations function is that R&D will get the opportunity to contribute more with their expertise when production or logistics problems arise, if they can be made more aware of the challenges and switch their perspective from a project focus to a process focus.

However, spreading awareness from the Operations function to R&D is only partially the need that was expressed. In some cases it could be spreading awareness about challenges from one department to the rest of the organisation. From the quality department specifically came the need that quality challenges has to become a priority for the entire organisation, and not only the sole responsibility of the quality department. The departments could gain a better understanding of all of the steps in the process of developing and producing CPAC's products. By becoming more process oriented, it is believed that CPAC can deliver products of higher quality. The quality department emphasised that high quality products will be crucial to maintain the good reputation among its customers. It is not enough to focus on being fast and innovative which has become a signature characteristic of CPAC. Rather, there has to be an internal understanding for the whole process, all the way from R&D to the delivery and after market assistance in order to reach the expected level of quality, and thereby move the focus to a holistic view of the organisation's deliveries. One way of increasing this understanding can be to visualise it. As Industrialisation, Quality, and Production Manager puts it:

> *A big screen with some sort of visualisation of the current production performance that everyone can see could be a good way of raising the awareness. It makes people think in the terms of why this or that might be. For example: "Why are there no products produced today?", "Why do we have such low yield?", "What can I do to help?", or "Will this affect my plans?"*

4.1.2 Work proactively

In addition to spreading awareness internally about organisational challenges, the departments in the Operations function explicitly requested a need to work proactively.

The production department related their need of working proactively to an example where they had output data easily accessible from the factories. If they could see a downward going trend where the output does not meet the required volumes, they could instigate corrective actions, rather than wait until deliveries are missed due to not meeting production goals.

Both the logistics and procurement departments would like to work proactively, even though it is difficult for them due to the situation with component shortages and the global economy at the time of writing. The current situation has resulted in significant market fluctuations and uncertainties, which makes long term planning

difficult. For both departments, most of the work tasks have involved solving different issues that arise during each week, and thus limited time has been able to be put into planning more than two weeks ahead.

In the quality department there was a clear need to work proactively as it is seen as closely related to quality and is mentioned by all interviewees. As an example of the need to work proactively Quality Assurance Engineer 1 described their objective in the following manner:

> *When problems occur we try to solve them as fast as possible. But only dealing with problems when they occur at the customer is not efficient. By working proactively and removing problems before they occur we can both reduce costs and increase customer satisfaction. My professional goal is to be needed as little as possible for urgent problem solving.*

4.1.3 Communication and transparency

A need for increased communication and transparency was also established from the interviews with the Operations function. In the interviews with the quality and production departments, this was expressed as wanting a strong information exchange with the factories. This need became apparent when the departments mentioned what new metrics they thought could prove useful. A metric that was specified was output and it clearly shows a desire from the quality and production departments to become even more involved in helping the factories sort production issues. Having output as an available metric would help the departments in their communication with the factories if they saw that the produced quantity had suddenly halted during the day. Becoming more involved would not only help the factories in potentially solving the issues faster, but also make sure that CPAC has an impact on quality work that might prevent customer claims later on.

The logistics and procurement departments expressed the need of increased communication and transparency, but it was conveyed differently than for the quality and production departments. For example, a co-worker from the logistics department mentioned that they would like a greater information exchange between logistics and procurement internally at CPAC. Procurement is responsible for acquiring some of the components that the factories use in their production. Therefore, if these components are not available, the logistics department would like to know as they might be more prepared if production of a certain product has to be stopped.

Logistics and management shared a need in wanting to become better at measuring supplier performance in general. They both expressed that CPAC is good at measuring performance towards the customers and work with the metrics that the customers are using to evaluate CPAC, but not good enough at evaluating the factories performance towards CPAC.

4.1.4 Intuitive and easy-to-access information

Something that was widely requested from the departments in the Operations function was more intuitive and easy access to information and metrics than what is currently available. The current systems are difficult to extract information from, which in turn has led some co-workers to instead rely on information being provided through emails and meetings. This has resulted in some co-workers feeling that their source of information can be inconsistent, as e.g., information about quality issues can sometimes be relayed by logistics and other times through another channel such as a group email at the quality department.

Furthermore, there was an expressed need that was brought up during the interviews with the logistics department, which stated that they would like to make better use of a single system, like the current ERP system, to access information. Right now, there is mixture of the information being partially located in the ERP system, while some information is provided by co-workers doing their own data gathering and presentation. This results in there being more workflows than is perceived necessary by the logistics department, and that there is a opportunity to streamline the way that information is provided.

Regarding easy-to-access information, the management team stated that it would help them to make better use of data-driven decision making. There have been times when members of the management team has needed data to make a decision, but has not had the time to wait for someone to gather the data and summarize it into a report. Rather, they needed the summary at the precise moment when the decision had to be made. Having a tool with the information readily available and less reliant on someone doing the manual labour to summarize the needed data would thus help the management team immensily in their decision making processes.

4.1.5 Automated data gathering

Continuing on the topic of less manual labour to gather and summarize data, all departments would like this process to become more automated. By not having to gather and visualise the data themselves, the co-workers at all of the departments would get more time to sit with the data and analyse trends and deviations themselves, which was a request from the management team. As CPAC is known for its ability to provide innovative solutions at a rapid pace to its customers, there was a consensus among the interviewees that the same standard should be achieved for its internal processes. Therefore, automated data gathering should be a priority in order for CPAC to achieve excellence in business intelligence as well.

4.1.6 Fair metrics

The last need that was expressed during the interviews was that if there were to be metrics at the departments, the metrics need to be fair and there must be agree-

ment on how they will be measured among all the involved parties. There was dissatisfaction among the departments regarding how some of the current metrics such as PPM and Delivery Precision are measured. Getting a poor score on Delivery Precision because a transport, which CPAC is not responsible for, is late makes proper performance evaluation difficult according to interviewees at the logistics department.

It was also important for the interviewees that a metric that is measured in both factories, such as yield, is measured in the same way across both factories. A Quality Assurance Engineer said:

> *All parties need to be in agreement of what the implemented metric is supposed to measure. Different interpretations of a metric can cause unjust comparisons. For example, if one factory counts the yield for First Time Through as passing the test without needing rework, it will achieve 100% yield as long as the product passes, no matter how many times it fails before the final pass. If another factory counts the yield on First Time Through as passing the test on the first try, it will only achieve a 100% yield if the product goes through the test the first time. A yield comparison between the factories with different interpretations would therefore be unjust.*

4.2 Table summary of interviews

Figure 4.1: Table of the Operation function's needs.

4.3 Metrics

In addition to evaluating KPIs from literature and mapping the needs of the organisation, the metrics currently used in the organisation as well as other metrics that the interviewees experience as potentially beneficial were investigated through interviews. The metrics currently and the potentially beneficial metrics are accounted for in the following sections.

4.3.1 Current metrics

To identify current metrics used in the organisation, a major part of the interviews consisted of questions regarding what metrics the respondents use themselves or metrics that they are aware of being used in the organisation. The respondents were also asked how the metrics are used, how often the metrics are used, who uses the metric, and how the metric is presented.

The current metrics in the organisation were compiled based on the respondents answers. Most of the current metrics are measured and forwarded by the customer or the supplier. This is motivated by the fact that CPAC wants to evaluate the performance with the same metrics as the customers and suppliers use. The main metrics currently used in the organisation according to the respondents were the following:

- Function Control Testing Yield: The percentage of products that make it through last test in production line measured by CPAC and their supplier. Commonly used in the Operations function broken down on individual product lines. Measured once a month.
- Quality Claims: Number of quality claims in relation to number of sold products measured in PPM by both CPAC and customer. Measured once a month.
- Supplier Lead Time: The lead time from customer order to delivery of products measured by customer. Measured once a month.
- Customer Delivery Precision: Percentage of deliveries that are correct and on time measured by the customer. Measured once a month.

The respondents expressed multiple issues with the measures from external sources. A major issue for several respondents were that some of the current metrics include aspects that lie outside the organisation's control. For example, the Customer Delivery Precision was measured by the customer on what precision the delivery had to the customer. This meant that the shipping was included, despite the fact that it was the customer that was responsible for the shipping and CPAC having little to no influence over it. Another example was that Quality Claims measured by the customer counted the whole batch as faulty if one of the items in the batch was faulty. This meant that one faulty product could impact the PPM different depend-

ing on the batch size of the shipment. The respondents expressed that this made improvement work more difficult and that it could give unwanted consequences as it incentives smaller batch sizes and more frequent shipping.

An issue with the supplier metrics is that the suppliers measure in different ways. For example, some suppliers referring to First Time Through as passing the end of line test on first try. Other suppliers refer to First Time Through as the product being able to pass the test without rework. This makes it harder for CPAC to evaluate the performance of the different suppliers. Comparing the different suppliers can not be done on the current metrics but rather require manual labor to adjust the metrics for the different measuring and reporting methods. This shows the importance of a standardised operational definition of the metrics, as to not let the definition slide over time [6].

Due to the pandemic and the component shortage, some product articles in the metric Customer Delivery Precision has been put out of order through an agreement between the customers and CPAC. Because of these articles being included in the metric, it went very low during the special circumstances and neither party thought that it could be productively utilised. The respondents expressed a need for metrics that can be used to evaluate internal performance when the external situation is unstable.

4.3.2 Potentially beneficial metrics from interviews

One of the main concerns with the interviews, alongside collecting information about what metrics are currently used, was to gather inputs from the interviewees regarding what metrics they would like to see. The intent was to catch potentially useful KPIs that might have been discussed informally by the co-workers at CPAC. Then, by providing a summary of the found KPIs, all co-workers would get the opportunity to use the summary as a focal point for further discussion about what KPIs would be the right ones for CPAC to use.

4.3.2.1 Proposed KPIs from Quality and Production

The following metrics proposed by the Quality and Production departments could potentially be used as KPIs:

- In-circuit testing (ICT) data and Yield.
- Output in relation to both planned and average output.
- Number of failures at other tests such as leakage tests.
- Number of failures due to production errors, design errors and component failures respectively.
- Number of quality claims versus No Fault Found (NFF).

There were multiple quality and production related KPIs that the co-workers found interesting for CPAC to implement. What was most emphasised was the need for some sort of output metric measuring the number of produced products. This was seen as beneficial for both the quality and the production departments as it could function as an alarm bell. The metric could be captured by counting the produced quantities at the main factories and then relating that number to either the planned or average outputs for a week. If the metric was tracked in real time, the quality and production department could react instantaneously if they saw that the production output was not reaching the needed quantities. Moreover, CPAC's earlier involvement when the problem occurs is also a precaution as to not let the factory sort the problem themselves and then having issues turn up later on when they could have been resolved earlier. A production engineer had their say on the topic:

> *I would like to know how the production is going, is it up or down right now? If they for example had an issue the previous week, does it seem like they have been able to resolve it? If I got instant access to the data, I could see that there was an issue around 9.00 am, give the factory some feedback on how to solve the problem, and then hopefully see the output increase at 11.00 am.*

Furthermore, co-workers from the quality and production departments felt that there could be more metrics related to different tests in the factories. Aside from FCT Yield, ICT data and ICT Yield would also be an useful metric. While FCT is done as the last step of the production line and tests the product's functionality, ICT is done on circuit boards. Thus, yield data from the ICT could catch faults at circuit level, which would be more difficult to find when the product is assembled and finished. For the same reasons, there could be value in providing data similar to yield for other test, such as results in leakage tests. By having metrics centered around the most important tests, the co-workers from quality and production feel that they could get a faster indication on where they need to act and support the factories.

Even though it may not be possible right now, the production department found that it would be interesting to track where the responsibility for faults lie. After the fault with the product has been found, perhaps the fault could be derived coming from either a manufacturing error at the factories, a design problem coming from CPAC, or component failure on a component bought from a supplier. This type of KPI could therefore help in deducing where the problems occur, who is responsible for handling the issue, and what actions should be taken to avoid the problems in the future.

Finally, from the quality and production departments, there was also the perspective that there could be value in having a metric that compares the customer quality claims (PPM) with investigations that result in NFF at CPAC. This new metric could help CPAC and its customers better understand if the issue is because of CPAC or not, and how many of these products can be reused.

4.3.2.2 Proposed KPIs from logistics and procurement

Similar to quality and production, the co-workers from logistics and procurement had their opinions on what metrics may be useful to have access to. The proposed metrics that could serve as KPIs can be summarized as:

- Delivery precision - On an available-for-pick-up basis
- Delivery precision - Factories to CPAC
- Delivery precision - Suppliers to factories
- Customer prognosis
- Metrics on factories' inventories and deliveries
- CPAC's financial metrics

DP has been the most important metric for the logistics department in particular, but as mentioned in the current metrics section, it is somewhat unjust and only measured from the customers' side. A better metric that was proposed was DP on the availability-for-pick-up basis, meaning how many of the products are available on the day of pick-up. As the customer is responsible for the pick-up of the product, this would result in CPAC not receiving penalties for the transport being late, and give a more accurate picture of CPAC's delivery performance. Another comparable metric would be for CPAC to measure the factories' delivery performance, meaning how many of the products that CPAC has ordered have been produced in time by the factories. One other option related to delivery precision would be to go one step further and measure the delivery performance of suppliers to the factories that supply CPAC. Using this as a metric, CPAC could monitor that the factories get their components in time to not halt the production of CPAC's products.

In addition to different types of DP, there was a request from logistics and procurement to get easier access to the customers' current production status and their prognoses in terms of what products they will need in the foreseeable future. If the production is at a halt, it would be great to know it as soon as possible to adjust the work accordingly. At the time of writing, both departments have struggled with planning for more than two weeks due to the component shortages for electronics manufacturers. Getting easier access to the customers' prognoses would thus help the departments work proactively and better estimate if the factories will be able to meet the customers' demands. Likewise, from the procurement department, came the request that it would be helpful to get not only more insight into what the customers will need for the foreseeable future but also more insight into the operations of CPAC's production. In particular, having metrics that show the factories' available capacity could help in understanding when there is a free capacity to switch the production to another product. Also, by simultaneously showing a metric related to set-up times creates an understanding of the factories' challenges when CPAC wants to change the production plan. A Strategic Buyer from procurement had the following to say related to getting more insight into the factories' operations:

> *I think it would be very good for us to understand the factories' challenges with jumping between different products. If you have one product going through one line it is very easy. But, when there are multiple products we have to understand the impact of switching between them. Perhaps that is not reasonable for the factories to do each day of the week. Instead, you might have to run a product for three days before switching to get the capacity up.*

Lastly, co-workers from procurement had some further remarks regarding what metrics they would like to see. The second Strategic Buyer that was interviewed thought of another way to get insight into the factories' operations. Their suggestion was to get access to some of the factories' logistics information. There could be some value in tracking the factories' inventory levels, incoming deliveries, and their material planning to ensure smooth production and supply of CPAC's products. Other than having metrics related to the factories' logistics, this strategic buyer said that they would like to have some of CPAC's financial metrics available to see the overall company performance. Other than it being interesting for them to see, the strategic buyer did not have any comments on how they would use the information in their work. However, neither of the Strategic Buyers was interested in seeing any KPI on yearly savings their department has achieved, a KPI that is often used for procurement departments. This is partially due to the previously mentioned component shortages and an unstable economy, which has made prices fluctuate significantly more frequently than in the past. Another reason for not wanting the yearly savings KPI is that both of the Strategic buyers found the KPI difficult to make useful in their daily work. The yearly savings KPI could also likely entice bad behaviour, such as buying poor components at a cheaper price, which results in more costs at another department such as Quality when they have to fix the issues.

4.3.2.3 Top management views on metrics

The three interviews conducted with the management team gave a different perspective on what should be considered when implementing new KPIs for the Operations function at CPAC. One member of the management team emphasised that they would like to see every employee affected by the KPIs get the opportunity to analyse the data themselves and look for patterns and trends. By each co-worker getting the opportunity to identify trends and patterns themselves, it is less likely that something will be missed compared to a situation where it is the sole responsibility of one individual to analyse the data. This provides the co-worker with a greater process perspective that enables them to transcend the boundaries of their department and contribute to issues in the greater organisation. Right now the main hindrance has been that co-workers are preoccupied with their regular tasks that there has not been enough time to sit with the data.

Another request from the management team was to include some sort of sustainability metric. Innovation for sustainability is one of the main strategic goals at CPAC, which the different departments work actively towards. However, sustainability metrics has not previously been an integrated part of the daily work of the

organisation. The two officers would therefore like to see a sustainability metric that could get the firm started with incorporating sustainability into their performance reporting. They did not consider a particular sustainability metric to be crucial to include, rather the request was to incorporate something that can act as a catalyst for further sustainability initiatives. Examples of sustainability metrics that could be included are measurements on CO_2-emissions from transports, how many products can be reused after rework, and metrics related to what type of transportation mode is used. A member of the management team had the following to say about sustainability metrics:

> *It is easy to become too ambitious about what should be measured, which once again doesn't turn into something useful. The solution could be expressed in so many different ways. We are already helping our customers in measuring the* CO_2*-emissions from their vehicles, but we have not yet applied metrics like this for our own company. I am very pragmatic about what approach we should use for our own sustainability metrics, but just something that could get us started and perhaps lead to others being inspired to either enhance the performance or come up with other metrics they find better. The important thing is to not become too ambitious regarding what metric should be used or how it should be measured so that the plan does not fall apart instantaneously. I would rather like something easy to implement, and that can be implemented already this year.*

The management team specifically requested that whatever metrics are used, they should be able to be collected and presented in an automated way. Currently, the metrics at CPAC are dispersed between different departments, and there is plenty of manual labour involved for co-workers at the departments to visualise the metrics. A result of this is that there are situations where the Chief Executive Officer needs up-to-date data for their decision-making immediately, but does not have the time to wait while a co-worker does the needed manual labour to provide the data.

Finally, when the departments' needs and metrics have been defined, there still remain some lingering questions that need to be addressed. For example, does the needs in any way stem from CPAC using outsourced production, and why have they not yet been satisfied? Furthermore, do these needs conflict or complement to each other? As for the metrics, are they suitable for implementation at CPAC based on the literature, and how easily can they be implemented given the current circumstances? All of these questions will be further discussed in the subsequent chapter.

5

Discussion

In the following discussion chapter, the findings and implications from previous chapters are analysed and discussed. The chapter is divided into two sections and the structure is based on the previous chapter. The first section is a discusses the operational needs of the organisation and the second section is a discussion of the metrics.

5.1 Discussion of operational needs

From the interviews, it has been concluded that the six main needs in the organisation span multiple departments. As previously stated, these six needs are *Spread awareness internally, Work proactively, Communication and transparency, Intuitive and easy-to-access information, Automated data gathering, and Fair metrics*. While these needs have somewhat of an overlap, the emphasis of the needs is what set them apart. For example, to *Spread awareness internally* it is necessary to have good communication but *Communication and transparency* on its own will not solve the problem of awareness which is why they are separated. As the six needs are expressed in multiple departments and by stakeholders in the organisation, they are to be seen as the CSFs from which the proposed KPIs should derive from. Like the explanation given on CSFs for an organisation in the theory chapter [22], the customers of the thesis are the employees in the departments, and the management team. To succeed with the implementation of KPIs in the organisation it is crucial to satisfy these CSFs.

One of the takeaways from the interviews was that the needs were stemming from the organisation having outsourced production. The need for spreading awareness internally about challenges in production and logistics would potentially be less eminent if the production was located internally at CPAC. If development was in the vicinity of production, major issues such as production stops would be difficult to ignore no matter if an employee was working for the R&D function or the Operations function. Additionally, the need to work proactively is likely also originating from having outsourced production. The distribution of responsibility and control of the outsourced process was mentioned in Section 2.3 to become increasingly difficult with geographical distance [24]. Accordingly, the departments in the Operations function presumably feel the need to work more proactively to prevent issues before

they occur and to maintain control of the outsourced processes.

Furthermore, communication was among the most important factors mentioned in Section 2.3 that determines the success of outsourced operations [23]. Unsurprisingly, the need for increased communication and transparency could be distinguished from the interviews. The requests for intuitive and easy-to-access information, combined with automated data gathering might also not have been as noticeable if CPAC produced its products in-house. The shared systems used by CPAC and its suppliers are difficult to extract information from, which could have been easier to streamline if only CPAC was responsible for maintaining the system. And, the last need for fair metrics can be argued to stem from outsourcing as well, due to coworkers from the Operations function feeling that the factories should be evaluated under the same circumstances.

Once the needs of the organisation are identified, the question emerges of why they exist and why they have not yet been satisfied. As indicated by the interviews, the cause of the needs seems to have emerged over time as the organisation has progressed and grown. An issue with needs that grow into an organisation over time is that it might be difficult to address them as it is not necessarily one person or organisation that is responsible for satisfying the need. Thereby, the need falls through the cracks until it is large enough that it will no longer fit and has to be addressed.

Another potential cause of not satisfying the needs could be that they collide with other needs in the organisation or other organisations. For example, could it be difficult for the suppliers to achieve full transparency to their customers as transparency could be negative for their need for survival? *Full transparency* could for example be used as leverage against the suppliers to lower their profit margins or negotiate with competitors. The same goes for *Fair measures* as it is not always easy to deduct what a fair measure is. What is fair from one point of view might be regarded as totally unfair from another. As seen with the case organisation it is evident that the customer views their metrics as fair because all their suppliers have the same metrics while the case organisation views them as unfair as their products and production do not fit well with some of them.

Many of the needs seem to be complementary to each other, and if one is satisfied another need will probably be at least partially fulfilled as well. For example, if automated data gathering is solved, easier access to information will ensue due to one person not needing to collect the information manually. Consequently, if the information is more readily available, spreading awareness about operational challenges can be simplified and information exchange and transparency is increased. However, some of the needs could be argued to be competing with each other. Automated data gathering might be implemented, but this could come at the cost of fair measures if one of the factories is not able to provide their data under the same circumstances as the rest of the factories. While the need for working proactively might be enhanced by easy-to-access information and automated data gathering, it could also make the user more reliant on historical data and solving issues as they

appear, rather than trying to identify future trends.

While there were multiple needs in the organisation, what was a reoccurring issue was the insight and information on production issues at the factory in real-time and the need for communication and transparency with the producers on issues when they occur instead of after. There was an explicit need in all departments of the operations function for a metric that can monitor the production and alarm when issues occur so that they may take action to help with solving the problems right away and adjust the workflow if necessary. While this is a relatively simple and reactive view on the improvement of the organisations, it can be seen as a first step towards higher quality. In the long term, it is not sufficient to only have an alarm function as this is a reactive approach to improvement and not the process perspective that in the literature seems to be the consensus for long-term improvement. Perhaps some encouragement for metrics that measures performance in the long-term should be directed from management towards the employees in the Operations function. Management has already expressed a desire for the employees to get the opportunity to analyse trends themselves and by implementing tools such as control charts this aspiration can be realised alongside fulfilment of the need for a metric that can act as an alarm bell.

5.2 Discussion of metrics

After the needs of the Operations function were defined, the conducted interviews established current metrics that are used among the departments and metrics that could potentially be useful in the future. The metrics that are used as of now are *FCT yield, Quality claims, Supplier lead time, and Customer delivery precision.* In addition to these currently used metrics, the interviews gave further insights into more metrics that the co-workers had contemplated, which could provide new information to the Operations function of CPAC. From the quality and production departments *ICT yield, Output, Number of failures at specific tests, Number of failures due to production errors, design or component failure, and Number of quality claims versus No fault found* were suggested. Meanwhile, production and logistics proposed to use DP, but slightly different from the DP that is measured right now. The departments' considered the possibility of measuring *DP on an available-for-pick-up basis, DP of factories to CPAC, and DP of suppliers to factories.* They further reflected on the usefulness of having metrics on *Customer prognosis, Suppliers' inventories and deliveries, and CPAC's financial metrics.* At the request of the management team came a suggestion to implement a sustainability metric, because sustainability being one of the key objectives of CPAC.

The currently used metrics have been fruitful for an extended period as providers of information to the Operations function of CPAC. FCT Yield and Quality claims have given the quality and production departments insights into the state of production, while supplier lead times and the delivery precision toward the customers help logistics and procurement evaluate their work. However, there are arguably issues

with only using these metrics to assess the performance of the Operations function. One problem is the measuring frequency for the metrics, as they are presented once a month. It was mentioned at the beginning of the theory section that KPIs should be measured 24/7, daily or weekly [22]. This is likely to allow for a process perspective, which is one of the most important features of KPIs [17], [21], because the information that the KPIs provide can be followed up regularly. Having metrics that are only presented once a month makes it difficult to have the process perspective as corrective actions are much slower to implement if the process deviates. Another problem with the current metrics is their lack of standardisation. FCT Yield is an example of a metric where one factory measures good quality products as the product passing all of the tests in only one run, whereas another factory allows for multiple reruns of the test but not any reworks. The literature claimed that a good KPI should be clear, and not suffer from any ambiguity in its interpretation [14]. Otherwise, there is a risk that the operational definition of the KPI will slide over time, and thus will impact the evaluation of the performance.

A reoccurring theme in the literature is that KPIs must be closely related to the strategic goals and objectives of the organisation [22], [32]. While the thesis has not gone into detail on the strategic goals and objectives of CPAC, the interviewees claimed that CPAC takes great pride in its distinguished ability in being fast and innovative. There is a clear conflict between this strategy where the pace is emphasised and simultaneously allocating sufficient time to achieve good performance on the used metrics of FCT Yield and Quality claims. While this conflict does not necessarily mean that it is impossible to balance the two, it is something that needs close attention from all parts of the organisation. Additionally, an officer of the management team mentioned that innovation for sustainability was one of the key objectives of CPAC. However, sustainability is not currently represented in the metrics that are used by the organisation. Neither did any sustainability metrics come up as a request from the interviewees working at the departments in the Operations function. Without having a sustainability metric, it will be difficult for CPAC to evaluate if it makes significant progress on achieving its key objective. Hence, due to there being a discrepancy between the strategic goals of CPAC and its metrics, and environmental reporting becoming increasingly important [26], a sustainability metric is recommended to be implemented as soon as possible.

As previously discussed in Section 2.5 it is important to consider multiple aspects when wishing to implement new metrics. Management support was concluded to be of importance both in internal and external enabler, internal availability of resources where the most important internal enabler and availability of information was the most important internal barrier [16]. For external enablers, there was also the matter of trust between actors and for external barriers, the major issue was often the IT system. Based on these enablers and barriers, the case organisation can be said to have relatively good conditions to have a successful implementation. As the project was initiated and supervised by the management of CPAC it can be assumed that there is at least relatively good support for the implementation. Most of the KPIs proposed by the departments could be argued to be relatively reasonable and potentially possible to implement as there are already some variants used for

most of the proposed metrics and the information should therefore be partially available. The actors also share some of their IT infrastructure which eases the work of gathering the information. If it is not possible to gain access to the necessary resources it will not be possible to go through with an implementation and if there is no access to information it will not be possible to use a metric based on that very same information. The suggested metrics also have clear themes in terms of functionality. They are centered on the main issues for each department and they reflect the needs of *Intuitive and easy-to-access information* and *Communication and transparency* which suggests that there might be a relatively low internal resistance to implementing such KPIs. A potential problem with implementation for some of the proposed metrics seems to be the trust and transparency between the supplier, customers, and CPAC. As the suppliers have multiple customers it might not be an option for them to share all their production information as this would be a breach of confidentiality. Therefore total transparency is dependent on the conditions in the agreement between the supplier and customer, and could thus be difficult to achieve.

An interesting aspect of the proposed metrics is that they could have synergies in implementation as several of them are related. For example, the delivery precision is dependent on whether the output of production achieves the planned output and whether the number of faulty products is not too high. Therefore, the metrics could potentially be related to each other and one metric might be able to reuse data from another metric depending on the wished functionality. The prognosis metric on the other hand, is relatively independent of the proposed metrics of the other departments but could be derived from the customers planning if shared in time.

In addition to the current KPIs and the KPIs that were suggested by the departments, there are some metrics from the literature that could be worth for CPAC to consider. Some of them are related to the manufacturing process, and in particular process breakdowns, such as MTBF, MTTR [15], and MDT [28]. These metrics in combination with each other could give insights into how often breakdowns typically occur, how long the breakdowns last, and how quickly the issues can be resolved through repairs. Further, the metrics would give more information to CPAC about the state of the production process, and not only the resulting products which are currently depicted by FCT Yield and Quality Claims. There could potentially be value in measuring the efficiency of the manufacturing equipment as well, by the metric OEE. OEE combines metrics related to the availability of the machinery, throughput, and yield in its assessment of manufacturing equipment performance [29]. The OEE can potentially be used to evaluate specific production lines and help identify opportunities for better manufacturing of certain products. Another metric mentioned in the literature was that of scrap ratio. The scrap ratio can be used to ensure the effectiveness of the production [15]. Similar to yield, it would help CPAC detect if the quality of products was diminishing. But, because of the similarity between the metrics, it might not be useful to use both as KPIs.

Inspiration can likewise be taken from the Six Sigma methodology when discussing metrics from literature. Control charts and the capability measures C_p and C_{pk} are

meant to be used for noticing deviations and understanding variation in the process [2], [3]. Alongside the FCT Yield which only measures the amount of good quality products to the total amount of products, these metrics would help CPAC in getting more detailed information about how well the manufacturing process manages to produce their products within a set of tolerance limits. The information would then allow for further investigation when there are causes of unnatural variation, which may help CPAC to reduce the amount of Quality Claims. For the metrics from the literature, it should, however, be stated that some of these are likely already implemented at the factories, but not shared with CPAC as of right now. Therefore, some might be easier for CPAC to collect than others.

6

Implementation of KPIs

In the following chapter, an overview of the application of the visualization tool will be presented as a proof of concept for the organisation. The first two sections of the chapter address the results of the implementation. The third and final section discusses the implementation, including its issues and possibilities.

6.1 Data handling and architecture

The current system that CPAC uses for collecting its test data is by uploading the data from test rigs at the factories to a File Transfer Protocol (FTP) server. The test rigs run different tests depending on the product, and all of the steps and test results are summarised in XML files that are generated at the end of each test. Due to the tests being different, the information in the XML files is consequently structured differently as well.

In the FTP server, the XML files are stored under multiple folders. The folder names specify information such as factory, product, test, year, and month to structure the data. Each XML file contains information that can be traced to a product and a test at a particular point in time. A problem due to the structure of the FTP server with its many folders is that it has become increasingly more troublesome to find sought XML files, the longer the FTP server has been in use. There was no formally set standard from the beginning, neither in structure nor naming, which has resulted in there not being a systematic method for introducing new folders and files in the FTP server. With time, more folders have been added while folders containing historic data for older products remain in the directory. Likewise, many of the XML files are located in folders with illogical folder names and structures, and some old XML files are located in the wrong folders.

Also, it is difficult to summarise and analyse the test data from multiple XML files. There is currently no way to easily export the data to a tool such as Microsoft Excel that would allow for computation and visualisation of the test data. Combined with the cumbersome work to find the right folders in which the sought .xml-files are located, the FTP server is far from an intuitive source of information regarding test data. Though, the purpose of the FTP has never been intended to be a source for data handling. Rather, the purpose is for the test data to be stored somewhere if a

follow-up is required for a certain product. With time, and due to a lack of better alternatives, the FTP has become the main source of production information in addition to the information provided by the suppliers through emails and meetings.

Nevertheless, data from the test rigs are not the only data that CPAC collects. Logistics data for computation and visualisation of delivery precision is collected from the organisation's ERP system. From the ERP system, data can be exported to Microsoft Excel, from which a co-worker can manually do the necessary calculations and graphs. In addition to the ERP systems, there are separate department-specific systems where data is located as well, such as quality claims being located in a system used by the quality department.

When the data is required for a follow-up in the operations department someone has to specify what data is needed, for what products, and for which period. When this is specified the information needs to be gathered from the FTP server. To access the information from a test of a product, an XML file most often must be downloaded and processed to extract the wanted data. This is currently done by a software engineer that creates an automated script that can download the files that match products and period and extract the wanted data by compiling it into a CSV file. Once the data engineer has created a script for the specified needs it is forwarded to the quality assurance engineer responsible for the follow-up. The QA engineer runs the script and this creates the CSV file. The running of the script takes approximately 5 minutes every time as it has to download each file. The QA engineer then imports the CSV file into Microsoft Excel where it is treated for duplicates. Once the data is cleared of duplicates the QA engineer uses the data to calculate the performance metrics and visualises them through different graphing tools and visualisations.

6.2 Dashboard

To automate the data handling and to make it more instantaneously accessible, the authors of this thesis wrote a program that executes the steps above and outputs a visualization of the requested data. The visualisation is that of a dashboard of KPIs on a website that is accessible to the whole organisation. Practically an executable file has been created from multiple Python-scripts that gather and compiles data from the organisation's servers and creates a HTML-file that can be accessed internally at CPAC in any common web browser. The program is uploaded to a site that runs the executable file at regular time intervals, which updates the HTML-page automatically. This allows for automated data handling, and does not require someone to update the dashboard themselves multiple times each day.

Yield and output KPIs of four products were chosen as the first to be implemented in this iteration of the dashboard, because of the relative simplicity to acquire the data and these four products being vital to CPAC right now. The output was visualised for each product in bar charts on a rolling seven-day period. Meanwhile, the yield

was presented at the bottom of the page in three different periods, last week, last month, and the current month's yield. These periods were deemed sufficient for their intended purposes. This is because the rolling seven-day output can be used as an alarm bell to react if production targets are in danger of being missed, while the summarized yield for a week or month allows for more proactive work.

Using the Plotly Dash library in Python, the necessary visualisation of the KPIs could be made. In Section 2.7, it was stated that there are some design principles for dashboard visualisation that the designer should adhere to. There should not be more performance metrics than necessary, and no excessive use of colors [17]. Likewise, the placement of the information is of importance as well. The most important information should be placed in the top left and the least important in the bottom right [8], [31]. For this first iteration of the dashboard, the most important product was placed at the top of the page, while the least important was placed at the bottom. The use of colors was sparse and only utilised to distinguish between different variations of the same product family. The dashboard is updated with five-minute intervals and thus provides the case organisation with a continuous stream of production information. Therefore, the dashboard can be seen as a visual management aid, that can help overcome the challenges of effective internal communications [30]. In the future, when more proactive measures are implemented, the dashboard will in best case be linked to a continuous improvement program that will allow for continuous improvement opportunities and a continuous improvement culture [7]. An illustration of the first iteration of the dashboard is presented below.

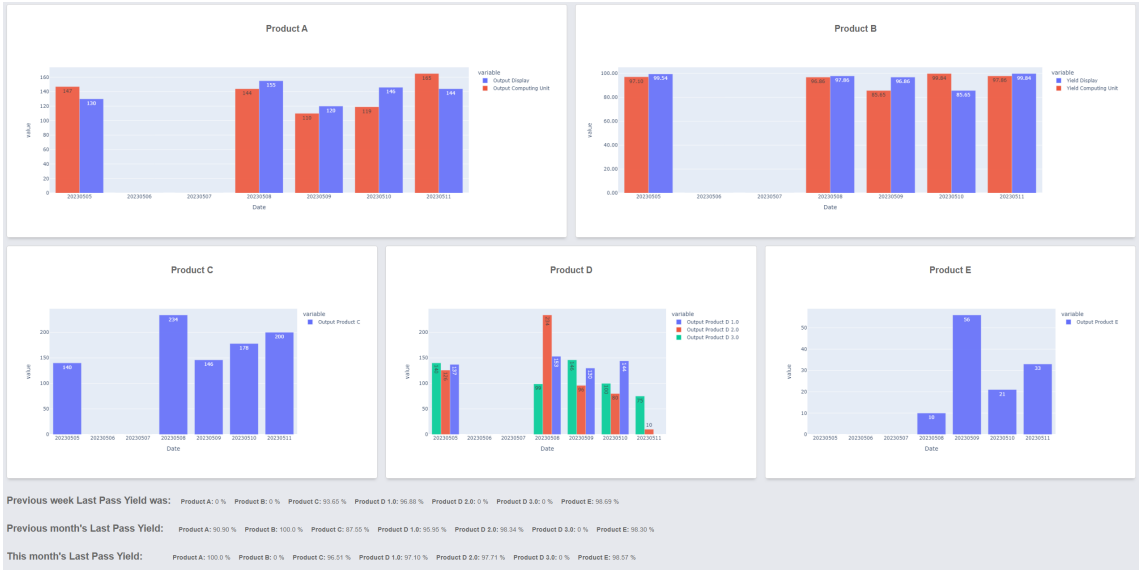


Figure 6.1: Visualisation of the dashboard with fictional data due to privacy concerns.

6.3 Discussion about the implementation

A suggestion brought up by an engineer in the organisation is to do a rework of how the organisation handles its data. The engineer suggests handling the data with the help of tools like Grafana or Power BI. The engineer did emphasise that an issue that has to be resolved before these tools can be used for data handling is the data architecture as it currently does not support such handling tools. The engineer suggested that some sort of database or server solution should be evaluated to structure the data and enable efficient handling. Some variant of this solution has to be in place for the data handling tools mentioned previously to be of practical use as they do not handle FTP servers very well. This database solution would be preferred over the first iteration of the dashboard that has been created for the thesis for several reasons. First, the reworked data architecture would allow to correct past mistakes, such as the poor structure of the FTP server. The database would be able to read the files from a source such as the FTP server and transform the data into a standardised format from which Grafana and Power BI can easily extract data from. Second, using a database solution would remove the need for enlisting programmers to write scripts for each possible scenario that might be relevant to measure. The programmers would then be able to spend more time on the development of the products. Third, employees without programming experience can use Grafana or Power BI to easily graph and analyse the data they are interested in. A consequence of this is that more employees will get the opportunity to analyse trends and deviations themselves, especially if control charts that can show historical long term data are also implemented.

The authors of this thesis came into the organisation of CPAC with the ambition to implement the theory learned and tools from cases studied in university. From the implementation, it has become evident that the theoretical concepts and case implementations that are written in literature and taught in universities all around the world are far from as straightforward or even practically implementable in reality as they may appear in theory. Despite that the authors of this thesis had previous experience and suspicions that an implementation will not be a straight path, the data handling and architecture became a much larger issue than what was first anticipated. The fact that data handling and architecture was such a large issue in a cutting-edge tech firm like CPAC implies that the issues encountered in this thesis are likely to repeat themselves if replicated in other organisations. Despite the disclaimers that are often made in literature, it seems likely that students have an image of the industry as much more perfect and controlled in detail than what has been concluded to be the case. Therefore, the authors of this thesis hope that this thesis can be a source of inspiration to other practitioners faced with the same situation.

Depending on the background of the practitioner it is likely that the way of tackling the issues might differ. With a management and quality background, the authors of this thesis began the work by mapping the needs of the organisation. A practitioner with another background might have taken a different path by starting

and evaluating the existing systems in the organisation to find possible issues with the implementation before evaluating the needs. While the identified needs of the organisation are likely to have remained the same, another approach to the implementation would likely have led to another outcome in terms of the dashboard.

7

Conclusion

From the start of the thesis, the purpose was to explore the possibility of using and implementing key performance indicators in an organisation with outsourced production. The purpose was to be fulfilled by answering two research questions.

- *RQ 1:* What operational needs are not satisfied in an organisation with outsourced production?
- *RQ 2:* What Key Performance Indicators are suitable for facilitating operational improvement, considering the operational needs of an organization that utilizes outsourced production?

For RQ 1, it was concluded that there were six unfulfilled needs at the Operations function of CPAC. These were to Spread awareness internally, Work proactively, Communication and transparency, Intuitive and easy-to-access information, Automated data gathering, and Fair metrics. All of these were discussed to be at least partially due to CPAC using outsourced production. Furthermore, these needs could be translated into the CSFs from which the proposed KPIs should derive.

For RQ 2, there were numerous metrics suggested in the theory chapter and Section 4.3.2 that could be implemented at CPAC in addition their currently used metrics. The current metrics are considered inadequate in certain aspects, such as the frequency and fairness of the measures. However, the introduction of new metrics could partially overcome these limitations. To fully leverage the potential of the new metrics, it may be necessary to integrate them into a continuous improvement program that systematically initiates improvement activities based on these metrics.

Moreover, the effectiveness of continuous improvement initiatives may be influenced by how the metrics are visualized. The way the metrics that have been incorporated in the dashboard are sub optimal for these initiatives, because of the limited proactive perspective. For instance, the dashboard can only visualise the output and yield on a rolling seven-day basis. As previously discussed, it is important to be able to go back to historical data and follow the development and trends over time and to be able to systematically work through the data for different time periods with the help of statistical analysis. To support continuous improvement activities, tools such as control charts, which can demonstrate trends over longer time periods, should be implemented.

However, there are no significant barriers to implementing the suggestions proposed by the departments in the Operations function. On the other hand, the possible implementation of metrics mentioned in the literature has not been extensively explored. In particular, a sustainability metric should be implemented as soon as possible, to ensure there is metric that can help achieve the key strategic objective of innovation for sustainability that CPAC has.

In addition to the answers to the research questions, it is recommended that CPAC to further investigate the use of a database solution for their data handling. The suggestion provided by an engineer at CPAC will simplify the data handling process significantly, compared to the dashboard that was created for this thesis. Primarily because once the solution has been implemented, a programmer will not have to write a script for every specific situation that is requested. Instead, everyone can more easily choose the KPIs and circumstances they would like to further analyse themselves.

For the authors of this thesis, it has been made clear that there is a gap between the optimal world of theory and the chaotic world of reality. The authors were made aware that even if data is already gathered and of high quality, the implementation and use of this data in an organisation might be more difficult than anticipated despite having a very high degree of management support. The implementation in this thesis encountered practical challenges that required extensive trial and error to resolve. This was a very time-consuming aspect of the thesis, and if the thesis were to be redone, the authors would have consulted expert competence in programming and data architecture earlier in the process.

7.1 Limitations of the thesis and future research

There are certain limitations to the thesis that should be kept in mind. First, there has not been sufficient time to implement and test all of the KPIs to see how well each of them works in the organisation, which is required to achieve an effective set of metrics. Second, there was not enough time to extensively explore how straightforward it would be to implement each of the new metrics and the proposed visualisations, such as control charts where KPI behaviour over longer time periods are displayed. Lastly, another limitation was that the suppliers and customers were not more involved in the thesis. Their perspectives could have helped understand the suitability of the metrics.

The thesis has stumbled upon multiple issues that could benefit from further research. One aspect of the study was the issue with data handling and architecture. A potential scope for further research would be to investigate the impact of insufficient data handling and data structure across various organisations other than CPAC. A second scope that has potential for further research is to investigate multiple organisations to see if any reoccurring patterns or solutions can be of interest. A third and final recommendation for future research is to explore the implementation

of KPIs in a case organisation for a longer period. By observing the case organisation after the KPIs have been implemented, some conclusions may be drawn about how well the KPIs drove the intended behavior, including improvement activities, and what changes that should be made to the implemented KPIs.

Bibliography

[1] Bell, E. Bryman, A. & Harley, B. (2019). *Business Research Methods* (5th ed.). Oxford University Press.

[2] Bergman, B. Bäckström, I. Garvare, R. Klefsjö, B. (2022). *Quality: From Customer Needs To Customer Satisfaction* (4th ed.). Studentlitteratur.

[3] Bicheno, J. Holweg, M. Anhede, P. Hillberg, J. (2013). *Ny verktygslåda för Lean*. (5th ed.). Revere

[4] Billups, D.F. (2021). *Qualitative Data Collection Tools: Design, Development, and Applications*. SAGE Publications.

[5] Carleton, S. (2016). *The Black Belt Memory Jogger* (2nd ed.). Goal/QPC.

[6] Deming, W. E. (1994). *The new economics for industry, government, education* (2nd ed.). MIT Press.

[7] Eaidgah, Y., Maki, A. A., Kurczewski, K., & Abdekhodaee, A. (2016). Visual management, performance management and continuous improvement: a lean manufacturing approach. *International Journal of Lean Six Sigma, 7*(2), 187-210.

[8] Eckerson, W. W. (2010). *Performance Dashboards: Measuring, Monitoring, and Managing Your Business* (2nd ed.). John Wiley & Sons, Incorporated.

[9] Elmuti, D. (2003). The Perceived Impact of Outsourcing on Organizational Performance. *American Journal of Business (Emerald Group Publishing Limited), 18*(2), 33–42. https://doi.org/10.1108/19355181200300010

[10] Forsberg, P. (2023). Övertron på mätning. Access, (1), 30 - 35.

[11] Hätönen, J., & Eriksson, T. (2009). 30+ years of research and practice of outsourcing – Exploring the past and anticipating the future. Journal of International Management, 15(2), 142–155. https://doi.org/10.1016/j.intman.2008.07.002

[12] Isaksson, A. Lantz, B. (2015). Outsourcing strategies and their impact on financial performance in small manufacturing firms in Sweden. *The International Journal of Business and Finance Research, 9*(4), 11-20.

[13] Ishaq Bhatti, M. Awan, H.M. (2014). The key performance indicators (KPIs) and their impact on overall organizational performance. *Quality and Quantity, 48*(6), 3127–3143. https://doi.org/10.1007/s11135-013-9945-y

[14] International Organization for Standardization. (2014). *Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management — Part 1: Overview, concepts and terminology* (ISO 22400-1:2014). International Organization for Standardization. https://www.iso.org/standard/56847.html

[15] International Organization for Standardization. (2014). *Automation systems and integration — Key performance indicators (KPIs) for manufacturing operations management — Part 2: Definitions and descriptions* (ISO 22400-2:2014). https://www.iso.org/standard/54497.html

[16] Keebler, J.S. Plank, R.E. (2009). Logistics performance measurement in the supply chain: A benchmark. *Benchmarking, 16*(6), 785–798. https://doi.org/10.1108/14635770911000114

[17] Kerzner, H. (2013). *Project Management Metrics, KPIs, and Dashboards - A Guide to Measuring and Monitoring Project Performance* (2nd ed.). John Wiley & Sons, Incorporated.

[18] Khan Mohammed, A. R., Ahmad, B., & Harrison, R. (2020). A holistic approach for selecting appropriate manufacturing shop floor KPIs. *2020 IEEE Conference on Industrial Cyberphysical Systems (ICPS).* https://doi.org/10.1109/icps48405.2020.9274690

[19] Kuada, J. (2012). *Research Methodology* (1st ed.). Samfundslitteratur.

[20] Merriam, S.B. & Tisdell, E.J. (2015). *Qualitative Research: A Guide to Design and Implementation* (4th ed.). John Wiley & Sons, Incorporated.

[21] Marek, S. Schuh, I.G. Stich, I.V. (2020). Identification of multidimensional key performance indicators for manufacturing companies. *2020 IEEE Technology & Engineering Management Conference (TEMSCON), Technology & Engineering Management Conference (TEMSCON), 2020 IEEE*, 1–6. https://doi.org/10.1109/TEMSCON47658.2020.9140138

[22] Parmenter, D. (2010). *Key Performance Indicators (KPI): Developing, Implementing, and Using Winning KPIs* (2nd ed.). John Wiley & Sons, Incorporated.

[23] Power, M. J., Desouza, K. C., & Bonifazi, C. (2006). *The Outsourcing Handbook: How to Implement a Successful Outsourcing Process.* Kogan Press.

[24] Rolstadås, A., Henriksen, B., O'Sullivan, D., (2012). *Manufacturing Outsourcing: A Knowledge Perspective* (1st ed.). Springer.

[25] Ridgway, V. (1956). Dysfunctional Consequences of Performance Measurements. *Administrative Science Quarterly, 1*(2), 240-247.

https://doi.org/10.2307/2390989

[26] Ruberti, M. (2023). The chip manufacturing industry: Environmental impacts and eco-efficiency analysis. *Science of the Total Environment, 858*(2). https://doi.org/10.1016/j.scitotenv.2022.159873

[27] Slack, N. Brandon-Jones, A. (2019). *Operations Management* (9th ed.). Pearson.

[28] Smith, J.D. (2017). *Reliability, Maintainability and Risk - Practical Methods for Engineers* (9th ed.). Elsevier.

[29] Tang, H. (2018). *Automotive Vehicle Assembly Processes and Operations Management*. SAE International.

[30] Tezel, A., Koskela, L., & Tzortzopoulos, P. (2016). Visual management in production management: a literature synthesis. *JOURNAL OF MANUFACTURING TECHNOLOGY MANAGEMENT, 27*(6), 766-799. https://doi.org/10.1108/JMTM-08-2015-0071.

[31] Tokola, H., Gröger, C., Järvenpää, E., & Niemi, E. (2016). Designing Manufacturing Dashboards on the Basis of a Key Performance Indicator Survey. *Procedia CIRP, 57*, 619–624. https://doi.org/10.1016/j.procir.2016.11.107.

[32] Verhaelen, B. Mayer, F. Peukert, S. Lanza, G. (2021). A comprehensive KPI network for the performance measurement and management in global production networks. *Production Engineering, 15*(5), 635-650. https://doi.org/10.1007/s11740-021-01041-7

A

Interview guide for co-workers

- How long have you been at CPAC?
- What is/have been your role and responsibilities at CPAC?
  - Could you shortly explain a regular day at work?
  - What products do you work with at CPAC?
- What are the biggest challenges you face in your job?
  - How do you deal with the challenges?
  - How do you follow up on your solution?
- What are the department's responsibilities and goals?
  - Why do you have these responsibilities and goals?
- In what way are you dependent on other departments and vice versa?
- Are there any metrics or data that you keep track of in your work?
  - Why do you track these metrics?
  - How often do you use the current metrics?
  - Is there any information you miss? Why do you miss it?
  - How often would you like to be able to use the metrics?
  - How and how often do you communicate the metrics?
  - With whom do you communicate and why?
- Have you previously used or heard of any specific performance measurements that you think could be useful for your role or CPAC in general?
  - Why would they be useful?
- Do you have any performance measures internally?

  - Why could it be useful / not useful?
- Do you use any tools or systems to track the metrics and data?
  - How do you access the data?
  - Where does the data come from?
  - How is the data measured?
  - What challenges do you face in monitoring these metrics?
- Are there any specific products you would like measurements for and why?
  - Do you think that these are already collected somehow?
  - How would you get access to these measurements?
- If you had a way to visualise all your metrics, what would it look like?
  - What would it show?
  - How do you think that it could be used?
- Is there someone you think would be critical for us to speak to considering the content of this interview or to succeed with KPIs?
- Have you reflected on something that you think will be useful for us that we have not asked or talked about?

B

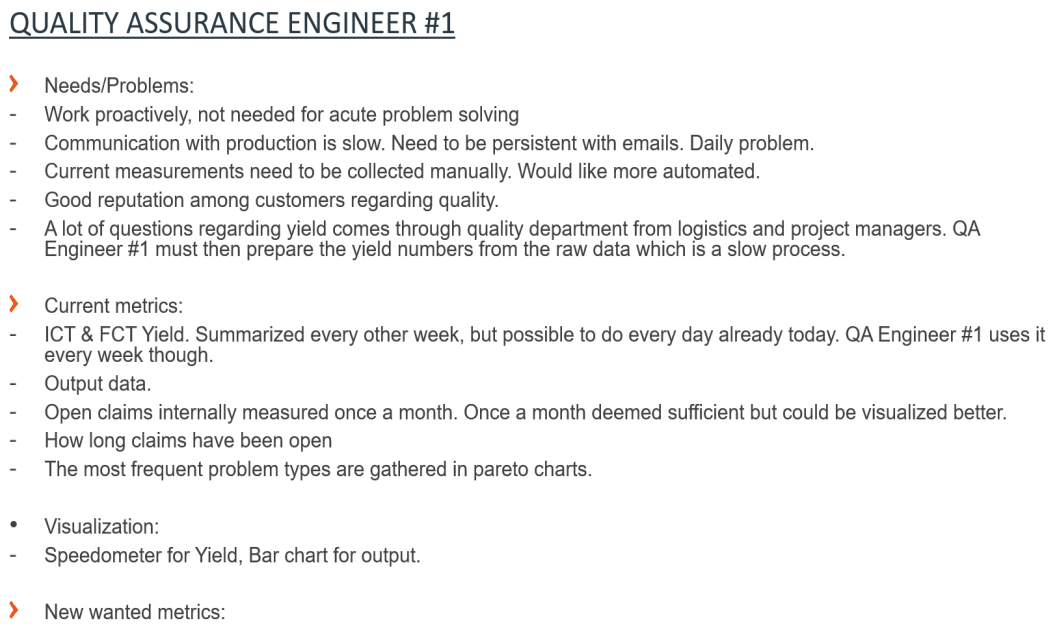
Interview guide for management

- How long have you been at CPAC?
- Considering your role at CPAC, what are your responsibilities and how do you manage and support the organsiation, both up and down?
- What is the business strategy of CPAC?
  - What do you see as the goals of CPAC?
  - Why these?
- Our thesis is with the Operations function. What kind of relation do you have to the function?
  - What kind of input do you get from them?
  - What do you do with the information?
  - What kind of information do you relay back to the function?
  - Is there any input you feel you are missing right now?
- How are the goals you set at management level broken down to the operations function?
- What milestones are set for the Operations department to achieve in the near future?
- How does the operations departments help achieve the overall strategy of CPAC? Specify for each department
  - How do you think one could measure progress of activities that help achieve the overall strategy?
- What metrics or data that you keep track of in your work?
  - Why do you track these metrics?
  - How often do you use the current metrics?
  - Is there any information you miss? Why do you miss it?

  - How often would you like to be able to use the metrics?
  - How and how often do you communicate the metrics?
  - With whom do you communicate and why?
  - Do you track metrics from external actors such as suppliers and customers?
- Do you track metrics for each specific department in the operations function or on an overall level?
- Do you use any tools or systems to track the metrics and data?
  - Where does the data come from and how do you access it?
  - Do you have any issues with accessing the metrics and data?
- Your customer is evaluating you based on 5-6 metrics. What are your thoughts on these metrics?
  - We know that the quality department feels that some of the metrics are unjust. Have you been involved in any of the discussions?
- Have you previously used or heard of any specific performance measurements that you think could be useful for your role or CPAC in general?
- Is there any cross functional communication related to operations departments and R&D that you would like to improve?
- Considering our work on developing KPIs and a dashboard that could guide the company in a certain strategic direction and impact performance; is there something you feel we should consider for our development of the KPIs and the dashboard?
- Have you reflected on something that you think will be useful for us that we have not asked or talked about?

C

Example of one-pager for a interviewee



QUALITY ASSURANCE ENGINEER #1

› Needs/Problems:
- Work proactively, not needed for acute problem solving
- Communication with production is slow. Need to be persistent with emails. Daily problem.
- Current measurements need to be collected manually. Would like more automated.
- Good reputation among customers regarding quality.
- A lot of questions regarding yield comes through quality department from logistics and project managers. QA Engineer #1 must then prepare the yield numbers from the raw data which is a slow process.

› Current metrics:
- ICT & FCT Yield. Summarized every other week, but possible to do every day already today. QA Engineer #1 uses it every week though.
- Output data.
- Open claims internally measured once a month. Once a month deemed sufficient but could be visualized better.
- How long claims have been open
- The most frequent problem types are gathered in pareto charts.

• Visualization:
- Speedometer for Yield, Bar chart for output.

› New wanted metrics:

Figure C.1: Example of a one-pager showing how interview information was summarised for one interviewee.

D

Example of one-pager on department-level

QUALITY DEPARTMENT NEEDS & KPIS

Quality needs	Proposed KPIs
Spread awareness of quality and production problems internally at CPAC	ICT & FCT Yield, but updated in ”real time”.
Make quality a priority at CPAC to achieve good reputation among customers	Produced quantities. Actual output + Planned/Target output
Work more proactively and identify issues and trends earlier	Most common fault type
Increased communication frequency with factories	PPM
Consistent source of information for production issues.	Claim data such as longest open claims, total claims, average time to close claim
Automated data collection solution	Mean time between failures or total downtime

Figure D.1: Example of a one-pager showing how interview information was summarised for a department.

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF SERVICE MANAGEMENT AND LOGISTICS
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY