Benchmark

UNIVERSITY OF TWENTE.

Bachelor of Industrial Engineering & Management

# Standardisation Quality Improvement Process and Management Reporting

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# Preface

Dear Reader,

Before you is presented the bachelor thesis "Standardisation Quality Improvement Process and Management Reporting". The company where this research is conducted is at Benchmark in Almelo between April 2022 and November 2022.

I would like to start by thanking Benchmark for this fantastic opportunity for me to work on an exciting assignment. This opportunity has provided me with multiple learning points that all contribute to my great overall experience at the company. One important figure that played a significant role was my supervisor Arjan Floris and I would like to thank him for always supporting and guiding me.

Furthermore, I would like to thank my first UT supervisor Renata Guizzardi for her support and guidance in terms of academic knowledge during the research. Our conversations were constructive and helpful, which definitely improved the quality of my bachelor thesis. Furthermore, I would like to thank my second UT supervisor Martijn Koot for his support during the past weeks. I really appreciated his additional and high-quality feedback, which made me look at my bachelor thesis from a unique perspective.

In addition, I would like to thank my buddies Stef Kosters and Max Derwig for providing feedback, support, and useful meetings.

Finally, for additional motivation and support, I would like to thank my family and friends for supporting me.

Thank you in advance and I wish you much reading pleasure with my bachelor thesis.

Koen Hobbelink

Enschede, November 2022

# Management summary


This bachelor thesis has been executed in collaboration with Benchmark. Benchmark is a company that offers customers localized research and development services such as industrial design, electronics, mechanical and embedded software engineering, and fast prototyping. Benchmark works with a 7-step process that guides product design and new product launch programs. This allows clients to step in at any point in the development process with their project.

**Motivation:**
Benchmark strives for excellent quality and is a client-based company since it offers services. In the agreements that Benchmark has with its clients, a yield is agreed upon with the client in advance. Therefore, it is up to Benchmark to reach that agreed yield in production; otherwise, it would result in costs or a deteriorating client relationship. Since Benchmark's collaboration with its clients is essential, this should be avoided. This is where the problem starts for Benchmark because they experience a suspicion that there is more space for improvement of these yield processes. According to Benchmark, its managerial dilemma is: "As management, we believe there is significant unused potential in the efficiency of our yield improvement process."

Yield is a performance indicator of how well the production process is going. Thus, if Benchmark is not reaching the agreed yield in their production which is the service they provide, it results in costs since the client receives less product than it has paid for, or Benchmark needs to make more products than was expected. According to Benchmark, this unused potential is confirmed in daily practice by the possible improvements in yield evaluation reports.

**Problem identification:**
The desired situation is where Benchmark has confidence that it is actively optimizing the use of its potential with respect to the efficiency of its yield improvement process. One aspect are the reports' structures, with each responsible employee submitting a report in a different structure. Consequently, causing different results and outputs, costing Benchmark management time to convert it to useful information.

Another essential issue they experience is reactive instead of pro-active behaviour in addressing the yield theme. According to Benchmark's management, reports are often made now when surprising defects occur rather than upfront with defined expectations. Another point they raised was the reporting quality of the yield per project. Benchmark's management initially expressed dissatisfaction with the different forms of reporting. Firstly, different reports require extensive explanations before graphs or diagrams can be thoroughly understood. Consequently, each report uses different visualization techniques of the production performance. At last, the data quality reporting differs per project. As a result, either too much redundant information is provided or too little information. This means that not always the right or valuable information is depicted in the visualizations of the reports. It is essential to determine the right variables that represent correct information and meet the specifications but are not too difficult to understand.

**Main research question:**
The research question aims to fill the current and desired situation gap. Therefore, the main research question is: "How to increase the efficiency of Benchmark's approach to its yield evaluation reports?" Maximizing efficiency enables a company to make the best possible use of the company's resources. First, it examines how to make the yield evaluation report more efficient. Second, because of Benchmark's processes, two different reports are designed for different steps of Benchmark's 7-step process. Finally, these reports are evaluated by the staff responsible for or collaborating with them, as this validates that the reports contribute to Benchmark.

**Solutions:**
The final solution consists of two different reports, responsible for different parts of the seven-step process. Both reports have the same structured approach and the same report objectives. The structured approach is the continuous improvement cycle Plan-Do-Check-Act (PDCA). The report objectives are; evaluate and conclude current yield performance; identify new opportunities for improvement; draw up an action or problem-solving plan; track progress of problem-solving plan; and prediction yield performance for the next report. The Plan phase includes the evaluate and conclude current yield performance objective. The Do phase contains both the identify new opportunities for improvement and draw up an action or problem-solving plan objectives. The Check phase is responsible for the track progress of problem-solving plan objective. At last, the Act phase includes the prediction of yield performance for the next report objective.

Moreover, the same visualisation methods and outputs of data quality are pursued, to make it as efficient as possible. The first report focuses on expected satisfaction level and performance with respect to this satisfaction level. This contributes to a pro-active behaviour for employees to treat and evaluate yield. In contrast, the second report focuses on improving yield to meet the yield target agreed with the client. The reports can optimally be implemented by using supportive documents and easily usable templates.  This is done by providing excel calculations which includes guidelines on how to get the desirable results that should be in the report. The report templates are made as simple as possible by already providing all visualization methods with the corresponding data outputs. For instance, for the evaluation of the current yield performance, an employee can directly see how the visualization should look like and what it should contain.

**Conclusion:**
The validation of the reports is done by a questionnaire performed by two employees from Benchmark. The questionnaire sections are as follows, the introduction, general evaluation, focus on data consistency indicators, implementation, connection to efficiency, and remaining remarks.

The main part is de assessment of the reports against the data consistency indicators, since if these are met, then an efficient yield improvement process is also achieved. These indicators can be provided as questions. For accomplishment it is: “What is Benchmark trying to accomplish with these yield evaluation reports?” In the case of the insight, “What insights will help Benchmark achieve its goals of the yield evaluation reports?” At last, “What decisions can be made supported by the yield evaluation reports?” In conclusion, these indicators are used in the questionnaire to test the data consistency of the reports.

The main result for accomplishment was either agree or strongly agree (6 x agree, 5 x strongly agree). The insight indicator was more distributed (2 x strongly disagree, 1 x disagree, 3 x neutral, 5 agree, 1 x strongly agree). The last indicator was also more distributed (2 x strongly disagree, 1 x disagree, 3 x neutral, 5 agree, 1 x strongly agree). Consequently, the accomplishment indicator is more than adequate. Furthermore, some strong disagrees for both the insights and decision-making was caused by the macro process overviews. By using the feedback, these macro process overviews were transformed into a slide that shows the process flow of a process or process step. In addition, to put it much earlier in the yield improvement report.

The main comment for any suggestions for a better implementation was to improve the how-to introduction of the satisfaction template, since it is more difficult to understand. At last, the question regarding a more efficient solution that the current reports were also considered positively since the results were: 7 x agree, and 3 x strongly agree. In overall, both responses graded the templates as good.

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## Reader's guide

**Chapter 1:**

Chapter 1 introduces the company and contains the problem statement. It starts with the management dilemma and ends with the problems defined to the core. Next, these respective problems are discussed with the corresponding research questions. Finally, this chapter discusses the methodological framework and research design.

**Chapter 2: Theoretical framework**

Chapter 2 provides the theoretical framework of this study. It introduces crucial factors that are basic information to know before the current situation can be examined. First, the concept of yield is defined. Second, the importance of test engineering and test processes is explained. Finally, the concept of defect waste is introduced, as it is part of yield and will eventually form the basis for a range of possible solutions.

**Chapter 3: Current situation**

Chapter 3 discusses Benchmark's current situation, which includes the company's overview, current yield evaluation reports, study relevant observations, and bottlenecks. The objective of investigating Benchmark's current situation is to find out why the core problems are occurring and how the solution can be integrated.

**Chapter 4: Solution framework**

Chapter 4 provides the solution framework of this study. This chapter aims at connecting the core problems with objectives that should be achieved in the yield evaluation reports.

**Chapter 5: Solution choice**

Chapter 5 decides on the solutions that are the best or most suitable for the desirable objectives in the reports. These decisions are based on either shortcoming in the current reports, or management requirements, or general improvement points.

**Chapter 6: Solution implementation**

Chapter 6 discusses how best to implement the new enhanced reports into Benchmark's current processes and procedures. This chapter presents the solutions with supporting documents to guide staff in the proper use of the reports.

**Chapter 7: Solution evaluation**

Chapter 7 evaluates the solution using a questionnaire that tests the desired report objectives against the indicators of the norm. This means that if the results are positive, this proves that the improved reports from this study contribute to Benchmark.

**Chapter 8: Conclusions and recommendations**

Chapter 8 describes the summary of conclusions for each part of the research. In addition, also the recommendations of this study are included. At last, this chapter ends with the provision of directions for future research.

# Chapter 1: Introduction

The introduction chapter aims to introduce the starting point of this bachelor thesis and describe how this led to a research study. Furthermore, this chapter will focus on translating this starting point in terms of a managerial dilemma into a concrete, tangible problem. The last part of the introduction is concentrated on creating a research approach to tackle the respective problems and creating a research design on how to collect data regarding the problem.

Furthermore, section 1.1 introduces the company, section 1.2 discusses the problem identification, section 1.3 discusses the measurement of the core problem(s), section 1.4 contains the research approach, and section 1.5 includes the research design.

## 1.1: Benchmark

The bachelor assignment has been done in collaboration with Benchmark. Therefore, this section will introduce Benchmark and explain its services. Furthermore, Benchmark's managerial dilemma is defined as the leading cause of this Bachelor thesis. This also includes a confirmation of the managerial dilemma to verify whether there is an actual problem.

### 1.1.1: The company

Benchmark is a company that offers customers localized research and development services such as industrial design, electronics, mechanical and embedded software engineering, and fast prototyping. Therefore, Benchmark's Quality Management System (QMS) intends to combine all the product life cycle elements from conception through production, including quality, cost, and maintenance. In practice, Management Processes, such as a Quality Manual, Risk & Quality Management, Management Review, KPIs, and Continuous Improvement, should ensure the quality of the production processes.

Benchmark is a company constantly trying to develop its business and increase the quality of its products. Additionally, Benchmark is situated in a market that requires high-advanced engineering; even though it has been shown to provide excellent quality, they are motivated to continue its development.

### 1.1.2: Managerial dilemma

As already mentioned, Benchmark strives for excellent quality and is a client-based company since it offers services like industrial design, prototyping, and production but does not own products. In the agreements that Benchmark has with its clients, a yield is agreed upon with the client in advance. Therefore, it is up to Benchmark to reach that agreed yield in production; otherwise, it would result in costs.

To know why this results in costs, the concept of yield must be introduced. Generally, yield refers to the percentage of non-defective items of all produced items (Chiang & Kawa, 2010). The main aim of yield is to detect failures in the system and be a performance indicator of how well the production process is going. Thus, if Benchmark is not reaching the agreed yield in their production which is the service they provide, it results in costs since the client receives less product than it has paid for.

This shows the importance of yield for Benchmark, because if the yield agreed with the client is not achieved, it can lead to another negative effect. Namely, a deteriorated client relationship, which may cause the client to decide not to do business in the future. Since Benchmark's cooperation with its clients is essential, this must be avoided. Therefore, Benchmark is constantly trying to improve the yield processes of its products.

This is where the problem starts for Benchmark because they experience that there is unused potential in these yield processes. According to Benchmark, its managerial dilemma is: "As management, we believe there is significant unused potential in the efficiency of our yield improvement process."1.2: Problem identification

The problem identification's objective is to find the core problem of why Benchmark's management feels uncomfortable with the efficiency of their yield improvement process. A core problem is a selected problem to solve that suit correctly with the available resources and time (Heerkens & van Winden, 2021). First, this identification starts with stating the action problem, which is the gap between having an inefficient yield improvement process now and a thoroughly efficient yield improvement process (Heerkens & van Winden, 2021).

### 1.2.1: Action problem

**Definition:**

The action problem is the discrepancy between the desired and current situation (Heerkens & van Winden, 2021). The desired situation is where Benchmark is fully confident with the efficiency of its yield improvement process, while the current situation is Benchmark's managerial dilemma. So, there are two possibilities, either the efficiency of the yield improvement process has a potential benefit, or the process is efficient, but Benchmark's management is dissatisfied for some other reason they are unaware of.

**Identification:**

To know which problem is occurring, a look should be made towards why Benchmark thinks its process could be more efficient. Their first reaction was that the entire process around the yield evaluation is not optimal, especially the yield evaluation reports. One reason they say it comes through the yield evaluation reports is that they experience several issues or discomforts.

One aspect that on which Benchmark can act better are the reports' structures, with each responsible employee submitting a report in a different structure. Examples are the Plan-Do-Check-Act (PDCA) cycle and the Define-Measure-Analyse-Improve-Check (DMAIC) cycle. Consequently, causing different results and outputs, costing Benchmark management time to convert it to useful information. Consequently, employees within Benchmark would better be thinking about their yield improvement process.

Another essential issue they experience is the responsible employees' reactive behaviour to evaluate yield. According to Benchmark's management, reports are often only made when defects occur, or the yield threatens to become too low. Two problems can be identified here: firstly, responsible staff waits too long to evaluate, whereas if these staffs were to do this earlier, these defects could have been prevented. The second problem is when the yield threatens to be too low, which can happen, for example, when it must go into production at a specific time. This means that earlier in the process, the yield was not improved enough or not assessed enough. If this were the case, a conclusion could already be drawn that the deadline was not feasible, and countermeasures could be drafted.

According to Benchmark's management, "What we see happening is that we are regularly shocked afterwards by a lower-than-expected yield in production. This while we can also very well ask ourselves why we would expect a higher yield in the first place. The scare manifests itself in different forms, and from everyone's role, this produces opinions, expressions, and actions. By thinking about this better beforehand and making our expectations more realistic, we can act better as a group is our expectation."

The last point they raised was the reporting quality of the yield per project. Benchmark's management initially expressed dissatisfaction with the different forms of reporting. Firstly, different reports require extensive explanations before graphs or diagrams can even be understood. This means that how it is being reported differs, which results in each report using different visualization techniques of the yield. Secondly, the data quality reporting differs per project. As a result, either too much redundant information is provided or too little information. This means that not always the right or valuable information is depicted in the visualizations of the reports. It is essential to determine the right variables that represent correct information and meet the specifications but are not too difficult to understand. In conclusion, the problems and core problems that are encountered are:

- Sub-optimal process of yield evaluation reports
    - Unstructured approach per report
    - Wait-and-see response to evaluate yield
        - Lack of preventive thought to increase yield
        - Lack of awareness of yield development during design phases
    - Different reporting quality per project
        - Visualization methods differ per project
        - Data quality reporting differs per project

**Efficiency:**
So, this study must look at three aspects before concluding whether management's discomfort stems from the lack of efficiency of the yield improvement process or comes from somewhere else. This is important because it prevents increasing efficiency without removing discomfort. Therefore, it is important to demonstrate the identifications of Benchmark, but also connect them to the concept of efficiency. The first step is to find the definition of process efficiency. The second step is to confirm these identifications, for which the first part is conducted through a "quick and dirty" survey described below. The second part delves deeper into this evidence and examines what the real problem is, which is described in Chapter 3. The third step is the actual link between efficiency and the core problems. This is the desired outcome, since if a core problem is solved, then the efficiency improves and discomfort decreases. This is also described in Chapter 3.

- Definition and objective

First, a general definition of the efficiency of a process is necessary to define. In general, the definition of process efficiency is the amount of effort or input required for a company to produce a product. Efficiency for a company is essential because maximizing efficiency enables a company to make the best possible use of the company's resources. Since efficiency is focused on minimizing costs and maximizing profits for a given output level.

- Proof of Benchmark's identifications

The next step is a "quick and dirty" survey to check whether the proposed core problems occur in the company. According to (Heerkens & van Winden, 2021), a "quick and dirty" survey means: "a rapid, uncomplicated or existing inventory of existing data and perspectives made without performing research." Below is a table describing which resource is used to find that respective core problem.

| Core problem: | Source: |
|---|---|
| Unstructured approach per report | Yield evaluation reports |
| Visualization methods differ per project | Yield evaluation reports |
| Data quality reporting differs per project | Yield evaluation reports |
| Lack of preventive thought to increase yield | Company's supervisor |
| Lack of awareness of yield development during the design phases | Company's supervisor |

*Table 1: Sources core problems*

### 1.2.2 Problem cluster

**Definition:**

The purpose of the problem cluster is to visualize and clarify the causes and effects between the action problem and core problems tackled in this study. According to (Heerkens & van Winden, 2021), core problems are organizational problems that can be classified as urgent, and their solutions could make a real difference for the company. Therefore, in this study, it is essential to identify the core problems to see what could positively contribute to an increase in efficiency.

**Visualization problem cluster:**

The problem cluster is visualized in Figure 1.

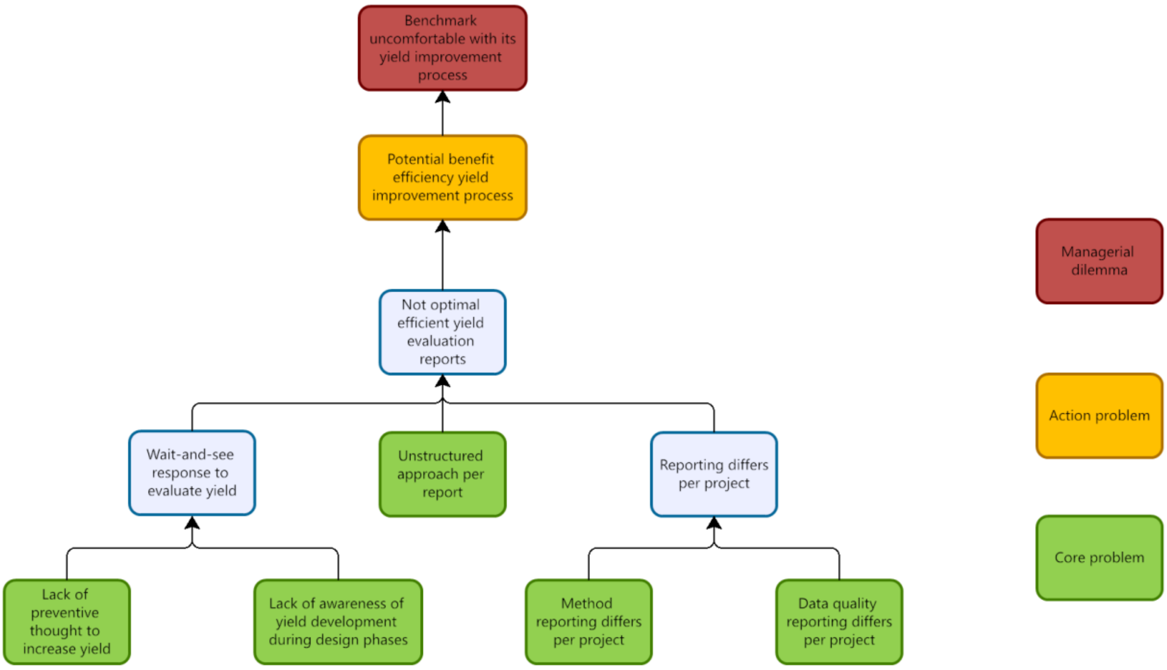



*Figure 1: Problem cluster*

The red block is Benchmark's managerial dilemma, the yellow block is the action problem, and the green blocks are the core problems. From top to bottom, the start is the managerial dilemma, which is: "Benchmark uncomfortable with the efficiency of its yield improvement process." Benchmark is uncomfortable with the efficiency of its yield improvement process since the following three points are occurring: unstructured approach per yield evaluation reports, reporting differs per report, and wait-and-see response on yield improvement using evaluation reports. The unstructured approach per report is a core problem. The other two's can be further levelled down. The wait-and-see response has two reasons: the lack of preventive thought to solve defects and the late awareness of yield development.

The reporting differs per report, and they are as follows: method reporting differs per report, and data quality reporting differs per report. The reasons why these connections exist are explained in previous sections.

### 1.2.3: Core problem motivation

The problem cluster shows that there are five core problems. The ideal situation is to provide a solution that tackles them all. So, to start from the beginning, four main aspects must be considered for each core problem to decide which core problem(s) to solve. These are as follows: relevance, ensuring that the core problem occurs, solving problems without direct cause; Influence, being able to influence and change the core problem; Importance, choosing the most important one (Heerkens & van Winden, 2021).

Relevance is vital to consider because solving a problem that does not occur will not significantly affect the desired situation and will be a waste of time. Causality is essential because solving a problem with other causes without solving those specific causes will result in a sub-optimal or not even a helpful solution. Finally, having influence is necessary because otherwise, it is not feasible to solve the problem, e.g., changing entire organizational structures. At last, the more critical the core problem is, the more it affects the action problem and the managerial dilemma, and the more gains can be made.

Regarding relevance and causality, as section 1.2: Problem identification proves, each existing core problem has no direct cause. In the case of influence, it is possible to produce advice on which structure or approach and suggestions on which methods and data quality improvements for reporting to use. However, it is different for improving preventive thought and creating awareness of yield development. Since this partly concerns other human thinking, which could be challenging to influence. At last, regarding the importance of the core problems, the rule is to choose the core problem whichever one whose solution would have the greatest impact effect at the lowest cost.

In this study, it would mean that the core problem: “unstructured approach per report” is the most important. The other core problems are logically influenced when choosing an approach. Therefore, it makes more sense to choose the structure of the yield evaluation report first and then adjust the other core problems accordingly. The order of the other core problems is to focus first on the reporting part since I would be able to have more influence instead than changing people behaviour.

## 1.3: Measurement core problem(s)

The next step is to establish a link between the action problem and core problems. So that eventually, based on this connection, it can be concluded whether this research provided improving advice. This is done by looking at how the core problem(s) can be measured.

### 1.3.1: Variables

There is a demonstrable potential benefit to the efficiency of yield evaluation reports. Moreover, there is a direct link between the efficiency of these reports and the efficiency of the yield improvement process. All this ensures that if the efficiency of these reports is improved, the action problem and hence discomfort decreases. This means that the efficiency of these reports can be considered a variable.

As to make the connection complete between the action problem and the core problem, the question is how to quantify the core problem: unstructured approach per report? The answer is to look at what Benchmark would like to see improved about this core problem. What is striking about the core problems is that in three of the five, having differences is a problem in terms of reporting. This is obviously due to the many different projects Benchmark has. Therefore, it would be convenient to look in the direction of standardizing the reporting process to improve the efficiency.

Well, according to (Kondracki, 2019), A key aspect of a standardized reporting process is data consistency. This article gives the following reason, standardized reporting aims at producing consistent, reliable, actionable information from disparate systems or sources. In accordance with the same source, a standardized report can achieve data consistency by having three indicators, which are as follows: “accomplishment”, “insight”, and “decision-making”. The best way to understand these indicators is by providing it as a question. For accomplishment it is: “What is Benchmark trying to accomplish with these yield evaluation reports?” In the case of the insight, “What insights will help Benchmark achieve its goals of the yield evaluation reports?” At last, “What decisions can be made supported by the yield evaluation reports?”

### 1.3.2: Norm

In this context, the norm is the level the action problem would like to reach (Heerkens & van Winden, 2021). For instance, if the action problem is measured in revenue increase, the norm could be 10% because an action problem only has 5%. Therefore, this research has the action problem: a potential benefit for the efficiency of the yield improvement process. In section 1.3, variables are described on how to measure the efficiency of Benchmark’s yield improvement process.

Thus, the norm represents the desired situation with solving an structured approach per report for sure, and optimally to solve all core problems afterwards. By measuring the norm in terms of the core problem, this study can validate whether the solution helps achieve the desired situation. However, indicators were qualitative data types; this is important to keep in mind for validating solutions to see if the norm has been met.

Therefore, the norm of this study is that the yield improvement process is efficient. In this study, efficiency can be gained through standardized reporting, which means that each core problem solution should be data consistent. So, if the solution of each core problem includes all three data consistency indicators, then the desired situation can be reached.

## 1.4: Research approach

The research approach will describe the scope, methodological framework, deliverables, and research questions. As a result, the research approach should form a framework from which this study operates and is guided.

### 1.4.1: Research scope

**Topics:**

The research scope aims to limit and set focus points for the research. So, the question is which topics should be focused on and why. First, it is essential to look at the action problem and break it down into individual components. In this way, it becomes clear what each point means. Therefore, the concept of yield should be investigated with subjects or factors that hugely influence the yield. Another topic is the efficiency of a process, where the investigation should concentrate on finding how to use the data consistency indicators and when the potential benefit is reached.

Secondly, possible solutions that would improve the efficiency of the performance review reports and the entire process should be investigated. To know which direction to investigate, an excellent first step is to look at current approaches of the reports. The next step is to find the standard structured approach. Finally, the standard structured approach combined with Benchmark’s requirements, wishes, and current shortcomings should result in an overall topic. This overall topic should provide alternative designs, implementations, and evaluation plans.

**Research boundaries:**
The scope explains which research areas this study will cover and indicates the limits of the research. Given my capabilities as an industrial engineer and the topics I have encountered during this study, it is essential to set boundaries. These boundaries come in different forms, one of which is what aspects and how deeply I will research specific topics that might be relevant to this research.

Benchmark, for example, is an electronics company with many employees with an electrical engineering background. For this research, it is interesting what the test engineering process looks like, especially their influence on the yield. However, from my point of view, it is not realistic to look at the machines from a technical perspective. This limits my ability to see when a product is repairable if it does not pass an electrical test or must be scrapped instead.

Another point is that I do not have to interfere with the choice of specific test equipment during the test. This includes some of the technical expertise from mechanical engineering, which I do not know. So, for aspects that concern mechanical engineering, most points are the same for electrical engineering. It is interesting to see what kind of mechanical engineering procedures influence yield. However, advising about the content of their procedures or deliverables is highly likely to be a waste of time.

### 1.4.2: Methodological framework

**Definition:**
I want to introduce the methodological framework, which will be the structure of this study to find a solution. The Managerial Problem-Solving Method (MPSM) is a problem-solving method that provides a path to a solution (Heerkens & van Winden, 2021). The MPSM is a continuous problem-solving approach divided into seven steps.

**Argumentation:**
The MPSM is not a only methodological framework that can be used as a path to find a solution for this study's issue. I choose to use the MPSM because even after exploring and formulating the core problem, good problem analysis is still necessary to find helpful solutions. Furthermore, the benefit of the MPSM is that it can be used in every situation at any time. Namely, the MPSM is a general method applicable for various problems encountered in various situations in all areas of expertise.

Another benefit of the MPSM is evaluating different solutions for the problem. Especially in this study, there could be multiple possible solutions to the various core problems. Therefore, the MPSM could help evaluate the different options to choose the best option, while other methods lack this step.

**Limitations:**
The downside of having a general method is that the broadness and inclusivity of different aspects could make the study too broad. This is a pitfall that should be considered while performing the different steps. In practice, if the core problem is well defined, a more suitable method can be chosen to find a more qualitative solution.

Another pitfall is that the MPSM is used too literally because the MPSM is meant to be a guideline for the study to work structurally and to evade hasty decisions. However, it becomes a limitation if all the provided steps are followed literally. The reason is that some steps cannot simply be done in each research.

**Steps MPSM:**
The MPSM is divided into seven steps, depicted in Figure 2, which is a circular method. Each step indicates what each step entails and what tasks will be performed to ensure that the core problems are solved.

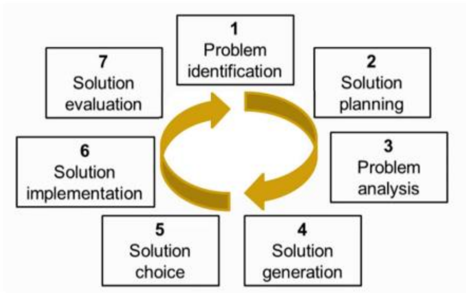



*Figure 2: MPSM method*

**1. Problem identification:** The problem identification phase is already performed in the previous section. The aim was to find if the managerial suspicions were true by searching for confirmation through a "quick and dirty" study. To solve the managerial suspicions, the core problem must be found through structurally levelling down the action problem using a problem cluster. The problem identification's connection with the solution of the core problem is that the problem identification finds the core problems. After that, it chooses the solvable core problem based on time and resources. The problem identification is already performed in sections 1.1 and 1.2.

**2. Solution planning:** Solution planning defines the solving problem approach, where the MPSM method is used as it contains a complete guide for implementing a solution. Solution planning aims to define the strategy that finds the correct information in the right place. This right place combines the topics described in section 1.3: Research scope and factors that affect the efficiency of Benchmark's yield improvement process and the yield evaluation reports. In addition, the solution planning contains the deliverables, the sampling design, the data gathering methods, and the data analysis. The sampling design, data gathering methods, and data analysis will help this study to find the correct information. This report divides the solution planning into several parts, e.g., in section 1.4.

**3. Problem analysis:** The problem analysis is a bundle of three chapters. Namely, chapters 2, and 3 are preparation for clarifying definitions of the yield, investigating Benchmark's current situation, and proposing possible and suitable solutions. All this information will form arguments in the next chapter to decide which solution is preferable.

**4. Solution generation:** The solution generation phase looks at possible solutions from the problem analysis phase. Therefore, it is necessary to determine the criteria to which the solutions should be weighted and scored. These specifications would like to be the result of Benchmark's requirements and shortcomings. The next step is to decide which scoring system to use that assign, e.g., grades to the possible solutions. This choice depends on how difficult or easy it is to say something about the precision between the solution and criteria. Since a grade between 1 and 10 is much more precise than 1 to 5 but is also more challenging to assign. The solution generation is described in chapter 4 of this report.

**5. Solution choice:** To be able to choose the solution, the needs of those involved must be included in the process to check whether the desired requirements are by the criteria assigned. Therefore, conducting interviews with the employees affected by the solution is essential.

The aim should be to find the best possible way in which the solution can contribute to Benchmark's shortcomings, be helpful for the employees, and reduce Benchmark's discomfort with their yield improvement process. There may be a difference between the advice on how a solution should be implemented theoretically and practically. This difference can be bridged by listening and talking to the relevant stakeholders. The solution choice is described in chapter 5.

**6. Solution implementation:** The aim of the solution implementation is that the proposed solution works with Benchmark's current systems and tools. Therefore, Benchmark's current systems and tools should be investigated before and considered during the solution generation and choice. Another activity that should be done in the implementation is creating a deliverable usable for the relevant stakeholders. The solution implementation is described in chapter 6.

**7. Solution evaluation:** The evaluation of the solution focuses on three aspects, namely checking whether the objectives have been achieved, identifying the possible effects of the solution, and assessing whether there is still room for improvement. Therefore, involving the stakeholders in the process and getting constructive feedback is important. This can be achieved by validating the proposed solution, for example, in the form of a questionnaire using the solution. These validation methods should test how the solution deals with the requirements of Benchmark and how it relates to the established efficiency metrics. The solution evaluation is described in chapter 7.

### 1.4.3: Research questions

**Main research question:**

Theoretically, the leading research question aims to fill the current and desired situation gap. Therefore, the main research question is: ***"How to increase the efficiency of Benchmark's approach to its yield evaluation reports?"***

To answer this question, the MPSM is introduced as a framework but still needs sub-research questions to guide what kind of information is exactly necessary. Hence, these sub-research questions serve as sources of information for this research. At each stage, new information is gathered, which, in sum, forms an answer to the main research question.

**Sub-research questions:**

The MPSM phases 1 and 2 are under chapter 1. Due to the report's order, problem identification is needed before research questions can be drafted. Hence it is illogical to develop sub-questions for this. For the solution planning, the question is: **"How should the data gathering strategy be set up?"**

MPSM phase 3 includes chapters 2 and 3, and this is the theoretical framework and Benchmark's current situation. This chapter aims to obtain information regarding yield since the efficiency of the yield evaluation reports should increase. Therefore, yield is a crucial indicator that should be well defined. This leads to the following research question: **"What are key factors affecting yield improvement and yield evaluation reports?"** It is important to note that yield is important and the factors that influence the entire yield improvement process. Therefore, it is important to look at how certain factors affect yield and act within the Benchmark for the current situation. This has led to the following research question: **"How are these key factors working within Benchmark?"**

Furthermore, to develop a proposed solution, the Benchmark's current situation should provide requirements, wishes, and shortcomings, which are partly based on the other core problems. Therefore, the last research question is: **"What are possible solutions that could probably contribute to the efficiency of the yield evaluation reports?"** It is important to find various solutions so that these can be scored against the before-determined criteria. These criteria points come from Benchmark's requirements or shortcomings and possible solutions for the core problems.

The sub-research questions devoted to the MPSM phases 4 and 5 also include this thesis' chapters 4 and 5, generation solution and solution choice. Here, it is important to choose a solution that has been decided through a well-defined and critical method. The aim is to clearly distinguish the solutions as precisely as possible, based on the criteria scores. Hence, the research question is: **"What is the decision-making process that delivers the proposed solution?"** A pre-determined preferred solution may win if the decision-making method is not well-defined or critical.

Then for the solution implementation chapter, this research will propose the final solution, and thus the research question is as follows: **"How should the final solution look like?"** However, such as the chapter's name suggests, it is not only focused on the solution but also the implementation. Therefore, the research question for the implementation of the proposed solution is: **"How can the proposed solution optimally be implemented?"** For the implementation question, the solution for the efficiency of the yield evaluation reports must be well implemented. Since the implementation phase is the bridge between a theoretical solution and becoming a practical solution. In addition, it will be used by employees from Benchmark and if they do not know how to work it, it may be not used.

MPSM phase 7 contains the evaluation of this thesis' chapter 7. This is as follows, **"How can the proposed solution be evaluated?"** The evaluation question focuses on the validation of the proposed solution. This is the final check of whether the practical solution improves the efficiency of the yield improvement process.

## 1.5: Research design

The research design aims to describe the strategy used for gathering data and information and from whom. This chapter tries to answer the following research question, **"How should the data gathering strategy be set up?"** The answer provides a method on how to get knowledge effectively. Therefore, the first step is to set up the deliverables. Next up, the sampling design is provided to ensure information obtainment. At last, the data gathering, and analysis methods are offered because they focus on how to get that information correctly.

### 1.5.1: Deliverables

Generally, a deliverable is a concept used to describe the quantifiable goods or services that must be provided upon the completion of a project (Bloomenthal, 2022). This study will provide each MPSM phase with a deliverable that acts as a milestone for the project.

**Problem identification:** The first MPSM deliverable is a problem description that starts from a managerial dilemma to a solvable well-defined core problem. For this research, the improvement is to have a real problem that, if well solved, ensures the efficiency of the yield improvement process.

**Solution planning:** The solution planning's deliverable is a strategy for this thesis' research, which includes the identification of where, how, and what information is retrieved. The improvements I will envision will originate from the observations of the design and manufacturing process, meetings about the yield evaluation reports, and questionnaires about potential requirements, wishes, and shortcomings.

**Formulating solutions:** This phase consists of three parts. First, essential information about the yield and relevant factors. Secondly, the current situation of the Benchmark is to identify what a solution should look like. Thirdly, proposing different workable solutions. These deliverables aim to define the general understanding of yield and influence from other factors. The objective of investigating Benchmark's current situation is to find out why the core problems are occurring and how the solution can be integrated. The proposal of different solutions aims to have a range of solutions, each with its benefits and limitations.

**Solution generation:** This phase includes a well-defined and critical decision-making process based on Benchmark's requirements and shortcomings, solutions for the core problems, and theoretical background. In this phase, the improvement envisioned is being able to choose the best solution objectively.

**Solution choice:** This phase describes the final solution, which should be the best, considering the requirements, shortcomings, and solutions for the core problems. Hence, the proposed improvement in this phase is a solution that aims at improving the efficiency of the yield evaluation reports. Consequently, this could improve the efficiency of Benchmark's total yield improvement process.

**Solution implementation:** This phase describes optimally implementing the solution as a structured approach in Benchmark's system. Why optimally? Because the implementation considers critical issues that make it possible that the solution can be used during regular workdays.

Therefore, the improvement is to provide a structured approach, in terms of a tangible solution, that actually improves the efficiency of the yield improvement process.

**Solution evaluation:** This phase contains an evaluation of the solution and evaluates whether the solution contributes to improving efficiency. Hence, the improvement of this research is validating the solution and use for Benchmark. The validation reflects on the efficiency indicators using a, e.g., questionnaire or testing the solution under experimental conditions.

### 1.5.2: Sampling design

A sampling design is a well-defined plan for obtaining a sample from a given population. A sample from a given population is a subset selected from the population that represents the population and is suitable for research. This means that the sample must be reliable and appropriate for research.

Benchmark is active in many different markets and stages of product development in design engineering and manufacturing. As a result, Benchmark has many different projects, and it is impossible to investigate them all. As a solution to reduce the population, this research introduces a New Product Introduction (NPI). This takes a concept from an initial working prototype to a fully refined and consistent final product (Haque & James-moore, 2004). The choice of a particular NPI was made based on the product development time corresponding to the duration of this study. This allowed this study to follow all the steps involved in such a process. This makes it a perfect example to observe how the process of improving yield is approached in a NPI process. For confidentiality reasons, it is impossible to mention the company, the project, or the product(s) from this NPI.

The great advantage is that it can provide an in-depth visualization of the process of improving a product's performance and of the shortcomings in the yield evaluation reports. Moreover, this can also shed light on other engineering and production aspects and processes within Benchmark. This way, I can identify other essential aspects that may impact yield efficiency.

### 1.5.3: Data gathering and analysis methods

Before deciding which data gathering methods are suitable for this study, the first step is to determine the necessary information. Given the construction of how the formulation of solutions is built up, this study has three primary information sources:

1. All the information regarding yield and their relevant factors.
2. Benchmark's current situation, requirements, and shortcomings in terms of core problems.
3. The various proposed solutions tackle all the yield and current situation issues in their respective ways.

The first part is a theoretical section in terms of a literature study investigating yield and relevant factors. The second part requires other data gathering methods to determine Benchmark's issues. For instance, observations on the manufacturing of a product, which could show specific factors affecting the yield. Meetings can be beneficial to find out why the core problems are occurring and how they can be solved. Another important data-gathering method for investigating Benchmark's current situation is to look at its current documentation and procedures. This is useful for discovering if several methods already exist at Benchmark and for finding gaps between the desired and undesired situation. The last part provides possible solutions, which combine observing the current and theoretical approaches from the literature. Observing the different current structures of the yield evaluation reports is important because it is possible that a reasonable approach already exists. The literature study is good for finding more suitable solutions if there are any.

The last phase that needs a data gathering method is evaluating and validating the solution. Both questionnaires and meetings are suitable because both methods discuss the quality of the solution with stakeholders that either uses it or are affected by it. Information and data collection from the meetings, observations, and questionnaires must be analysed. The last parts already explain which various data gathering methods are used. The analysis methods to analyse the data are tools used, such as MS Excel or tools from Benchmark.

# Chapter 2: Theoretical framework

The theoretical framework's aim is to provide a framework consisting out of information that is going to help to understand the problem and Benchmark's current processes. The research question that will be answered in the theoretical framework is: ***"What are key factors affecting yield improvement and yield evaluation reports***?" So, the research question suggests to first find out what theoretically yield improvement and evaluation means and what it should mean according to the theory. This is in line with Benchmark's desire to find an overall and clear definition of the yield.

In the case of the sections, section 2.1 introduces the concept of yield, section 2.2 introduces the topic of test engineering, section 2.3 describes the definition of defect waste, and it ends with section 2.4 with this chapter's conclusion.

## 2.1: Yield

To start off, it is important to introduce the concept yield. Especially since yield is a general term and many different variants exist. It is therefore important to know which variants are interesting for this study and eventually for Benchmark.

### 2.1.1: Definition

In general, yield is the ratio of the number of good units of a manufactured product that meets all the performance, power, functionality, and quality specifications of the product to the total number of manufactured units (Chiang & Kawa, 2010). Hence, the higher the yield, the fewer defective items, the less waste there is.

So, the question is, what yield metrics exist that accurately reflect the performance of the process? There are four types of yield: First Time Yield, Final Yield, Throughput Yield and Rolled Throughput Yield (Team, 2022). Figure 3 shows these four metrics in a matrix where they are broken down by accuracy and cumulative. Accuracy is a metric that represents the inclusion of hidden factors, such as rework and delays. The higher the accuracy, the less hidden factors exist other than a product passing through a process step defect-free in the first time. Cumulative represents the fact whether the metric is showing the entire process flow or a process step.

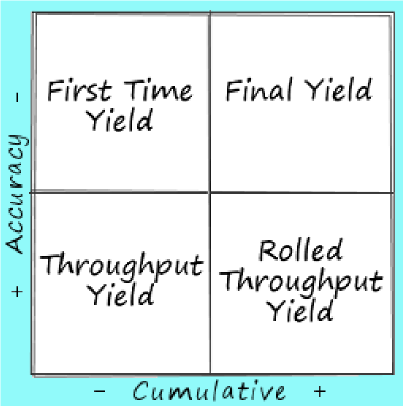



*Figure 3: Matrix different yield metrics*

- First Time Yield is obtained by dividing the number of units of good products by the total number of units that entered the process in each process step.
- Final Yield is obtained by counting the number of units of product that passed the last step divided by the total number of units that entered the process.
- Throughput Yield or First Pass Yield is the probability that a unit of a product or service passes a given process step without failure. Only the good units that passed through a process step the first time without failure are considered.
- Rolled Throughput Yield is obtained from the cumulative effects of inefficiencies found throughout the process. In other words, it indicates the probability that a process consisting of several steps will produce a unit free of defects.

Given the matrix, the First Time Yield and the Final Yield are certainly the least accurate, since they do not consider rework or delays in their calculations and thus do not fully reflect the correct quality. Correct quality is seen as a metric where products are right in the first time of their production. Products that need repair or rework did not have the correct quality and therefore do not meet this criterion. The Final Yield is cumulative, as it calculates the yield over the entire process, whereas the First Time Yield concentrates on one process step. This contrasts with the First Pass Yield and the Rolled Throughput Yield, which do take account of rework. The First Pass Yield only relates to a particular process step, whereas the Rolled Throughput Yield relates to the entire process. Since the First Pass Yield and the Rolled Throughput Yield are more accurate than the other two, the combination is a perfect match to see the measure the yield performance per process step but also for the entire process.

### 2.1.2: First Pass Yield

**Definition:**

The key variable that expresses the current situation and norm is the yield. The First Pass Yield (FPY) is the variable for the yield and stands for the number of products coming out of a process divided by the number of products going into the process over a specified phase of time (Mohan et al., 2012)(Stadnicka & Litwin, 2019), and the FPY is calculated as follows, $FPY = \frac{N_{PO} - N_{PR}}{N_{PI}}$. The main indicators, that are affecting the yield percentages, are retrieved from the formulas of the FPY. This calculation and definitions of variables are as follows:

- $PI = N_{PI}$ = the number of products that go into the process
- $N_{PS}$ = the number of scraped items
- $N_{PR}$ = the number of reworked items
- $N_{PO}$ = $N_{PI} - N_{PS}$ = the number of good quality products that go out of the process

The FPY is a metric that captures all the inefficiencies and failures from their exact location early in the process. Therefore, the FPY is not about improving quality but ensuring the right quality.

### 2.1.3: Rolled Throughput Yield

**Definition:**

The RTY is defined as the product of First Pass Yield values from all the steps in a process to produce a product or service (Graves, 2002). In general, the RTY estimates the probability that a unit passes through a process detect-free, regardless the type. The RTY's calculation is $RTY_j = \prod_{j=1}^{k} FPY_j$, $FPY_j$ is the proportion of units good at step j in a multistep production process and represents rework or scrap for sequentially processes. For parallel processes, the RTY is the minimum of all the individual processes operating parallel. Therefore, the formula is as follows, $RTY_j = \min\left(\prod_{j=1}^{k} FPY_j\right), FPY_j$ is the proportion of units good at step j in a multistep production process and represents rework or scrap. The RTY is a good metric to overcome the limitations of the FPY in determining the overall efficiency and failures in a process.

## 2.2: Test engineering

Opening the FPY and RTY formulas reveal several components. One of the most important ones is the number of good-quality products that pass the process the first time. The question is then what causes this and how is this number determined. This number comes from the process testers, who decide whether a product passes or fails. In this section, the importance of test engineering will be discussed and how this will affect my research. Therefore, it starts with the definition of test engineering, then its objective, and lastly the test coverage which is an important metric for test engineering.

### 2.2.1: Definition

Test engineering in electronics is the basic knowledge of the design and conduction of testing on concepts, techniques, hardware, and software (Absher, 1991). This includes an extensive list of functions such as compliance (specifications and standards), performance (capabilities and limitations), suitability (technical and operational), applications (functional usage), production (quality), operational (employment), and documentary (operations and maintenance).

### 2.2.2: Objective

Test engineering aims to evaluate the quality of a product and improve its quality by identifying defects. Therefore, several levelled-down objectives primarily focused on evaluating and verifying requirements, preventing, and identifying defects, and delivering high quality to the stakeholders. It is important to consider test engineering and thus the test steps in a process since these processes decide whether a product is a defect or non-defect item.

So, it is important to consider Benchmark's test processes since they measure the yield. If the yield is not correctly measured, then it is also not possible to find out the truest yield of a project and the performance of a testing step. This also means that the order, e.g., series or parallel, of the testers is important, which affects how the RTY is calculated.

### 2.2.3: Test coverage

The study of (TestView, 2010) defines test coverage as fault coverage and describes fault coverage as "the ratio of detectable faults to the total number of faults". Test coverage has a range of applications that suggests a relationship between test coverage and reliability (Malaiya et al., 1994). In hardware, test coverage is measured in terms of number of possible faults covered (Malaiya et al., 1994). For instance, 80% test coverage means that the tests applied would have detected any one of the 80% faults covered.

## 2.3: Defect waste

Moreover, the FPY and RTY also reveal other important components such as the number of repaired items and the number of scrapped items. Now the question is under which general area these two components belong, because then the focus can be shifted, and new information can be gathered to create a completer framework. According to (Biwas, 2021), repairs or scraps are covered by the term: defect waste. In this section, the importance of defect waste is being discussed and how this could affect yield. Therefore, it starts with the definition, and it continues with the introduction of important defect waste characteristics.

### 2.3.1: Definition

The definition of defect waste is: "repair or rework of a product or service to fulfil customer requirements as well as scrap resulting from materials deemed to be un-repairable or un-reworkable". Defects result in customer dissatisfaction, because these un-repairable or un-reworkable products do not conform to specification or to customer's expectations. The last important aspect in terms of definition is the difference between a product being defective or having defects. Namely, a product can only be defective once but could have multiple defects, e.g., if it fails multiple tests.

### 2.3.2: Characteristics

According to (Biwas, 2021), typical characteristics of waste due to defects are: complex material flow, excess finished goods inventory, excessive floor space or tools or equipment, excessive manpower to rework or repair or inspect, customer complaints or returns, high scrap rates, poor production schedule performance, questionable quality, and reactive organization.

Well, given Benchmark's problem identification, some of the above characteristics are already known before Benchmark's current situation is examined. For instance, problems with yield improvement are precisely aligned with customer complaints. If a yield value is lower than agreed, it leads to customer complaints. Moreover, a reactive organisation is in line with the wait-and-see reaction to evaluate yield.

The final step is to consider why further characterisations of waste in terms of defects are important for this study. If any of these characteristics are found during the study of Benchmark's current situation, it could mean that there is waste in terms of defects. This could imply that there repairs or defects and hence the FPY or RTY are not optimal. Finally, it suggests that there is room for improvement in yield and therefore the process of yield improvement could be better. These characteristics give this study clues or a basis for where to research.

## 2.4: Conclusion

Chapter's 2 conclusion will be defined by the answer on the respective research question and if the aim is met. The research question was: ***"What are key factors affecting yield improvement and yield evaluation reports***?" So, there are three key factors that influence the improvement of yield: the definition of yield, testing processes and defect waste. How yield is perceived and defined is important because it is a metric that can be calculated in different ways and thus have different meanings. According to this study, the RTY and FPY are the best measures of yield because they are the most accurate for the production process performance. The test processes are also important because a tester determines the FPY and the entire test process system determines the RTY, yield of the overall process. Finally, defects must also be considered as this reflects yield loss and determines what types of defects occur.

# Chapter 3: Current situation

Chapter's 3 aim is to investigate Benchmark's current situation and get a grasp at how the yield evaluation and improvement processes are working within Benchmark. It should focus on finding answers for the issues regarding the core problems and possible bottlenecks to solve. This chapter attempts to find an answer for the following research question: **"How are these key factors working within Benchmark?"** This is different from Chapter 2, where yield is described theoretically.

This chapter is divided as follows, section 3.1 introduces the company overview, section 3.2 describes the New Product Introduction process, section 3.3 looks at the yield evaluation reports, section 3.4 introduces the assembly process, section 3.5 describes this study's observations, section 3.6 is the description of the bottlenecks, and section 3.7 ends with the conclusion.

## 3.1: Company overview

The aim of this section is to provide information of Benchmark's general and current processes. This is important to investigate since this provides the context of where the yield improvement process operates.

### 3.1.1: 7-step Product Creation Process

Figure 4 visualizes Benchmark 7-steps Product Creation Process. This approach has 7-steps to guide product design and new product launch programs. This 7-step approach allows clients to step in at any point in the development process with their project. Therefore, each product has its production and testing process combined with the standards of Benchmark's 7-step process, which are collaborated with the client. As a result, this 7-steps approach could cut rework, ensure that customer needs are met and speeds up overall product development time. According to Benchmark, each step is defined as follows:

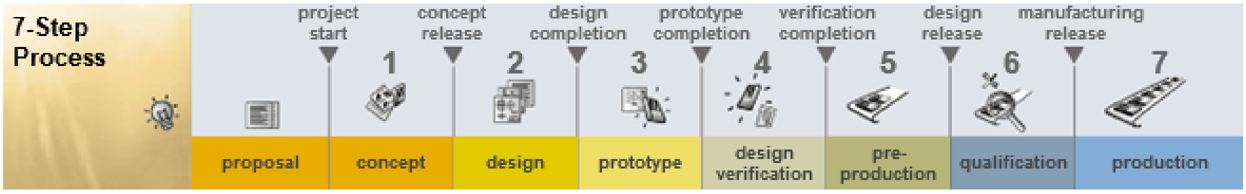



*Figure 4: Benchmark 7-step Product Creation Process*

**Proposal:**

The proposal phase is when Benchmark receives a request from a client that would like to collaborate with Benchmark on a new project. This includes a Quote Risk Assessment which is a pre-qualification document of the customer and the confirmation that all other important agreements are in place. Therefore, it is essential to understand the customer's needs and expectations. This includes a successful plan for the project that Benchmark can execute to meet these demands and expectations.

**Concept:**

The concept phase's purpose is to define product specifications and intended use. This is in collaboration with the customer to include user and regulatory requirements. Generally, concepts are developed and assessed against the requirements criteria. The main activities that are performed during the concept phase are concentrated on agreeing on the product specifications and risk management and developing concepts for the product design and supply chain.

**Design:**
This phase's objective is to design several elements that will be conducted against engineering verification using different analyses. These analyses must show that the performance can still meet the requirements identified in the concept phase under the worse circumstances. The design elements that are developed are a product design, supply chain model, and manufacturing process with test design. Significant activities that are performed and are attractive for this study are the design for the detailed product, such as the BOM and software. Furthermore, the design of the manufacturing process includes the test design.

**Prototype:**
The prototype phase's purpose is to build the design integration of product development used to demonstrate or prove most aspects of the design into prototype A. The project team builds integrated prototype units during the prototyping phase. Additionally, prototypes followed the integrated test plan and recommended product design changes are defined. Finally, the prototype A build design review is together held with the customer, and updated design documentation is released for the design verification.

Prototyping and optimization of the design are taken place at the exact moment, so that product cost, processes, and quality can be improved by feedback from the prototyping activities. Engaging activities from this phase are the build of Prototype A, product verification against requirements, optimization of the design, update of the detailed design, and the definition of tools necessary for volume production.

**Design verification:**
The design verification phase aims to verify that the product meets customer demands and requirements. In addition, prototype B is manufactured in this phase, which aims to deliver the product in a representative manufacturing process.  Key activities necessary in this phase are mostly focused on verifying the product.

Therefore, these are aspects such as, the description of the verification plan, establishing the acceptance criteria, and design evaluation with the customer. With these activities, Benchmark would like to know if they can meet the customer product requirements and produce the design for its price.

**Pre-production:**
This phase's purpose is to determine the manufacturing process and make the process equipment up to consistent manufacture. Therefore, pilot units are manufactured und specific circumstances that are precisely the same as they should be during production. To determine a manufacturing process that is stable and mature, several activities are important. These are to optimize and secure the production process, build several pilot units, and update the risk management plan.

**Qualification:**
Next up is the qualification phase. This phase's purpose is to complete the manufacturing process validation and the qualification process. Here it likes to answer whether the manufacturing process design meets its requirements. After it has demonstrated the consistent quality standards in manufacturing and the customer approves the products, the products are released.

**Production:**
The production's objective is to successfully execute the manufacturing contract, including all the essential specifications and requirements. For continuous improvement, data is collected and used as input. Additionally, changes to the product or process are implemented in this phase only after mutual agreement with the customer.

## 3.2: New Product Introduction process

The previous section introduced Benchmark's 7-step Product Creation Process that guides product design and new product launch programs. Or in other words, it is an entire process that takes a concept to a final product. The major question is what Benchmark's 7-step process has to do with the efficiency of the yield improvement process. Well, the answer is to use the research design, which is the observation of a New Product Introduction.

The New Product Introduction process takes place steps 1 to 5. Since, a product's yield should be on the agreed level with the customer before it goes into production, it is best to start as soon as possible with the evaluation of yield. Consequently, this does not mean that the other step is insignificantly important, on the contrary, during the production step a product's yield should meet the agreed yield with the client. This could be a boundary since it sets e.g., a time limit for when it is possible to get the yield number to the right level.

**Definition:**
Before this study dives into Benchmark's New Product Introduction process, it makes it clearer to define the concept, a New Product Introduction (NPI), which is a process that takes a concept from a first operating prototype to a refined and consistent final product (Haque & James-moore, 2004). Each new product or client who comes to Benchmark for a project will be labelled a NPI once.

According to Benchmark, its NPI process should be able to produce empirical evidence at each stage so that appropriate actions are completed to ensure the quality and reliability of a product, program, or device. This is in line with the goal of this study to improve the efficiency of the yield improvement process. Since, as explained earlier, yield is to some extent a measure of the quality and reliability of a product, program, or device. The higher the yield, the higher the quality of a production line and the more reliable it is to reach the agreed yield of a client.

### 3.2.1: Yield at Benchmark

**Definition:**
Benchmark expresses yield in First Pass Yield, which is the same First Pass Yield concept as in Chapter 2. Benchmark calculates the FPY as follows, $FPY = \frac{First\ time\ Pass}{First\ time\ Tested} * 100\%$, and thus there is a slight difference with the theoretical one. Instead of making the distinction between input, output, rework, and scraps, Benchmark counts the number of products that passes the test in the first time dividing by the total number of products tested by that tester.

**Requirements:**
So, to be able to calculate the FPY at Benchmark, for each product is necessary to know if it is a pass or fail and if it is the first time. Knowing whether a product is a failure or pass is determined by the testing machines in a production process. Therefore, the next section is devoted to test engineering to gather more information on how this precisely works.

### 3.2.2: Test engineering

**Objective:**
The objective of Benchmark's test development is to deliver high quality, custom-made automation, and test solutions. A standard test design platform is used by Benchmark to minimize development time and costs. However, due to the huge customization of products within Benchmark, custom test solutions are designed that can match a projects specific test requirement. A custom tester design is primarily based on a general process, but can be separated in specific guidelines to accommodate product-specific test instrumentation, cable connections, shielding, lighting, etc.

**Test Coverage:**
In the beginning of the NPI process, a test strategy is created that includes several aspects, such as costs for testing, potential defects, test coverage etc. The most important one is test coverage, which is used a metric for determining electrical quality of the products. The test coverage is percentage metric that has the ability of covering a certain number of defects for a specific tester. For instance, if a tester has a test coverage of 90% that means after a component is tested with this particular test, only 10% of the fails remain. In addition, test development has a list of components that can be tested, which are both electrical and mechanical. This also means that Benchmark has electrical and machinal specific tests.

Combining the test engineering theory and Benchmark's testing processes, there is a correlation between the yield and test coverage. The test coverage is determined by the quality of the testing machines and the testing specifications. It is the case that the fewer testing specifications exist of a tester, the easier a product can pass the test and thus a higher yield. However, this is misleading since fewer test specifications mean that certain product functions are not tested while they should have been (TestView, 2010). Consequently, products can pass the test, while they are a failure. So, to get the truest yield values, test coverages should be either as best as possible or as high as standards agreed with a client in the beginning of a project. The test coverage can grow over time if the tester gets better, for instance, using better testing software.

**Tester engineering process:**
In the scope of the test engineering process, there are several employees involved with the tester engineering process. These employees should operate from his/her role within the scope and do the job as well as possible. The different employees are as follows, the test engineering manager, the project leader, the senior test engineer, the test engineer, and technician.

A logical next step is to look at Benchmark's tester engineering process. This tester engineering process describes all the necessary steps for creating a testing process for a project, see Table 2. It starts at the 1st step of Benchmark's 7-step process and ends at the 6th step. The benefit of this table is that each tester engineering process is linked with a Benchmark's step. This advantage should lead to faster detection of problem causes.

| **Tester engineering process:** | **Corresponding step of the Benchmark 7-steps process:** |
|---|---|
| Request for Quotation Tester(s) | 0 (Proposal) |
| Quote Process Equipment Engineering | 0 (Proposal) |
| Quote Process New Project | 0 (Proposal) |
| Analysis | 1-2 (Concept and Design) |
| Release Outputs Test Team | 1-2 (Concept and Design) |
| Tester Design | 3 (Prototype) |
| Release Tester Design | 3 (Prototype) |
| Tester Build Integration and qualification | 3-4 (Prototype and Design Verification) |
| Release Tester Build | 4 (Design Verification) |
| Transfer Tester to production line | 5-6 (Pre-production and Qualification) |

*Table 2: Tester engineering processes and corresponding Benchmark step*

### 3.2.3: Defect waste

Chapter 2 describes defect waste as: "repair or rework of a product or service to fulfil customer requirements as well as scrap resulting from materials deemed to be un-repairable or un-reworkable". The main defect waste characteristics that were in line with Benchmark's identifications were: having customer complaints if yield is lower than agreed, and a reactive organization with the wait-and-see response to evaluate yield. In addition, it could be possible that Benchmark encounters more defect wastes that relate to this study.

Regarding defects and repairs, Benchmark has standardised procedures that ensure the handling of repairs and scraps. This includes processes that determine when a product can be repaired and how, or that it needs to be scrapped. Benchmark has several employees responsible for these processes, such as quality engineers. However, according to employees, this is not done always 100% accurately. This means that the chance is high that products that are repaired do have a lower quality. Therefore, again a good reason to use the FPY and RTY.

## 3.3: Yield evaluation reports

The next step is to examine whether yield reports can gain any benefit in terms of efficiency. To find out, it is first necessary to look at the yield evaluation reports themselves. Therefore, the aim is to identify possible shortcomings and strengths of the current reports. To this end, aspects such as definition, objectives, and stakeholders. Thereafter, the remaining core problems will be addressed and the reasons for those problems justified.

### 3.3.1: General information

**Definition:**

According to Benchmark, they define the yield evaluation reports as the QIT Management Reports. QIT stands for Quality Improvement Team, it is meant for the management and is conducted weekly.

**Objectives:**

There are several objectives and sub-objectives that need to be met in Benchmark's yield evaluation reports. The main objective is to weekly evaluate the yield improvement process per project. Therefore, the evaluation consists of multiple focus points of sub-goals, otherwise the evaluation will not be useful and of high-quality. The sub-goals are as follows:

- Evaluate and conclude current yield performance
- Identify new opportunities for improvement
- Draw up an action or problem-solving plan
- Track progress of problem-solving plan
- Prediction yield performance for the next report

By considering these objectives and sub-objectives in the current process, it becomes possible to see if these objectives are met and if there are any shortcomings.

**Stakeholders:**

It is important to examine the stakeholders in the yield report because any solution recommended in this study must collaborate with the current stakeholders. Failure to do so, for example, could affect the implementation of this study. In this case, the stakeholders of the yield evaluation reports are employees responsible for making it, receiving it, and are involved whether that is direct or indirect.

The current reports are prepared by quality engineers as they are part of the Quality Improvement Team. There are no standard procedures or documents for preparing a yield report and so they make them on their own. My supervisor receives the reports. Looking at the people involved, the first two are obvious: the quality engineers and my company's supervisor. Other employees involved are those responsible for fixing a defect. It is difficult to examine who else is involved, because each solution is unique and so the number of people involved can vary enormously.

### 3.3.2: Current yield evaluation reports

To determine the current state or performance of yield evaluation reports, in collaboration with the company's supervisor, two yield evaluation reports were examined. The aim was to identify already useful strengths and take notes of possible improvements to the reports. The answer to why a sample of two was used is because there were only reports from two different projects. By looking at both reports, it is possible to think of common strengths and areas for improvement to ultimately arrive at a basis that is satisfactory for both projects.

**Strengths:**

- 1st report

The first report contains an evaluation of one product, described in a total of six pages. It is divided into five parts, visualisation of the FPY, bucketing and pareto on failures, management report, action tracker, and process flow FPY.

The strength of the visualisation is that the values for FPY and volumes are easy to read. This report introduces the concept of bucketing: categorising certain test specifications based on a common characteristic. The benefit of bucketing defects provides a better understanding of the types of defects that occur in a product or project. It gives a clearer overview of defects or failures and changes the representation of defects in the pareto. For example, the most frequent defect may not belong to the most frequent defect groups. Consequently, it is more advantageous to resolve the groups with the most defects, because they contain the most defects and will therefore have the most impact on yield. Furthermore, the report itself tries to connect the client's testing process with its own (this does not have to be the case). Another point is the comment section for when changes have been made to the grouping of defects.

In the case of the management report, this is a component that links each defect bucket to an improvement plan while tracking progress and containing a solution plan, where each step can be validated. Linking a defect bucket is done through documentation and the improvement plan for each defect bucket has a structured approach to solving the problem. It tracks improvement progress by checking for each step in the approach whether it has been implemented, is in progress or has not been started. At last, it ensures the case that if a step is finished, that the engineer is forced to state why a step is ready, by, say, an Ishikawa etc. The improvement plan includes the following steps, detailed description, Root Cause Analysis, Action List (QIT), solution finding, verification, and implementation. The strength, therefore, is that this component helps manage improvements.

The main strength of the action tracker is that it tracks the actions against the buckets. In addition, it prioritises the various defects per defect bucket. This is based on estimates of effort and chance. Prioritising defects is important because there are always limited resources to solve a problem. By solving the defects with the highest priority, the limited resources are used as efficiently as possible. Again, progress is tracked by viewing the status of an action for a defect. The statuses can be overdue, in progress, or done.

- 2nd report

The second report is an evaluation of a project consisting of several products, each with its own FPY values, described in a total of four pages. Each page has its own product and is divided into the sections: visualisation of the FPY, FPY participation of each test specification, prioritisation of defects, and highlights section.

The strength of the visualisation of the FPY is that the purpose is clear and the relationship between FPY values and volume is good. The prioritisation of defects is concise and therefore clear. At the highlights, each product gives a closed FPY of the past week and, for each prioritisation, a summary of actions. Overall, it tries to keep it concise, even though there are more products and fewer pages than the first report.

**Improvements:**

Possible improvements identified in both reports are described in this section. Therefore, this section is divided into several subjects to which those potential improvements belong. These subjects are based on the report objectives of the yield evaluation reports.

- Evaluate and conclude current yield performance

Both reports do not specify which yield metrics they are trying to visualise. In line with the theoretical framework of this study, there is a difference in yield understanding and calculation if only one tester or the complete process is meant. If the focus is on the final test, e.g., the functional test, then the FPY metric is used, otherwise focus on the entire process means using the RTY.

Moreover, the variables visualized in the graph(s) should be clear and readable. This means that the target should be a clear line and clearly legible, the y- and x-axes should be clear, and values should not be mixed up in the graph.

Finally, both reports lack a brief conclusion on current performance. This is because there are also no other supporting features to form this conclusion, such as a trend line or moving average. Moreover, this conclusion should also relate to production volume, as the combination of efficiency and production volume determines how many defects exist. Ultimately, this should lead to conclusions that say something about improvements or drawbacks made.

- Identify new opportunities for improvement

For identifying or depicting new opportunities for improvement, both reports have different ways of reporting it. The conclusion is that the first report does a much desirable job than the second report. However, the point that the first report lacks is to connect the defect bucket differences over time. The report shows two different pareto charts from two different time stamps. However, it is not possible to see immediately the changes in the "defect buckets" in the following period and link them to changes in yield in the same period. This is due to the lack of information such as yield change in the different time periods, the difference in total defects, and same axes. Incorporating these aspects will fill the gaps that currently cause connectivity to be lacking.

- Draw up an action or problem-solving plan

While the second report does not contain a problem-solving plan, the first does. However, it is not as simple as copying the approach of the first report for every other report. In fact, there are two points of discussion. The first is whether it makes sense to include the problem-solving approach in the report, and if so, how comprehensive that approach should be. The first report includes an approach contain multiple pages. If this approach were used in the second report, the report would have become too long. So, from the feedback of two reports, I would say that it depends on the number of components or products of a project evaluated in the report.

The second question is whether the steps in the first problem-solving plan report even guarantee success. Or in other words, are all the necessary steps included in the current plan. This will become evident in the following chapters, where different approaches will be examined and assessed. From these, an approach will emerge that best fits the action problem of this study and thus provides the necessary steps. This can be compared with the current plan and possibly lead to adjustments.

- Track progress of problem-solving plan

The second report, like the previous objective, does not track the progress of the problem-solving plan, while the first report does. During the discussion with the supervisor, it was concluded that the current way of monitoring progress in the first report is adequate.

- Predict yield performance for the next report

Overall, what could have been improved about both reports is the fact that the process of yield improvement is a process that takes time. These yield evaluation reports are a tool to continue improvement. This directly implies that the yield evaluation reports should also address what has happened in the previous evaluations and will happen in the next evaluations. The point of what happened in the past is already in the reports, but I miss the link to the future to make it more continuous. For example, there is no expectation or forecast for future yield values, making it more difficult to conclude whether yield development is on track or not. A benefit from this is that the predicted values can be compared with the measured values of the next reports. This gives the ultimate evaluation of the yield development.

### 3.3.4: Unstructured approach

To start off with the most important core problem, by reviewing the yield evaluation reports, I observed no same structure for both reports. Looking at both reports separately, we can see that there is some logic in the approach of both, but an overall structure is missing. This got me thinking, is there a general procedure or documentation that quality engineers can use to create them. This is exactly the point; these do not exist.

### 3.3.5: Reporting yield

On closer inspection of the core problems, the section on yield reporting is consistent with improving yield reporting. This is because it also focuses on what is reported and how yield is reported. With the aim of consistent reporting so that the data quality and data output is maximized. This means that by solving the core problems: method reporting differs per project and data quality reporting differs per project, it should improve the yield evaluation reports.

In the introduction chapter, a quick look has been given if about the causes of how the efficiency of the yield improvement process has a potential benefit. Chapter 1 also describes that these two-core problem above mentioned do influence the efficiency. Now, the question is, how exactly does these two core problems affect efficiency, because that proves that there is actually a connection between the core problems and the action problem. Furthermore, it gives directions for the solution that should be considered.

**Visualization methods of reporting:**

In the case of reporting methods, data visualisation tools can provide an approachable way to foresee and understand trends and patterns in data (Kösters, 2022). The potential benefits mentioned are unlocking core values, identifying patterns, better to understand, more attractive and user-friendly, and displaying complex relationships. The potential benefits are important because if they can be linked to process efficiency, it could mean opportunities to improve efficiency.

Given the definition of process efficiency of the process to improve efficiency described in Chapter 1, the first four align with process efficiency. Indeed, this has everything to do with maximising the clarity, comprehensibility and message presentation of the current data being measured. All this is aimed at reducing the time spent on understanding, writing, and evaluating reports. Moreover, pattern identification focuses on maximising the output of the measured data by finding interesting information.

**Data quality:**
In the case of data quality differs per project, by finding consistent data quality per project, it is the same as having guaranteed quality. What guaranteed quality does is, it minimizes the chances of overlooked crucial details (Brandall, 2018). The common ground with process efficiency is that it also focuses on maximizing quality output with a limit on available resources. Benchmark aims to improve the quality of the information's output, while the concept of process efficiency aims to maximize process output. This means that Benchmark's issue with data quality differs per project is in line with the concept of process efficiency.

### 3.3.6: Wait-and-see response to evaluate yield

The last section that influences the efficiency of the yield improvement process, is the wait-and-see response to evaluate yield. This expresses itself in the following core problems, lack of preventive thought to increase yield and lack of awareness of yield development during design phases. The main question if these core problems will be solved when the yield evaluation reports are improved by introducing a structured approach and having a standard way for the method and data quality for the reports. Otherwise, other solutions have to be found.

The first step is to look whether those core problems can be observed. Chapter 1 made it clear that the suspicion existed. This was evident partly because it led to escalation. Escalation refers to the unrest within the project team. Namely, there was no preventive thinking and yield values were realised too late. This is further confirmed by Benchmark's supervisor. So, this means that both core problems are at play. Another argument is that the choice of yield evaluation reports was scarce, while there are multiple projects. This just shows that the idea of constantly evaluating yield is not there.

The next step is to determine whether solving these core problems improves the efficiency of the yield improvement process. Because if not, there is little point in solving them. There is a common objective regarding the more efficient use of resources in terms of time. There are three different areas where the amount of time can be reduced, and these are as follows: reducing the time to make the yield evaluation reports, reducing the time to assess the reports, and reducing extra employee time resulting from the wait-and-see response.

**Lack of preventive thought to increase yield:**
The link between process efficiency and this core problem is that the core problem leads to a waste of time. Namely, being reactionary rather than preventive means that once a problem has occurred. All the actions needed to solve it are wasted time, because with the right mindset and actions, it could have been prevented. Process efficiency is also focused to maximize the amount of time available to reduce waste.

**Lack of awareness of yield development during design phases:**
The similarity between lack of attention to yield development during the design phases and process efficiency is, otherwise, unnecessary time and resources are required to get the yield to the target level. For example, if yield development is not evaluated during the design phases, the yield will have an unpredictable level before reaching the pilot steps where the yield should meet the target.

This yield level may therefore be lower than expected. As a result, any amount of time and resources required to close the gap between measured and expected yield is waste.

One reason is that people are not aware of yield development and do not act pre-emptively because there is no procedure for yield evaluation in the earlier design stages. The big question is whether the same format of the current yield evaluation reports can be used. This means including the same structured approach, the same methods of data visualisation and the same output of data quality. The aspect that made me think there might be a difference that has to do with the way yield is measured at Benchmark. To find an answer to this question, it is necessary to look deeper into how yield is deployed in the earlier prototyping steps and how it is measured. Therefore, it is interesting to look at the assembly and testing process of the NPI and extract information from observations and meetings or interviews.

## 3.4: Assembly process

The previous chapter has thus highlighted why it is necessary to look at the assembly process of a NPI. This raises the question of what the assembly or production process looks like from which yield can be derived. It is also important to consider whether current reports on yield evaluation are adequate to use based on the assembly or production process of the earlier steps in the NPI. This is also related to the other topics in this chapter, namely Benchmark's 7-step process, the NPI process and test engineering. Since these topics are also important factors on or in the assembly process of a product.

### 3.4.1: Assembly process NPI

As mentioned, this study was submitted to an NPI that could have served as a perfect example on how an NPI process works at Benchmark. When I observed the assembly process of the assigned NPI, the NPI was in steps 3 and 4 of Benchmark's 7-step process. This means that this study is able to draw and explain the assembly process of the NPI for steps 3 and 4 but lacks the knowledge to do the same accurately for the later steps 5, 6, and 7. A logical question is why the assembly process of steps 3 and 4 is not the same as for steps 5, 6 and 7. The answer is the state of development of a product. Because when a product is in step 1, 2, 3, 4, they are considered prototypes or even concepts, while after step 4, the design is verified and thus final. Consequently, prototypes can still change and be improved, leading to changes in workstations or testing processes.

This does not mean that nothing is known about the assembly process of steps 5, 6 and 7, as there might be already plans to modify certain assembly steps and certainly the ideas arising from the lessons learned from steps 3 and 4.

**NPI process steps 1-4:**

In Figure 5, a generalized version of the NPI's assembly process is visualized that I have observed. The main important things to note is that the NPI consist out of two components, each component's assembling is two different processes, and they are coming together when the entire product is tested. A workstation is a place where sub-components are assembled to create eventually two main components of the NPI.

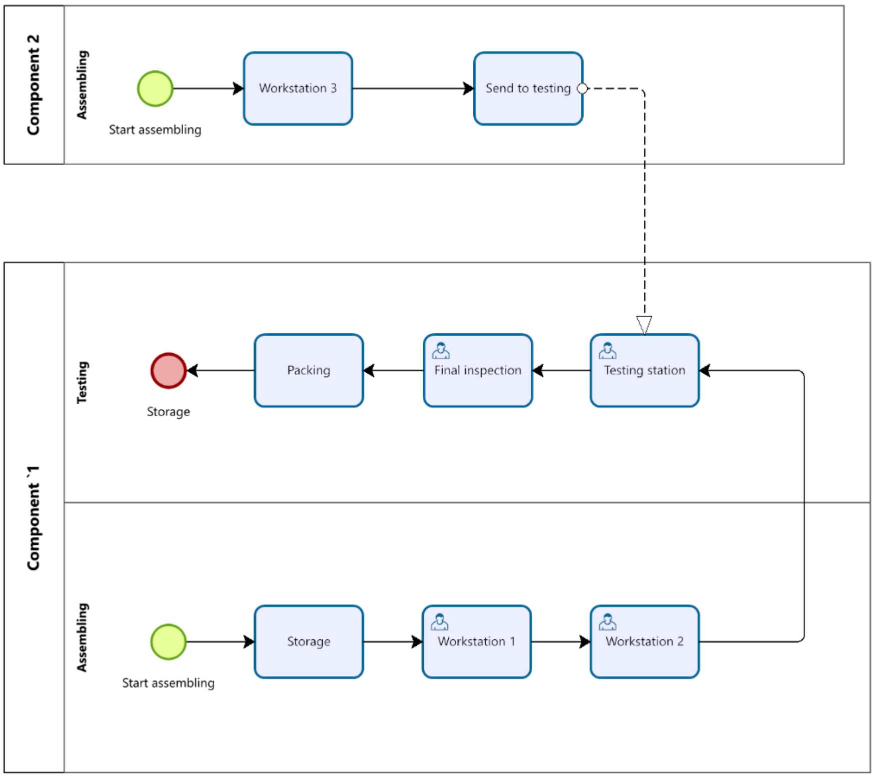



*Figure 5: Example assembly process NPI*

**NPI process steps 5-6:**
The NPI that I observed did not yet reach process steps 5 and 6 and thus it is not possible to make a complete and total accurate assembly process. Except from the fact that I already described it, it was also confirmed by several employees since they said multiple times that I had to be curious with what kind of information I used from the NPI because it will probably change in the future.

However, considering what could be known for the assembling process of steps 5 and 6, a look has to be made about the plans or deals made in the proposal, and at the lessons learned from steps 3 and 4. An example is that in the current situation the testing steps are done manually, while the plan is to automize it. Consequently, influencing the yield improvement process, since an automized testing process does have a higher coverage or accuracy to detect defects. As a result, it makes the entire process more reliable and providing a more truthful yield value.

### 3.4.2: Product flow:

Table 3 visually depicts the connections between the product and equipment processes and exactly where they are in the 7-step process. This process flow is created based on Benchmark's documentation.

| Step Product Creation Process: | Equipment level: | Product output: | Process level: |
|---|---|---|---|
| 1: Concept | - | - | Manufacturing concept |
| 2: Design | Installation specification | - | Process design |
| 3: Prototype | Installation specification/Installation design/Built installation | Proto A | Process specifications |
| 4: Design verification | Built installation/Install equipment/Installation qualification | Proto B | Process specifications |
| 5: Preproduction | - | Pilot | Operational qualification |
| 6: Qualification | - | Pilot | Performance qualification |
| 7: Production | - | Production | - |

*Table 3: Product flow*

The first observations are that a product goes through four different states in the NPI process before it goes into production. Resulting that a product can change multiple times with each having their own decree of variation. In the beginning, this degree of variation is much bigger than later in the stage. The second important thing to note is at which step each equipment level, product output, and process level is.

## 3.5: Observations

In the previous sections, general information and NPI-related topics from Benchmark were mainly discussed. Using the theoretical information on the NPI's assembly process and given the aim of finding a solution to the wait-and-see response to evaluate yield, I observed the NPI's assembly process in practice. Furthermore, I conducted meetings and interviews to find out why this happens and what can be done to solve it, or in other words to find the bottlenecks.

### 3.5.1: Yield NPI

First the observations of the NPI's assembling process. The major question is what kind of conclusions or observations I need from the assembling process. The main aim should be to identify observations from the assembling process that influence the efficiency of the yield improvement process.

The NPI's observations took place when the product was in steps 3 and 4 of Benchmark's seven-step process. This was perfect because this wait-and-see response takes place because little or no yield evaluation takes place in these steps. So, the first question was whether it was possible to evaluate yield in these earlier steps. Well, I found that large level differences can still occur in the assembly process in these earlier steps. This is true for small steps like adding handling steps or changing parts, or for substantial changes like moving the test system from manual to automatic. Given the effect of these changes on the yield, the test device must also be considered, as it determines what the yield will be. As shown in the Figure 5, in this NPI the testing steps are already included in the assembly process. So, in this NPI, there were changes to components that were critical to operation and thus needed to be tested. Therefore, the testing system had to be completely revised, making the effect on yield difficult to predict. So, these process changes affect the yield, and if the process changes, the yield also keeps changing. Therefore, Benchmark should consider whether they should introduce a different type of report for yield evaluation.

However, as seen as in the current evaluation reports at some point it is possible to measure the yield using the testing machines. Therefore, the question that pops up is when is this possible and the answer is when no huge changes can be implemented anymore, hence the assembly process is fixed. My conclusion is that the key factor are the installation qualifications in the NPI process. These installation qualifications are suited between steps 4 and 5, see Table 3.The installation qualifications' purpose is to provide evidence for the defined equipment/system in the specified site, building, area, or line that is installed according to specifications and performs the intended functions. Functions that have been incorporated into these installations' qualifications are such equipment, system control, level of automation, software validation, etc. So, the installation qualifications can be considered as a bottleneck for this study proven by the combination of these observations and the general product flow from Benchmark.

### 3.5.2: Targets NPI

The same applies to the yield targets during the prototype stages. In other words, does it make sense to stick to the yield targets agreed with the client even in these stages, when the yield calculation will most likely to be different? The answer is no, it does not make sense because of the following, which is almost the same reason as for why to have a different yield evaluation report for the earlier steps.

The key question is, how should these yield targets look like and why is it important to have them? Well, whether a target is met says something about the performance and satisfaction of the process or system. The sooner this becomes clear, the sooner action can be taken. The next step is to determine what these yield targets should be, but this is difficult with current methods because of the following example. For example, due to the wide range of changes, it would be possible that the target should be around 90% one time and then 50% at some point, for example. A 50% target might be fine if it is a difficult product to make e.g. So, now it is not possible to say how the targets will be based in the earlier stages, but these will be based on the new yield values.

### 3.5.3: Key factors impacting yield during NPI

As can already be seen from both observation sections above, the yield cannot simply be the same as in the current reports. Therefore, these observations of the assembly process in the early stages of NPI were an excellent opportunity to explore what other factors mattered. There were crucial factors observed, which influence yield. An influential circumstance was that this was the first time the whole NPI product was put together, so experience, training, and skills were not yet available; so, it was beginning from nothing. Consequently, my observations could focus on determining how these operators could assemble an adequate product as quickly as possible.

My observations revealed a direct link between poorly described operations and operators making mistakes during assembly. These poorly described operations were the instructions operators had to follow to assemble a product. So, the higher the quality of the WPI, the more products were adequate, the more were marked as passed, and finally the higher the yield.

Due to the circumstance of that it was an entire new product, my observations noticed that relatively simple mistakes were made in the beginning. This was logical since it was unaccustomed. This unaccustomed can be removed by training and skills. This was also confirmed by the employees present that the lack of training and skills caused this. Moreover, as operators made more products, this led to fewer simple errors as they acquired more skills.

Next up, the PFMEA, which works as follows, it identifies the failure modes which are the ways components, sub-assemblies, products, inputs, or processes could fail to perform their intended function (George et al., 2004).

Then a list is made where each failure mode has one or more potential effects, or in other words, if a failure occurs, what are the consequences. The possible failures caused by the assembling process should be identified by the PFMEA. The PFMEA will be further explained in Chapter 5 since it also includes factors, such as severity, occurrence, and detection to identify the potential effects for each failure mode.

The last importance key factor that is observed, which affects the number of good products in process, is the test coverage. In the theoretical framework, the test coverage of a tester was already defined as an important measurement. It became clear that by improving the test coverage, maybe some products will be considered as failed, but the overall performance will be more accurate. This is important if a company strives for high quality overall.

## 3.6: Bottlenecks

In this section, the bottlenecks are described that are affecting the efficiency of the yield improvement process. The bottlenecks that are identified are the yield evaluation report and the installation qualifications. The aim of this section is to use the bottlenecks as input for this study's solution.

### 3.6.1: Installation qualifications

**Confirmation:**

So, the question is whether this study can confirm that the installation qualifications are indeed a bottleneck for the efficiency of the yield improvement process. Therefore, this study can confirm that the installation qualifications are the exact moment when the production conditions cannot change anymore. This means that at the stages of protypes A and B, the products can be tested in different production conditions. This is precisely the point that as the tests in a production process change, the test specifications change, the difficulty of the tests may change, and thus the yield becomes unpredictable. However, once the product has passed the installation qualification step, the production conditions cannot be changed. The installation qualifications are built up by several criteria. Each criterion could have multiple requirements with each having values that need to be passed.

**Qualifications:**

There are 13 cases in total, see Table 4.

| **Description:** |
|---|
| 1. Operating environment |
| 2. Layout requirements |
| 3. Facilities requirements |
| 4. Additional installation requirements |
| 5. Operation instructions |
| 6. Maintenance Procedures and Schedules |
| 7. Calibration Procedures and Schedules |
| 8. Machine Configuration Verification |
| 9. Computer Control Systems |
| 10. User Rights and Permissions |
| 11. Power Up Test |
| 12. Emergency Stop Safety Test |
| 13. Machine Capability Analysis |

*Table 4: Installation qualifications*

**Efficiency yield evaluation reports:**
The lack of efficiency for the yield evaluation reports can also be seen as a bottleneck. Therefore, it blocks the improvement of the yield process. Obviously this was already a known bottleneck by Benchmark, but this study confirms that these reports actually have a potential benefit regarding their efficiency process.

### 3.6.2: Visualization bottlenecks

Now the bottlenecks are identified, it is useful to make the connection with yield improvement visually. This is going to give an overall view of the yield improvement process and how it can be more efficient.

**Current situation:**
Now that yield and the NPI and all related issues have been discussed, it is useful to combine the two and look at the process of yield improvement during the NPI process. Figure 6 is a general visualisation of the process of yield improvement in the NPI process. First of all, it should be noted that these visualisations are a simpler version of reality. This means it is not hardcore science. However, it is a tool to show how bottlenecks block the yield improvement process. Moreover, for interpreting the graphs, the emphasis is on the slope of the line rather than the height. The slope represents the possibility of improving the yield process.

So, the question is why the emphasis is on the slope and not the height of the line. Well, this is because of the large variance of yield values in the steps before installation qualifications, as observed. This means that there are many possibilities of what the yield can or will be for Protos A and B. Protos A and B are the prototypes of a product during steps 3 and 4. From a yield improvement perspective, it is a waste of time to focus on yield improvement by looking only at measured values in these steps. Then, the period between the pilots and prototypes is the best time to improve yield, so that during the pilots, yield can be aligned with the target. After all, the goal of the pilots is to get the product(s) in the right conditions for production.

Then there is also a kink in the further development of yield towards the target. The decline starts at the point where yield improvement reports should continue the increase in yield. This is when the second bottleneck emerges and was the original problem of this study. Namely, the efficiency of yield improvement reports, which prevents management from making useful decisions, consequently, yield improvement is delayed. Thus, yield improvement reports should not only continue yield improvement but also ensure that yield targets are met.

A good point is that this Figure 6 also shows this study's core problems. Well, the unstructured approach, different reporting methods per project and different data quality per project are obvious, because those core problems are part of yield evaluation reports. But the core problems of the wait-and-see response to evaluate yield are also visible. The x-axis shows time, it takes a long time to start with the improvement of yield. Solving the core problems of the wait-and-see attitude should reduce the time to start with the yield improvement, increasing the efficiency of the process.

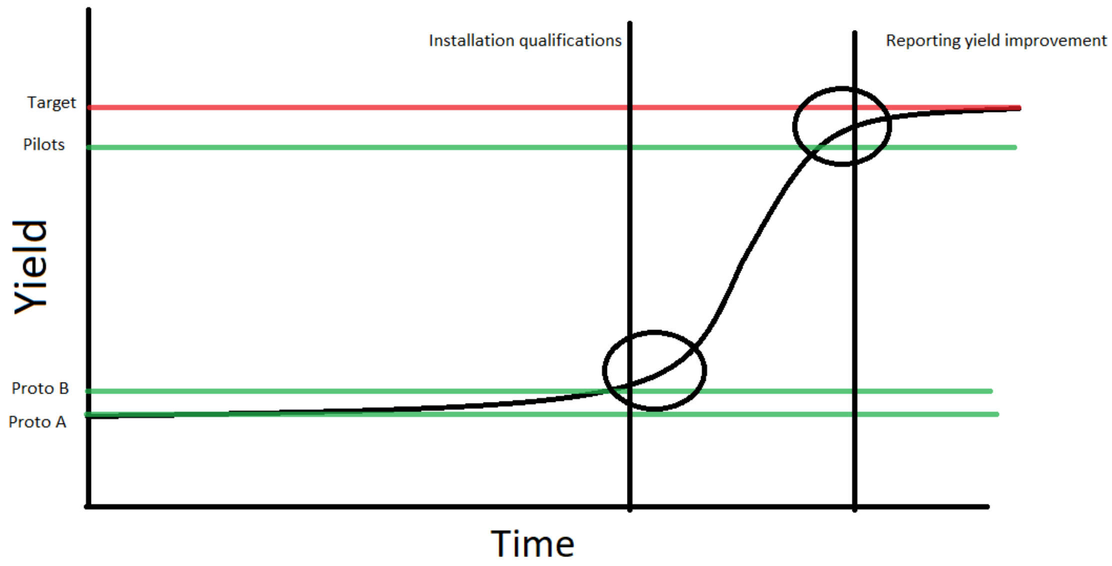



*Figure 6: Current situation bottlenecks*

**Desired situation:**
So, considering the comments from the previous figure, there are two focus points where this study's solution has to focus on. These are the two bends in the curves that provide the speed of the yield improvement process. The first bend is where the slope of the yield improvement increases. In the desired situation, this means that the solution can deal with the installation qualifications. As the second bend is where the yield improvement stagnates, which Benchmark would like to see disappear, or at least see happen after the target is already reached. So, in the desired situation, this study's solution should improve the efficiency of the yield evaluation reports.

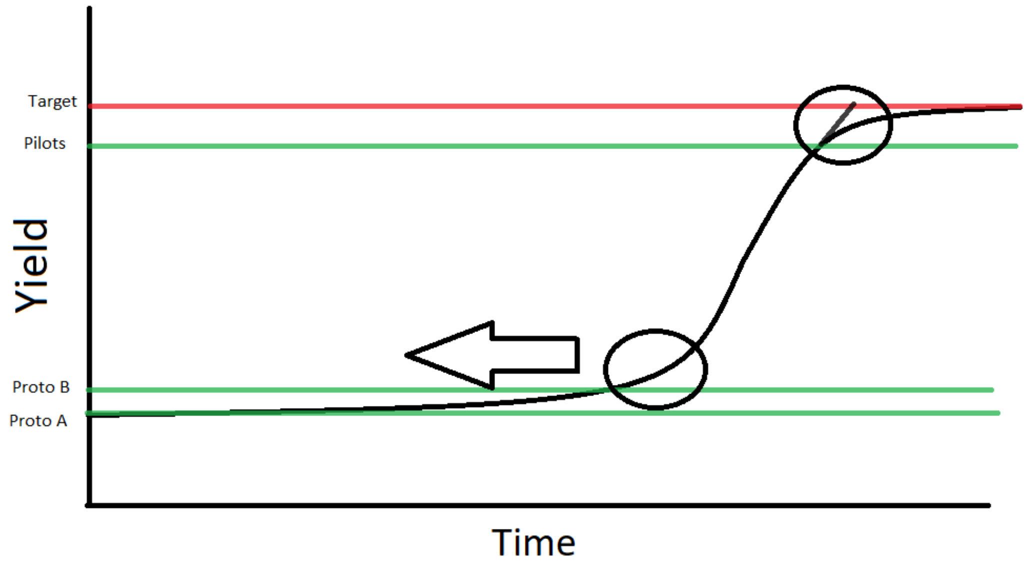



*Figure 7: Desired situation yield improvement*

### 3.7: Conclusion

Chapter's 3 conclusion will be defined by the answer on the respective research question and if the aim is met. The research question was: ***"How are these key factors working within Benchmark***?" The main conclusion is that yield becomes predictable and valuable after the installation qualifications. Both the installation qualifications and the inefficient yield improvement reports are bottlenecks blocking of yield improvement. This is since the production process of a NPI can change a lot before the installation qualifications. Hence, making the yield very arbitrary and difficult to evaluate.

This means that a new metric should be introduced, which need other indicators. The observations of the assembly of a NPI have helped to understand what kind of factors are significantly important. These decisions are made in Chapter 4.

Moreover, the current yield evaluation reports were also reviewed, and potential improvement points gained. The main shortcoming was the evaluation, visualization, and conclusion about the current yield performance. For instance, the yield of the entire process, the RTY, was not even examined. For the visualization it was mostly the way of presenting the data and that it should help to provide a conclusion, which was not the case.

## Chapter 4: Solution Framework

The aim of this chapter is to create a solution framework based on the information from the theoretical framework and the current situation of Benchmark. In doing so, it answers the following research question: **"What are possible solutions that could probably contribute to the efficiency of yield evaluation reports?"**. Finding an answer to this question requires several steps. The first step is to re-define the objectives of the yield evaluation reports, since these were only introduced at the beginning of Chapter 3 containing limitations of current reports on the report objectives. However, the observations of this study, described later in chapter 3, resulted in new perspectives on what these objectives mean. The last step is to provide solutions to the core problems that thereby meet the report objectives.

Section 4.1 describes the report objectives, section 4.2 introduces all the possible solutions, and it ends with section 4.3 which is the conclusion.

### 4.1: Report objectives

As the introduction of this chapter already mentioned, the report objectives should be met. Otherwise, it is not possible to say whether the solutions for the core problems are actually contributing to the improvement of efficiency for the yield evaluation reports. To establish the relationships between the core problems and the report objectives, the input from the bottlenecks and observations is added.

#### 4.1.1: Report objectives and sub-objectives

The added objectives from this study's observations are defined as sub-objectives since they have no significant changes to the original report objectives. For instance, the process of setting targets, which is different before and after the installation qualifications. This was before the observations no point of discussion but became relevant and thus is added as a report sub-objective. This is one of the examples, but there are many more. Below is a table with all the original objectives and sub-objectives.

| | | | | | |
|---|---|---|---|---|---|
| **Report objectives:** | Evaluate and conclude current yield performance | Identify new opportunities for improvement | Draw up an action or problem-solving plan | Track progress of problem-solving plan | Predict yield performance for the next report |
| **Report sub-objectives:** | Visualization yield performance | Identifying defects | Draw up problem-solving steps | Problem description per defect | Yield improvement focus |
| | Conclusion yield performance | Visualizing defects | Prioritizing defects | Problem solving plan per defect | Prediction yield change |
| | | Comparing defect change | | Visualization tracking progress | |

*Table 5: Report objectives and sub-objectives*

The advantage of splitting the report objectives into sub-objectives is that they function as requirements for the solutions. This is not the end since some sub-objectives can be further split up. For instance, the visualization of the yield performance, which should include: a yield target, weekly yield (can either be FPY or RTY values), weekly volume, yield prediction of previous reports, indicated changes in the process, and clear axes. All these specific requirements per sub-objective are described in chapter 5, where the solutions need to be assessed against these requirements.

### 4.1.2: Input from bottlenecks

There are two bottlenecks blocking the continuous improvement of the yield process. a) The installation qualifications and b) the lack of efficiency of yield evaluation reports. The main input of the bottlenecks is that the yield can be defined differently depending on where the project or product is in the Benchmark's 7-step process. Then the question is how to deal with yield values and yield targets that are unpredictable due to the influence of the constantly changing production process. The best option is to look for other ways to calculate yield values, and the first is to identify which factors influence the yield and can be assessed earlier in the process. These factors are determined after a standard structured approach is chosen, as this approach affects the perspective on these factors. For instance, the Define-Measure-Analysis-Improve-Control cycle focuses on improvement through measurement and thus quantification. The big question is whether the definition of yield values and yield targets before the installation qualifications should be quantified or need a more qualitative approach.

### 4.1.3: Connections between core problems and report objectives

The last step necessary before providing a set of solutions is to connect the core problems with the report objectives. This is important for knowing whether a solution is useful or not, because if it does meet the objective, but has no proper connection, it will not solve the core problem. In addition, there will be levels on how good a solution will solve the objectives, since these will be measured by the indicators. The more indicators are proficiently assessed, the better the solution.

**Unstructured approach per report:**
To begin with, the problem stated as “an unstructured approach per report” is solved if the ideas behind the report objectives are reflected in the steps of the solution. This is not certain, as there may be differences. For example, one objective may identify new opportunities for improvement, while a specific solution may aim at finding only the most important opportunity based on a research study.

**Visualisation methods differs per project:**
Next, the core problem stated as “reporting visualisation methods differs per project” has to do with the fact that the same visualisation methods are used for each project. Therefore, this means that the same visualisation methods should be used in all projects for each objective.

**Data quality differs per project:**
Furthermore, another core problem stated as “data quality reporting differs per project”, might be solved if the output of each reporting objective is consistent in each case. This is because data quality aims at understanding trends and patterns in data. These patterns are therefore aimed at maximising the output of the measured data by finding interesting information. This consistency can be measured using the variable data consistency and its indicators.

**Lack of preventive thought to increase yield:**
Another core problem, the lack of preventive thinking to increase yield, relates to the same relationship as the core problem unstructured approach by report, but for the reports before the installation qualifications. This is not the case for the current reports, as both reports shown to have a component of prioritisation in which defects are prioritised. It remains unknown how this preventive thinking is in the other projects, as they do not send evaluation reports. However, this could be resolved if the report objectives of identifying new opportunities for improvement and tracking the progress of the problem-solving plan are met.

But since there will be a new solution for new reports before the installation qualifications, this means that, consequently this prioritisation process must also be updated. If the ideas of the report objectives are also represented in these new reports, it means that the preventive idea is included.

**Lack of awareness of yield development during design phases:**
The last core problem, stated as “the lack of awareness of yield development during the design phases”, might be solved if these yield evaluation reports before the installation qualifications include a proper yield evaluation methodology. It relates to the output of the report objects, the same as for differences in data quality by project. Only when the output of the report objects is data consistent, it leads to greater awareness of the yield during the earlier steps of Benchmark 7-step process. For example, the major changes in the production process affects yield, which may not be immediately solvable. However, if these reports have a good methodology for yield evaluation, they can at least create an awareness of what the levels of yield values are all the time.

### 4.1.4: Visualization connections between core problems and report objectives

To make connections in the previously described section clearer, Table 6 describes them.

| **Focus points:** | **Core problems:** | |
|---|---|---|
| **Evaluation report:** | Yield improvement after installation qualifications | Yield improvement before installation qualifications |
| **Structure** | Unstructured approach per report | Lack of preventive thought to increase yield |
| **Visualization methods** | Visualization methods differ per project | Visualization methods differ per project |
| **Data output** | Data quality reporting differs per project | Lack of awareness of yield development during design phases |

*Table 6: Focus points core problems*

The core problems can be categorised by two different types of evaluation reports, before and after the installation qualifications. These evaluation reports have three main focuses where all the core problems fall under, namely: the structure, the visualization methods, and data output. The unstructured approach per report and lack of preventive thought to increase yield are both focusing on the structure. The visualization methods have the aim to have the same for both reports. At last, in the case of data output, data quality reporting differs per project is in line with lack of awareness of yield development during design phases.

## 4.2: Possible solutions

Thus, now that the links between the core problems and the reporting objectives have been established, solutions can be provided. The question is now in which direction or from which perspective is it useful to look at for solving the core problems. A theoretical perspective acts as a base, which will help with finding solution choices for the core problems. In addition, a theoretical perspective helps the study narrowing it down.

### 4.2.1: Theoretical perspective

To know which theoretical perspective is the most suitable for this study, a look back to the beginning will have to be taken. This research started with the action problem of having a potential benefit for the efficiency of the yield improvement process. So, there are three topics important in this action problem: efficiency of a process, improvement of a process, and yield. By looking at the common grounds, it should be possible to produce a perspective that is useful for this study. The theoretical perspective together with the theoretical framework are the theory base of this study.

**Efficiency process:**

The definition of an efficiency process was as follows, the amount of effort or input required for a company to produce a product. By maximizing efficiency, enables a company to make the best possible use of the company's resources. As section 1.3 says that by improving and standardizing the yield evaluation reports, the efficiency of the yield improvement process will reach that potential benefit. Namely, according to (Berger, 1997), standardisation can work as a framework for a continuous improvement process. Thereby, it uses different quality tools that could make the improvement process visible and measurable while also being a link between improvements and standardised routine work. Hence, standardized, and improved reporting will ensure data consistency.

**Improvement process:**
As shown in section 3.6.2, the yield improvement process is focused on continuing to improve yield values so that they meet the target. Installation qualifications and yield evaluation reports block this improvement or slow down the speed of the improvement process and are therefore called bottlenecks. Considering what it needs to have in the theoretical perspective, is the focus on a continuous improvement process.

**Defect waste:**
As is known for the yield, the less defects, the higher the yield, but the importance of this principle is already described in chapter 2. Therefore, it is important to look at defect waste for common grounds with the efficiency or improvement process to produce a theoretical framework. The definition of defect waste was: “repair or rework of a product or service to fulfil customer requirements as well as scrap resulting from materials deemed to be un-repairable or un-reworkable”.

**Lean and Six Sigma:**
Given these aspects, the theoretical perspectives that effectively interpret the problem of this study are the principles of Lean management and Six Sigma. Lean focuses on maximising added value towards customers, while Six Sigma focuses on minimising defects (MĺÍkva et al., 2016). For efficient improvements, Lean and Six Sigma are methods for organizing quality and efficiency improvements and serve as methods to systematically innovate processes. In the case of reducing defects, reducing waste is in line with yield improvement, because it is all about reducing waste in terms of defects or yield loss. Next, maximizing added value is the same as improving the efficiency of the yield evaluation reports with current resources. At last, the methods of Lean and Six Sigma provide ideas that contain continuous improvement, in the form of continuous improvement cycles.

As above is explained, standardisation can work as a framework for a continuous improvement process, since a standardized reporting process can ensure data consistency. Therefore, continuous improvement processes can be a solution for the structured approach. Since the yield evaluation reports are a weekly process with the aim evaluating from previous report and predicting for next week’s report, these reports are continuous improvement cycles. Therefore, possible solutions of a structured approach in term of continuous improvement cycles should be considered.

### 4.2.2: Structured approach reporting per report

So, the solution to a structured approach is a continuous improvement cycle. A continuous improvement cycle can be defined as: “a continuous improvement cycle gives the ability to move from the actual state to a new desired, recognizing the path ahead as unclear and unpredictable, requiring sensitiveness and responsiveness to actual conditions on the ground (Pessôa & Trabasso, 2017).”

**Continuous improvement cycles:**
There are several continuous improvement cycles described with respective definitions, objectives, benefits, and limitations. By identifying these four aspects, it will be possible to make a solution choice in the next chapter. The continuous improvement cycles that are discussed are retrieved from Lean management and Six Sigma and are as follows, the Plan-Do-Check-Act (PDCA) cycle, the Define-Measure-Analyse-Improve-Control (DMAIC) cycle, and the Theory of Constraints (TOC) cycle.

| CYCLE: | DEFINITION: | OBJECTIVE: | BENEFITS: | LIMITATIONS: | SOURCES: |
|---|---|---|---|---|---|
| **PDCA** | The Plan-Do-Check-Act (PDCA) cycle is four-step problem-solving iterative technique used to improve business processes. | To differentiate a company from its competitors here businesses are always searching for ways to streamline their processes, reduce costs, increase profits, and improve customer satisfaction. | - Minimizing errors<br>- Maximizing outcomes<br>- Standard operating procedure through continuous improvement | - Takes time<br>- Not a one-time event<br>- Requires commitment from employees | - (Hargrave, 2021) |
| **DMAIC** | The Define-Measure-Improve-Analyse-Improve-Control (DMAIC) method focuses on statistical improvements to a business process and advocates for qualitative measurement of success. | It is used by businesses to eliminate defects and improve any of their processes to boost their profits. | - Minimizes defects in the process<br>- Customer satisfaction<br>- Eradicates the variation and waste from the process | - Skipping a step is associated with high-risk | - (George et al., 2004) |
| **TOC** | The Theory of Constraints (TOC) is a methodology for identifying the most important limiting factor or constraint that stands in the way of achieving a goal and then systematically improving that constraint until it is no longer the limiting factor. | TOC's objective is to gain more profit or to earn more money. | - Increased profit<br>- Fast improvement<br>- Improved capacity production<br>- Reduced lead times<br>- Reduced inventory | - Hugely dependent on the workforce<br>- Mostly concentrated on earning money instead of other resources | - (Hessing, 2022) |

*Table 7: Summary continuous improvement cycles*

**Phases:**
The previous section has described the definitions, objectives, benefits, and limitations. However, it is also important to describe each cycle's phase, since those phases will also be visible in the reports.

**DMAIC:**
The DMAIC method includes five steps, which are Define, Measure, Analyse, Improve, and Control, see Figure 8 The phases' definitions and decision steps are based on the research of (George et al., 2004).

- Define: Getting the project team and stakeholders to agree on the scope, objectives, financial and performance targets for the project.
- Measuring: Thoroughly understand the current state of the process and collect reliable data on process speed, quality and cost that will be used to uncover root causes of problems.
- Analyse: Identify and verify causes affecting key input and output variables related to the project objectives.
- Improve: Learn from testing the chosen solution(s) and execute full-scale implementation.
- Control: Complete the project work and hand over the improved process to the process owner, with procedures to maintain the gains.


*Figure 8: DMAIC cycle*

**PDCA:**
The PDCA is a cycle that contains four steps. These are defined as follows, Plan, Do, Check, and Act. The phases' definitions and decision steps are based on the research of (Tiwari & Garg, 2021) and can be seen in Figure 9.

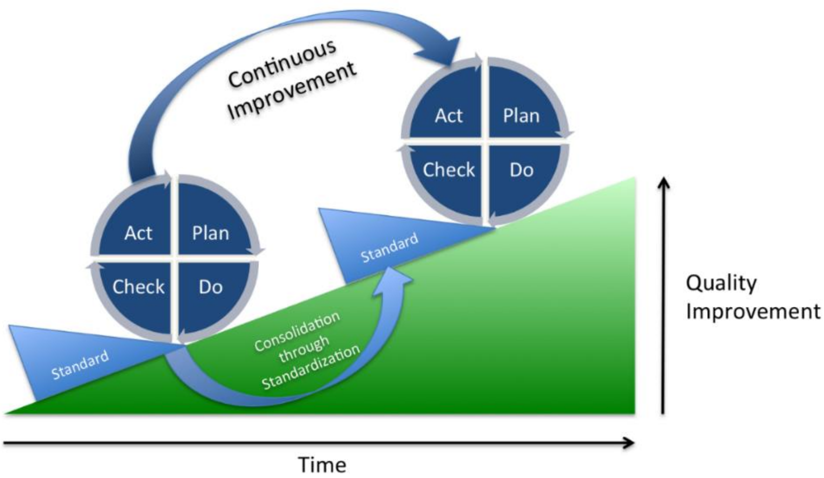



*Figure 9: PDCA cycle*

- Plan: Typically, any improvement effort begins with planning what a company wants to achieve or implement in the future. This can be referred to as setting the benchmark goals or a small improvement. This also includes planning the methodology to achieve the set target.
- Do: The "Do" step is the practical implementation of the aspects according to the plan to achieve or accomplish the desired results.
- Check: The “Check” step involves monitoring and assessing the progress made so far, ensuring that everything is going according to plan, and observing challenges and obstacles.
- Act: The last step of the PDCA cycle, the “Act” step, is to act accordingly on the conclusions of the "Check" step to further adjust or redefine the objectives. The process should be standardised and stabilized if the set goals or results are achieved, otherwise planning is required to achieve the set targets.

**TOC:**

The TOC is a method consisting of five steps, which are as follows: Identify the constraint, Exploit the constraint, Subordinate & synchronize to the constraint, Elevate the performance of the constraint, and repeat the process. The phases’ definitions and decision steps are based on the research of (Vargas et al., 2017) and can be seen in Figure 10.

- Identify the constraint: The identification of the constraint phase of the system should start from process information, focusing on latency or where usually the most work hours are needed, meaning that the constraint identification starts from previous knowledge of the process.
- Exploit the constraint: Management should focus on eliminating all waste or unproductive time in activities where the constraint occurs, thereby increasing the capacity of the production system.
- Subordinate & synchronise to the constraint: The subordinate step consists of the process of making a non-constraint produce only what the system constraint allows.
- Elevate the performance of the constraint: This step aims to find alternative ways to increase the capacity of the constraint. Once the capacity of the constraint has been increased, a new constraint can take place in another activity of the production system, or the constraint can remain in the same place but with increased capacity.
- Repeat the process: From the cycle of the TOC, depending on the decisions made during the process, a new constraint is created. In this way, the fifth and last step is to go back to the first when the constraint is resolved or to go to the identification of a new constraint because of the elimination of the bottleneck.

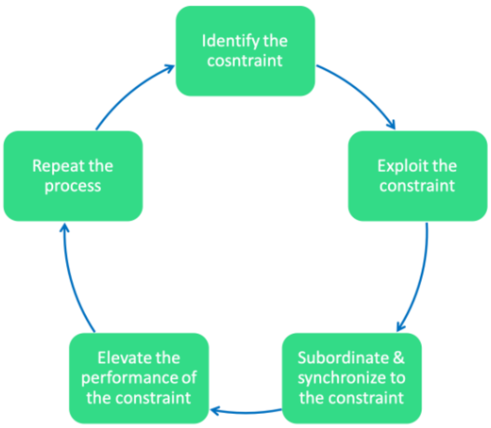



*Figure 10: TOC cycle*

### 4.2.3: Reporting yield

**Visualization methods reporting:**

The visualization methods reporting can be solved if for each report objective the same visualization methods are used. Therefore, it is important to look at what kind of information need to be evaluated and presented.

So, there are multiple categories of charts visualizing data and information. These are as follows with respective examples, change over time (line chart, sparkline), distribution (bar chart, histogram, pareto chart), part-to-whole (pie chart, stacked bar chart, stacked area chart), and relationship (scatter plot, bubble chart, grouped bar chart, heatmap). Figure 11 shows most of the described visualization methods.

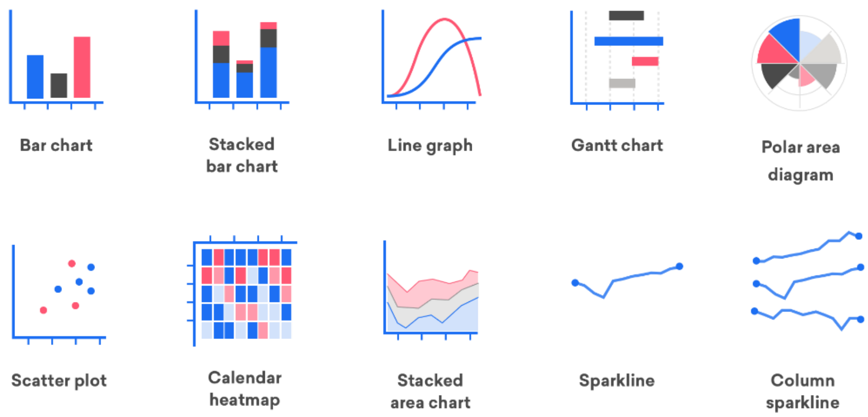



*Figure 11: Examples visualization methods*

The last kinds of visualization methods are not completely quantitatively, but also including some qualitative thinking. The previous methods could all use columns with values and could create a chart. However, examples such as Ishikawa diagrams and the 5-Why method, need some qualitative thinking.

- Evaluate and conclude current yield performance

For the evaluation and conclusion of current yield performance, the main aim is to evaluate the yield change over time and how it relates to the production volume. So, for this, charts of the categories: change over time and part-to-whole would like to be suitable.

- Identify new opportunities for improvement

To identify new opportunities for improvement, visualisation methods such as the Ishikawa diagram, the 5-Why method, the Process Failure Mode and Effects Analysis (PFMEA) or the Pareto chart can be useful. The identification of defects or new improvements cannot be expressed in numbers because the reason it occurs can be due to many things. The reason it occurs and by what is called Root Cause Analysis. Generally, Root Cause Analysis (RCA) is defined as, "a collective term describing a wide range of approaches, tools and techniques used to uncover causes of problems". The sub-objective is to evaluate the defect change over time, so the obvious thing to do is to create a line chart or sparkline. However, another option could be to use two pareto charts or bar charts, since it will compare two periods, instead of an entire timeline. This makes the second option also suitable.

- Draw up an action or problem-solving plan

Creating an action or problem-solving plan has two sub-objectives: creating problem-solving steps and prioritising defects. Considering the discussion with the company's supervisor about the visualization of these report objectives, we concluded that there were no issues.

- Track progress of problem-solving plan

Tracking the progress of the problem-solving plan has three sub-objectives: the problem description per defect, the problem-solving plan per defect, and the visualisation of the tracked progress. During a discussion with the company's manager about the quality of the current yield evaluation reports, it did not appear to be many problems in terms of visualisation. The problem description for each defect lacked some visual clarity, but this could be solved by adding a photo of the defect, tester or process step. In addition, a visual problem could be that if there are multiple parts, as in the second report, it could be too extensive. The best solution is a discussion between receiver and sender, quality engineer and program director, who can decide what to do. The current method of visualising the status of each step is satisfactory. This is a table with the defect buckets in the row, and improvement steps in the columns. Each cell in the table represents the state of each defect bucket per step. These respective states are not started, in progress, finished with each having its own colour.

- Prediction yield performance for the next report

The prediction of the yield performance for the next report has two objectives: focus on yield improvement and prediction of yield change. The visualisation of yield improvement from the first report is considered satisfactory and thus can be implemented for all reports. However, there were some problems with the visualisation of yield change prediction for the upcoming reports as it was not even visualised in both reports. The main requirement was to visualise it in the yield evaluation and conclusion section of the report. Possible solutions include indicating the weeks in which changes are made throughout the process and calculating the potential yield by resolving the respective number of defects.

**Data quality:**

The data quality reporting can be solved if for each report objective the output is considered data consistent. Therefore, it is important to look at each report if there are any respective solutions necessary to make the output good or if the output is already satisfactory. Hereby, the changes in visualization methods are also important, because they affect the output of a report objective.

- Evaluate and conclude current yield performance

For the evaluation and conclusion, solutions should be drafted for the sub-objectives: visualization yield performance and conclusion yield performance. However, both sub-objectives can be further split up. The reason for that is, Benchmark has clear knowledge about the requirements for data quality of these parts. Namely, visualization of the yield performance should include: a yield target, weekly yield (can either be FPY or RTY values), weekly volume, yield prediction of previous reports, indicated changes in the process, and readable axes. Next up, the conclusion of yield performance reflects having the following: a trendline of the yield, clear if it is about the entire process or an important test (mostly the end-tester), and conclusion section.

- Identify new opportunities for improvement

For report objective: identifying new opportunities for improvement, if any solutions are necessary, a look have to made at the sub-objectives. However, the data output of the identification of defects is dependent on the kind of method that is used to visualize it. The main difference with for instance the evaluation and conclusion of the current yield performance is that there are also possible qualitative methods instead of only charts. Consequently, each method has its own kind of output. Therefore, the same possible solutions provided in the visualization methods reporting section, also holds here, such as the PFMEA, 5-why method, and Pareto Charts.

The only difference what could influence the data output independent of the visualization methods, is whether the decision is to make defect buckets or not. Section 3.3.2. describes the benefits and limitations of bucketing defects.

- Draw up an action or problem-solving plan

To get data consistency for this report objective, the issues with sub-objectives: drawing up problem-solving steps and prioritizing defects should be considered. As mentioned earlier, reflection on the current reports concluded that the current problem-solving steps were sufficient and thus also its data output. The main reason was that implementing a new problem-solving method would be so extensive that it could be a study on its own. It involves the following steps: 1. Detailed description, 2. Root Cause Analysis (RCA), 3. Action List (QIT), 4. Solution search, 5. Verification, and 6. Implementation. Further explanation of these steps will be given in the solution chapter.

For prioritising defects, it is important to consider based on which factors defects should be prioritised and how, because this process decides the priority per defect. In addition, the priority per defect is the output of this objective. Fixing the most common defect is obvious, but the question is whether this is most efficient. As mentioned, there is only one report that clearly indicates what kind of prioritisation technique is used. First, defects are classified into certain groups or buckets, after which a certain number of groups are chosen to be solved. Then, for each group or bucket, each defect is prioritised based on an effort estimation and a chance estimation. The effort is the estimate of the time required to solve the defect. The estimate of chance indicates how likely the defect will occur. The main question is whether these factors are good to stick to? According to (Mathenge, 2020), the most common prioritisation model is to understand impact and urgency, and priority is a combination of the two. In this paper, impact is defined as a measure of the effect of an incident, problem or change on business processes. Then, urgency is defined as a function of time; urgency depends on how quickly the business or customer expects or wants something. Given the current factors, I can therefore conclude that the current prioritisation process is adequate. The current factors may not completely match the definitions, but they certainly come close. Probability estimation corresponds to impact on the product or process, while effort estimation corresponds to urgency.

- Track progress of problem-solving plan

As is also the case for the visualization methods for tracking progress of the problem-solving plan, there are no improvement points.

- Predict yield performance for the next report

To predict the yield performance for the next report, it is suggested to include a macro process overview, as in the first report. This process overview shows where the focus is on improving yield. This method was found to be satisfactory.

For predicting yield for the following reports, the first part was to look into the future when a change in the process is expected to improve yield. This value can be calculated because it is known how many defects can potentially be solved. The second part is to provide ways on what to do with the weeks in between. There are three possibilities: a horizontal line constructed from the last measured yield value which is oblique between the week of the change and the week before, since no improvement is expected; a linear oblique line between the last measured value and the predicted value, since an improved needs time to finetune, at last based on historical measured values calculated by the forecast function in excel.

### 4.2.4: Wait-and-see response to evaluate yield

**Preventive thought:**

As mentioned earlier, a solution to this core problem has much to do with the lack of a structured approach for yield evaluation reports before the installation qualifications. Indeed, the introduction of a continuous improvement cycle dictates that one should always be engaged in improving yield. This is the opposite of being reactive to solve occurring defects. Therefore, the choice of solutions here is the same as for the other core problem, which are the PDCA cycle, the DMAIC cycle, and the TOC cycle.

**Awareness of yield development:**

This core problem relates to the output of the report objects which is the same as for differences in data quality by project, but then for the evaluation before the installation qualifications.

- Evaluate and conclude current yield performance

As mentioned, yield cannot be measured and observed in the same way as it is currently done in reports, because yield values and targets can are unpredictable in the earlier steps. To find the solution, one must ask what Benchmark wants to say about early yield development. Normally, Benchmark is satisfied when the yield improvement process ensures reaching the agreed yield target. Or would like to know when a project or product is ready for production. So, the answer is that Benchmark wants to evaluate yield and conclude in terms of satisfaction. In discussion with the company's supervisor, it was discussed on how to express satisfaction and he suggested that normally his satisfaction came from how much trust he has in the process and if the route of a product is known. Hence, this study will clarify this relationship and look how trust and route can be found in subjects affecting yield.

According to the Cambridge dictionary, trust is "to believe that someone is good and honest and will not harm you, or that something is safe and reliable". In this case, it is about a process' and a product's trust and thus it should be safe and reliable. According to the Cambridge dictionary, a route is defined in two ways, "a particular way or direction between places" and "a method of achieving something". In this study, it is about a process' and a product's route, from which its yield should met the target. Hence, it represents a method of achieving something.

So, if there are proper connections between satisfaction and both trust and route, then it was a valid suggestion. Well, according to the Cambridge dictionary, satisfaction is "the act of fulfilling (=achieving) a need or wish". Hence, the connections are existing, since the act of achieving is like a method achieving something from the concept of route. In addition, the need or wish part from satisfaction can be in line with the concept of trust, because a product or production process being safe and reliable is the need or wish that Benchmark wants. So, from this point on, reports before the installation qualifications are called satisfaction reports.

Assessing a product's route and trust requires considering how the factors that influence yield can be measured in terms of route and trust. Well, what can be assessed about a factor, such as the WPI, is its quality and how progressed it is, such as non-existent or in an updating phase. If we connect these two characteristics with trust and route, then quality represents trust and progression represents the method. Because the higher the quality of a factor, the faster it reaches an acceptable level, and the more trust or reliability there is that the product's yield will reach the final goal. On the other hand, the faster a factor is completed, the faster the method is known about how to favour that factor. Thus, the factor achieves a yield which able to faster reach its end-target.

To decide which subjects in total can be a solution, this study introduces the 6M' of production. The 6m's of production are six different types of variation that almost completely encompass every type of variations that a company can experience (Liliana, 2016). This means that this method can look at every possible factor that a company can experience that might influence the yield.

Figure 12 shows the 6M's, which are as follows: Measurement, Material, Machine, Mother Nature (Environment), Manpower/Man, and Method. In general, an Ishikawa diagram is a tool for cause-effect situations. According to (Barsalou, 2014), the causes are mostly factors represented by six M's: Man, Machine, Material, Method, Measurement, and Milieu. In chapter 5 each M is explained and on basis of this explanation, there will be subjects chosen from the NPI process.

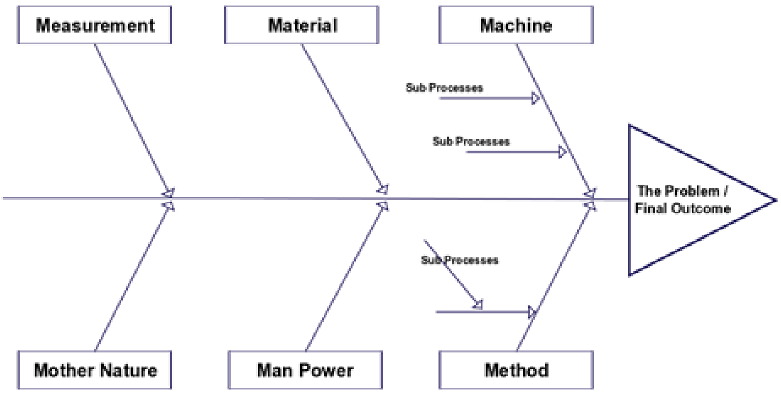



*Figure 12: General 6M's of production*

- Identify new opportunities for improvement

So, the same proposed solutions as for the data quality are considered here with one exception. Namely, Ishikawa diagram, Pareto chart, and 5-Why method are considered, but not the PFMEA. Since, the PFMEA is a subject affecting yield and thus cannot be used as a Root Cause Analysis, because that would be double.

- Draw up an action or problem-solving plan

The same problem-solving steps as in the current reports are used, as they have proved their data output to be adequate. These are the following steps: 1. Detailed description, 2. Root Cause Analysis (RCA), 3. Action List (QIT), 4. Solution search, 5. Verification, and 6. Implementation.

For prioritising subjects, it is important to consider which subject should be prioritised and how. In this case, the same prioritisation factors are not used because the chance estimate makes little sense here. This estimate is defined as the probability of failure, but subjects cannot fail. They only have an acceptance or progression level, which can be low but not a failure. Therefore, a suitable alternative is to change this estimate to an estimation in terms of satisfaction change. The higher the estimate of the positive change in satisfaction for a product, the more interesting it is to pay attention to, and the more priority it should get.

- Track progress of problem-solving plan

As already mentioned, tracking the progress of the troubleshooting plan does not have any data consistency issues because it is a monitoring process.

- Predict yield performance for the next report

To predict yield performance for the next report, it is suggested to also include a macro process overview, as in the first reviewed report.

However, for the report before the installation qualifications, it will be better to show a similar process overview, but with a focus on where satisfaction needs to be improved. Moreover, instead of looking at where a change in the process is expected to improve yield in the future. The prediction should be about what the progression or acceptance of the subject can be to improve satisfaction.

### 4.3: Conclusion

This chapter's conclusion should answer the research question mentioned at the beginning of the chapter, namely, **"What are possible solutions that could probably contribute to the efficiency of yield evaluation reports?"** The answer is that the five core problems can be categorized in three focus points: visualization methods, data quality, and structured approach. In Chapter 4, structured approaches are proposed that will be the standard structure for all reports. However, for each report objective, there are different visualization methods and the data quality solutions proposed.

In the case of a structured approach, continuous improvement cycles such as, the DMAIC, the PDCA, and the TOC are considered. The main reason that these three approaches are chosen is because the TOC is a good method to tackle bottlenecks. In addition, the PDCA and DMAIC are two of the most used, known, and best methods to use from the Lean and Six Sigma perspectives.

The list of possible visualization methods includes, change over time (line chart, sparkline), distribution (bar chart, histogram, pareto chart), part-to-whole (pie chart, stacked bar chart, stacked area chart), and relationship (scatter plot, bubble chart, grouped bar chart, heatmap). However, also methods such as Ishikawa diagrams, the 5-why method and simpler methods as colouring cells are considered.

For the data quality, there were not that many possible solutions compared to the visualization methods, since Benchmark had some requirements. In addition, the data quality of some report objectives was already satisfactory.

# Chapter 5: Solution choice

The main objective of Chapter 5 is to assess the possible solutions from Chapter 4 for a structured approach by report and choose the best option. The research question of Chapter 5 is: **"What is the decision-making process that delivers the proposed solution?"**. The answer ensures that no predetermined solution is certain to win. To combine the literature from Chapters 2 and 4 with Benchmark's current situation, see Chapter 3. In addition, by following steps from the methodology of (Heerkens & van Winden, 2021), the decision-making will be of high quality and reliable.

Section 5.1 assesses different continuous improvement cycles that can act as structured approaches for the reports. Section 5.2 introduces the solution choices for the reporting issues. Section 5.3 introduces the solution choices for the wait-and-see response issues. At last, section 5.4 provides this chapter's conclusion.

### 5.1: Assessing structured approach per report and preventive thought to increase yield

In this section, it is important to reflect on the continuous improvement cycle that I would like to use as a structured approach per report. As mentioned in section 4.1.4, the same solution for the structured approach is the same for core problem, preventive thought to increase yield. Therefore, it is important to assess the requirements from the report objectives against the continuous improvement cycles.

### 5.1.1: Weighting structured approaches

The various continuous improvement cycles should be weighed against each other to find which one is the best to use. In this, the Benchmark's requirements should be met, the various continuous improvement cycles' argumentations from the literature study should be debated, and it should fit Benchmark's current situation. The various continuous improvement cycles that are weighed against each other are DMAIC, PDCA, and the Theory of Constraints.

The way of how this weighting continuous improvement cycles works is to establish the criteria and then to assign points on a scale from 1 to 3 to these criteria for each continuous improvement cycle. The thing with scaling is that it is a trade-off between precision of scores and easy decision to assign scores. For instance, a scale from 1 to 10 allows for better precision in estimating scores, while a scale from 1 to 5 makes it easier to decide on scores. This is the reason I choose a scale from 1 to 3, because Benchmark prefers easy decision-making over precision. In addition, the criteria are not that quantifiable but qualitative which directly makes it difficult to say something about the precision. Finally, the continuous improvement cycle with the highest score, is the most suitable as a solution.

### 5.1.2: Requirements

As earlier mentioned, the requirements are the same as the report objectives. These requirements can receive a score from 1 to 3, where 1 is unacceptable, 2 is neutral, and 3 is acceptable to use. For all the requirements hold, the higher the score, the better a continuous improvement cycle suit as a structured approach for each yield evaluation report.

**List of requirements:**

1. Evaluate and conclude current yield performance
2. Identify new opportunities for improvement
3. Draw up an action or problem-solving plan
4. Track progress of problem-solving plan
5. Predict yield performance for the next report

All the requirements are considered even important, since all the requirements are considered important parts of the templates. It is comparable to removing a step or phase from the continuous improvement cycles, it works to a certain extent, but it is not optimal.

### 5.1.3: Scaling matrix

Below is Table 8 that visualizes the scaling matrix where the continuous improvement cycles are assessed against the requirements. The continuous improvement cycle with the highest score will be the best suited structured approach. The decision is made to not use different weights for the report objectives, because they are no significant differences in importance. In other words, one cannot live without the other.

| **Options/Criteria:** | **DMAIC:** | **PDCA:** | **TOC:** |
|---|---|---|---|
| 1. Evaluate and conclude current yield performance | 3 | 3 | 2 |
| 2. Identify new opportunities for improvement | 3 | 2 | 3 |
| 3. Draw up an action or | 1 | 3 | 1 |

| | | | |
|---|---|---|---|
| problem-solving plane | | | |
| 4. Track progress of problem-solving plan | 1 | 3 | 1 |
| 5. Predict yield performance for the next report | 3 | 3 | 1 |
| **Total:** | **11** | **14** | **8** |

*Table 8: Scaling matrix*

### 5.1.4: Result

The tricky thing with these kinds of matrices where requirements are quantified, is that it is done by qualitative reasoning. Of course, the better the argumentation, the better the assigning of scores. However, it remains that it is comparing two different things and thus the final score should critically be reviewed. In other words, a higher score is not automatically a better result. Namely, if the difference is 1 point with scores from 1 to 3, does that one point make a significant difference? On the one hand yes, because there are only three different levels and therefore there should be large differences between the scores. On the other hand, no, because in practice it turns out that the arguments are remarkably close to each other and differ in small details. The question then is whether such a small difference causes, say, one to get a 2 and the other a 3? Therefore, I use the rule of thumb, if the difference is greater than 3 points then there is a significant difference.

So, the conclusion is that the PDCA method is the best suitable standard continuous improvement cycle, since it has the highest score of 14 and a difference of 3 points with DMAIC. Hence, the PDCA is thus chosen as the most appropriate standard structured approach for the evaluation reports.

## 5.2: Assessing reporting per project

This section determines the solution per report objective per core problem. Unlike the structured approach per report, these solutions are not extensively weighted, scaled and assessed. The reason for this is firstly that some report objectives do not require solutions, secondly that for some report objectives only one solution exists, and thirdly that the choice of one solution can simply be made by weighing the pros and cons.

### 5.2.1: Visualization methods per project

Considering Table 5, the core problem of different visualization methods per project relates to both yield evaluation reports before and after the installation qualifications. Therefore, this section decides the visualization methods for both reports.

**Evaluate and conclude current yield performance:**

- Yield evaluation report

Based on Benchmark's specific requirements, the visualization of the yield performance should include a line chart for the FPY or RTY, because the report has the objective to evaluate yield change over time. In addition, line charts for the target and the linear trendline. Next, the volume production is visualized in bar charts. In case of the axes, on the y-axes the volume in quantities and FPY or RTY in percentage, and on the x-axis the number of weeks. At last, for the conclusion, a note section that reflects on trendline and prediction for improvement or change from the previous reports.

- Satisfaction report

Satisfaction can be interpreted the same as FPY or RTY of the yield evaluation reports. Therefore, a line chart is the most suitable. However, instead of having a production volume, the satisfaction is determined by the subject's participation. The best way to visualize this participation is by a pareto chart, since a pareto chart distributes how much each subject is contributing, which is the participation.

**Identify new opportunities for improvement:**

- Yield evaluation report

For the visualization of the identification of new opportunities for improvement, the possible solutions were an Ishikawa diagram, the 5-Why method, and the Process Failure Mode and Effects Analysis. The report objectives that need to be visualized were identifying defects, visualizing defects and comparing defect change. In the yield evaluation reports, opportunities are identified through the testing specifications, this means that the PFMEA drops out, since the PFMEA focus on the failures of the process instead of specific testing specifications. However, due to the complexity of these defects, the 5-why method is not suitable. Consequently, the Ishikawa diagram remains the best option.

The comparison of changes in defects can be best visualised using two Pareto charts of two different weeks or periods which the report wants to compare. The difference with using bar charts is that it is not part of the whole; in other words, it does not give a direct insight into what happened to the total number of defects. Pareto charts do have this principle, as they contain the cumulative sum of defects and compare two different weeks or periods.

- Satisfaction report

For the satisfaction report, opportunities cannot be measured, unlike the other report because the subjects qualitative. These improvement opportunities should come from qualitative reasoning and therefore the pareto chart is not suitable. Moreover, the PFMEA itself is part of the solution and therefore cannot be used. So, the 5-Why method and the Ishikawa diagram remain since both have characteristics to be suitable. However, the general aim is to provide standard visualisation methods as much as possible, for this reason the visualisation of the Ishikawa diagram is again chosen, as it is also used for the yield evaluation report.

The last report objective, comparison of defects, is somewhat different, since there is no number of defects for the subjects. A subject can have multiple improvement points, but each point is only happening once. So, it should be the comparison of improvement points per subjects. Consequently, this can be visualized the same as for yield evaluation report using a two Pareto charts.

**Draw up an action or problem-solving plan:**

There were no visual difficulties in drawing up the action or problem-solving plan to resolve defects or address improvement opportunities. This applies to both the yield evaluation report and the satisfaction report. This means that the visualization method of the first reviewed report is used as solution.

**Track progress of problem-solving plan:**

There is one solution for tracking progress of the problem-solving plans. This is to advice a discussion between receiver and sender for the extensivity of this monitoring part. Other than that, there are no problems with visualising the monitoring of the problem-solving plans to increase yield or satisfaction. Hence, this applies to both the yield evaluation report and the satisfaction report. This means that the visualisation method of the first evaluation report is used as a solution.

**Predict yield performance for the next report:**
The visualization solution for the prediction of next reports, should show visually a change in the process where is planned to improve the yield. This can be done using an arrow in the evaluation of yield performance graph. Next up, to add the predicted yield or satisfaction values, and planned production volumes for the yield evaluation report.

### 5.2.2: Data quality reporting per project

**Evaluate and conclude current yield performance:**
The solution for this part is straightforward, because Benchmark has made their requirements noticeably clear, the solution should include: a yield target, weekly yield (can either be FPY or RTY values), weekly volume, yield prediction of previous reports, indicated changes in the process, and readable axes. The decision for the FPY or RTY should be made by the responsible employee. Next up, for the conclusion is to include a linear trendline based on the yield.

**Identify new opportunities for improvement:**
The visualization method that will be used to identify new opportunities is the Ishikawa diagram. Compared to the 5-Why method, it is a better method to identify all the root causes instead of extensive identifying one. This is not necessary to include since this is part of the problem-solving steps.

The decision of whether to bucket or group defects, is a discussion for the project team, and especially between sender and receiver of these reports. This is because each bucketing process of a project is different and should be done by people with expertise.

**Draw up an action or problem-solving plan:**
The solution choice for drawing up a problem-solving plan, a look has to be made towards each sub-objective. For drawing up problem-solving steps, the choice was already made by using the following steps: 1. Detailed description, 2. Root Cause Analysis (RCA), 3. Action List (QIT), 4. Solution search, 5. Verification, and 6. Implementation. Further explanation of these steps will be given in the solution chapter.

For the objective, prioritising defects, the solution choice was also straightforward, since precious section concluded that the current method is adequate. This means that defects are prioritised based on an effort estimation, which is the amount of work necessary to get the job done. In addition, the chance estimation, which is a probability of a particular defect will occur.

**Track progress of problem-solving plan:**
The current method of monitoring progress of the problem-solving plan was also adequate. This means that each problem-solving steps can have three different states: not existing, in progress, and done.

**Predict yield performance for the next report:**
To predict yield performance for the next report, two choices are made to the two report objectives. Firstly, to include a macro process overview that focuses on where the yield will be improved. Moreover, for predicting yield values, calculating the weekly yield with a predicted change is obvious. However, the approximation of yield values between this calculated yield and the current yield does not exist. The choice is between a horizontal line, a linear sloping line, and values based on historical measured values. The horizontal line was chosen, except for the sloping line when improvement is expected because it best reflects the improvement process of a PDCA cycle. Figure 13 is a simplification of how this line is visualised. Another reason for using it is that if theoretically no improvement in the production process is expected, no improvement in yield is expected either. Moreover, this is not included in the method of a linear sloping line between measured and predicted yield values.

Indeed, one expects an improvement in the following weeks, which would increase yield, but this cannot be reflected. Moreover, there are many prediction methods, which are more complicated than previous methods. Given the importance of these values, it is not worth investing time in them. Since most attention is paid to the yield values where an improvement is expected and not the values in between.

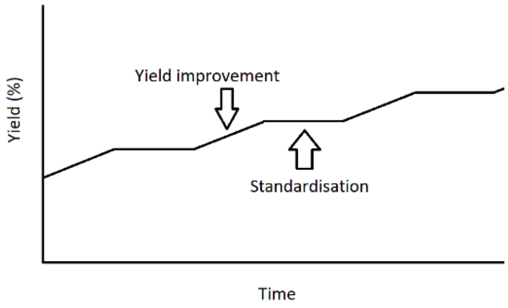



*Figure 13: Theoretical prediction yield improvement and standardisation*

## 5.3: Assessing wait-and-see response to increase yield

The wait-and-see response to increase yield section has two core problems where for one core problem a solution is already provided. However, the problem of having lack of awareness of yield development during the design phases, still needs some solution choices which will be done per report objective.

### 5.3.1: Awareness of yield development during the design phases

**Evaluate and conclude current yield performance:**

Before the satisfaction can be evaluated and concluded, it is necessary to determine the NPI subjects or activities that are affecting the satisfaction. Hence, the 6M method is used to identify all the subjects that should be incorporated in the satisfaction evaluation report. Therefore, it is necessary to look at the definition of each M and find useful subjects that are part of Benchmark's NPI process. Each M is defined in Table 9.

| 6M: | Definition: |
|---|---|
| **Manpower/man** | **Manpower** is the operational and functional labour of people who provide a product and service. Thus, this includes staff and workers who can cause variation, focusing on problems that arise from a lack of worker competence. The main factors affecting employee competence are staff motivation, lack of morals and principles, or lack of staff training. |
| **Method** | **Method** is the production process and its contribution to the service process. This includes problems that result from a lack of control over the procedures of the entire company. Examples are lack of quality control and lack of control procedures to ensure the adequacy of results, among other problems. |
| **Machine** | **Machine** includes facilities, systems, tools, and equipment used for production. These causes may be due to maintenance or inadequate planning of machine or equipment availability. |
| **Material** | **Material** includes raw materials, components and consumables for production and services. It therefore includes problems related to the materials used in the process, such as improper volumes and inadequate quality. |
| **Milieu** | **Milieu** is all about uncontrollable and unpredictable events. Therefore, a distinction is made between internal and external factors that influence this cause. Internal factors are the conditions within the facility, such as the space |

| | |
|---|---|
| | available, the noise in the workplace or the layout of the facility. External factors are assumed to be pollution, weather conditions, etc. |
| **Measurement** | **Measurement** includes inspection and other physical measurements, such as distance, volume, temperature, etc., manually, or automatically. In addition to the environmental cause, there are also two diverse types of measurement cause. The first is whether the process is evaluated well or poorly. The second cause can be due to lack of calibration and maintenance of the measurement systems. |

*Table 9: Definitions 6M's of production*

- Man/Manpower

As this study's observations already presented, two important aspects that falls under the M of Man/Manpower is the WPI, and training or competence.

The first subject is the WPI, the WPI stands for "Werkplek Instructie" is the work instruction for an operator. A product's WPI acts as a manual for the operators when they are assembling a product. The rule of thumb is the better the WPI is written, the better the operators assemble the products, the higher the quality of the product.

The second and third subject of man/manpower are competence and training from employees. Within Benchmark the competence and training from employees is determined by the training requirements (Opleidingsmatrix) and skills requirements (Inzetbaarheidsmatrix). These matrices show the number of employees who fulfilled their training and who can work independent.

- Material – Method

For the other five M's, the question is whether there is an activity or deliverable that Benchmark provides for each M that represents it, or that the reports should combine certain M's. Considering the NPI activities, the Process Failure Modes and Effect Analysis (PFMEA) emerges as a particularly good option, see **Error! Reference source not found.**. The PFMEA has several purposes; determining the w ays in which a product, service, or process can fail; estimating rick associated with specific failure causes; prioritizing the actions to reduce the risk of failure and evaluating the current control plan.

| Step number | Process Function: Operation | Requirements: Item | Potential Failure Mode | Potential Effect(s) of Failure | Severity | Class | Potential Cause(s)/ Mechanism(s) of Failure | Occurrence | Current Process Controls Prevention | Current Process Controls Detection | Detection | R.P.N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | inspection FOD | SUMP | Wrong part orientation | Improper fit to asssembly | 8 | - | Operator mistake, Standardize FOD instruction not followed - | 5 | Process steps description in Standardize work instruction | visual inspection by operator | 8 | 320 |
| | | | Sharp chips in the threads | Assembly damage, time loss | 8 | - | Operator mistake, Standardize FOD instruction not followed | 4 | Process steps description in Standardize work instruction. Pictures of nonconforming FODs | visual inspection by operator | 8 | 256 |

*Figure 14: General PFMEA*

The PFMEA works as follows, it identifies the failure modes which are the ways components, sub-assemblies, products, inputs, or processes could fail to perform their intended function (George et al., 2004). Then a list is made where each failure mode has one or more potential effects, or in other words, if a failure occurs, what are the consequences.

At last, each failure is assigned with ratings for severity, occurrence, and detection, which are as follows,

- Occurrence = the likelihood that a specific cause/mechanism of failure will occur
- Detection = the ranking of the best detection control listed in the Current Process Control column for a specific failure mode or cause/mechanism of failure
- Severity = the most serious effect for a specific failure mode

According to (George et al., 2004), in order to know which failure mode should be mitigated or eliminated, the highest priority risk should be chosen. This is done by calculating the risk priority number (RPN) for each effect, which is the multiplication of (severity * occurrence * detection). However, the same source also emphasizes one of the aspects that is more important than the others, namely the severity rating. An error with a severity level of 10 must be corrected immediately, as it has a significant impact on customers.

There is a slight difference on how Benchmark works with the PFMEA, because Benchmark make some assumptions. First, in principle severity will not be altered, unless severity of the failure mode effect is influenced (e.g., safety airbags). For PFMEA severity will remain the same, even after process improvements are made. This can only affect occurrence or detection. Furthermore, uses also other risk scores than the only the RPN. Namely, first the severity * occurrence, which defines the limits for direct action needed which sets the priority for continuous improvement. Second, the severity * detection, which defines the limits for direct action needed for high impact items.

Considering what the PFMEA covers, people are one of the aspects already included, but it also includes materials, since components, sub-assemblies, products, inputs, or processes have failure modes and thus can have inadequate quality. It also covers the method M, because the PFMEA concentrates a lot on control and risk mitigation.

- Machine – Milieu

Installation qualification falls under the M's: machine and milieu because installation qualification ensures that equipment and systems must meet the requirements established in the relevant protocols. Therefore, uncontrollable, and unpredictable events are minimized as much as possible, which is in accordance with the milieu. Finally, the installation qualifications contain acceptance criteria for the equipment and control systems, so that the possible causes of failures are also limited.

- Measurement

NPI activity that falls under measurement is the test coverage. Benchmark's test coverage calculation is important for the calculation of the yield target that Benchmark is supposed to reach when it is in production. The test coverage is agreed upon before the start of the project, and during the project the testers are improved to reach these test coverages.

**Identify new opportunities for improvement:**
As mentioned, the choice of visualisation method can affect the quality of the data. In the previous chapter, identification will be visualised using the Ishikawa diagram. Consequently, several areas of improvement will be identified for each subject that can improve acceptance or progress.

In the case of bucketing defects, the subjects are already kind of buckets for areas of improvement will be identified. These buckets are visualized in a pareto chart with the aim of concluding which subject has the most improvement points.

**Draw up an action or problem-solving plan:**
The solution choice for drawing up a problem-solving plan, a look has to be made towards each sub-objective. For drawing up problem-solving steps, the choice was already made by using the following steps: 1. Detailed description, 2. Root Cause Analysis (RCA), 3. Action List (QIT), 4. Solution search, 5. Verification, and 6. Implementation. Further explanation of these steps will be given in the solution chapter.

For the objective, prioritising defects, the solution choice is different than for the yield improvement reports, because one factor different. The estimation for the effort still remains, because it is necessary to know how much time an improvement will cost. The other factor is the satisfaction increase which is the difference in terms of yield between acceptance or progression levels.

**Track progress of problem-solving plan:**
The current method of monitoring progress of the problem-solving plan was also adequate. This means that each problem-solving steps can have three different states: not existing, in progress, and done.

**Predict yield performance for the next report:**
The same as for the yield improvement report, a macro process overview should also be included. However, the difference is that this overview does not visualize a process but visualizes the subjects and their respective improvement for either their progression or acceptance.

Moreover, instead of looking at where a change in the process is expected to improve yield in the future. The prediction should be about what the progression or acceptance of the subject can be to improve satisfaction.

## 5.4: Conclusion

This chapter starts with the following question: **"What is the decision-making process that delivers the proposed solution?"** Well, the continuous improvement cycles were scaled based on the idea behind and order of the report objectives. The PDCA cycle got the highest score. This means that there is a solution for the core problems: structured approach per report and lack of preventive thought to increase yield. In the case of the core problem: the visualization methods are combination of line chart and bar chart, pareto charts, Ishikawa diagrams, management report, action tracker, and process flow.

For the other two core problems: lack of awareness of yield development during design phases and data quality differs per project. These core problems are solved by adding the following: measuring satisfaction, FPY, and RTY; predicting satisfaction FPY, and RTY; targeting FPY and RTY; showing previous and upcoming changes in improvement process; trendline satisfaction, FPY, and RTY; adding Pareto Charts of defect buckets and subject contribution; problem-solving steps; and prioritization of NPI subjects and defect buckets.

# Chapter 6: Solution implementation

The chapter’s 6 aim is to provide the final solution for inefficient process of yield evaluation reports. Therefore, the research question is: **“How should the final solution look like?”** However, before the two different evaluation reports can be presented, the first step is to look at how the solution looks like in general. This includes the integration within Benchmark’s 7-step process.

The second part is the implementation itself. Therefore, the research question for the implementation is: **“How can the proposed solution optimally be implemented?”** The answer includes the respective tools made in this study that should support the solution to be optimally implemented.

Section 6.1 provides the general solution. Sections 6.2 and 6.3 present the two different evaluation reports. Lastly, section 6.4 provides the conclusion of this chapter.

An important note is that the values and numbers of the satisfaction and yield improvement templates do not represent reality. They are a demonstration to show how the e.g., the visualizations look like.

## 6.1: General solution

So, the general solution is the implementation of two different evaluation reports with each having its own aim and focus. These evaluation reports include the same continuous improvement cycle that function as the structured approach for each report. Figure 15 shows the clear distinction between evaluation reports on where they are in Benchmark's 7-step process.

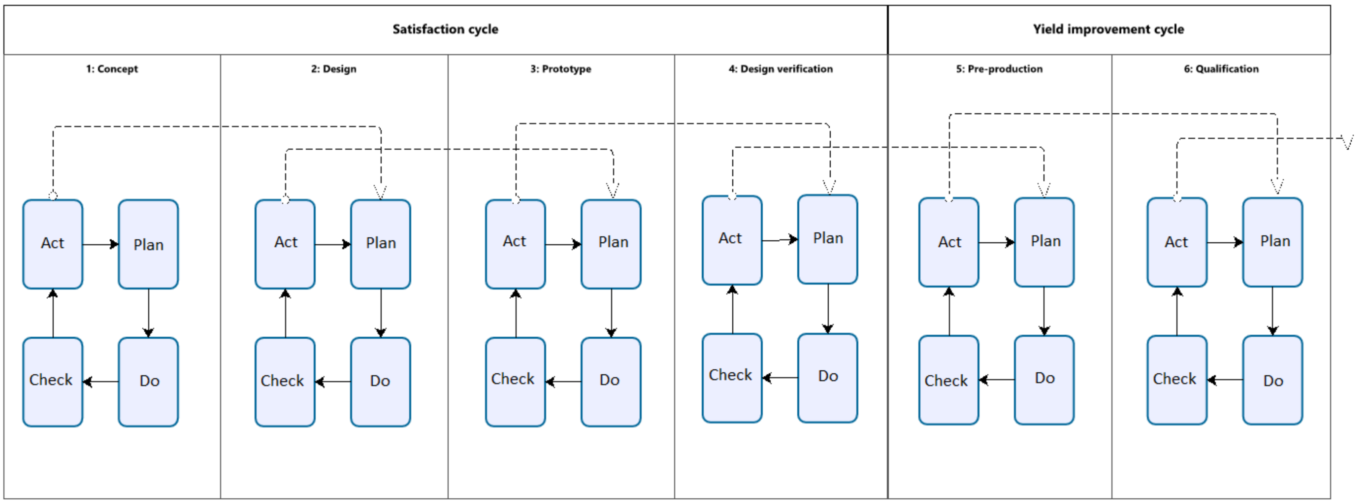



*Figure 15: General solution*

The conclusions that can be made from this figure is that the transition from satisfaction evaluation report to yield improvement report is determined by the finalisation of the installation qualifications. For the report objectives, the connection between each cycle's phase and the report objects are described in Table 10.

| **PDCA cycle phase:** | Plan | Do | | Check | Act |
|---|---|---|---|---|---|
| **Report objectives:** | Evaluate and conclude current yield performance | Identify new opportunities for improvement | Draw up an action or problem-solving plan | Track progress of problem-solving plan | Predict yield performance for the next report |

*Table 10: Connection between a cycle's phase and corresponding report objective*

## 6.2: Satisfaction evaluation

Thus, from the overall solution it can be concluded that the satisfaction evaluation report is responsible for the first four steps of Benchmark's Product Creation Process. The main purpose of the PDCA cycle is to be a standard structured approach that represents the yield development in the earlier stages of the NPI process. This satisfaction can be expressed in terms of route and method, which in place represents a NPI subject's acceptance or progression. The solution of the satisfaction evaluation report is below described.

For the implementation, the evaluation template is added, which makes it possible for the employees to use this study's solution. It will also include instructions to support the implementation so that it will not create any confusion.

### 6.2.1: Plan

The purpose of the Plan phase is to establish the methodology to achieve the set goal. Unlike the yield evaluation report where the yield is automatically measured by the testers and can be visualised immediately, in this report, satisfaction must be calculated first. The Plan phase explains how this is done, followed by the visualisation of the satisfaction values and the conclusion on how to improve.

**Cause-effect diagram:**

It starts off with the cause-effect diagram to show the process from a subject to eventually satisfaction. Figure 16 shows a general Ishikawa diagram with two intermediate steps added (acceptance and progression, trust, and route).

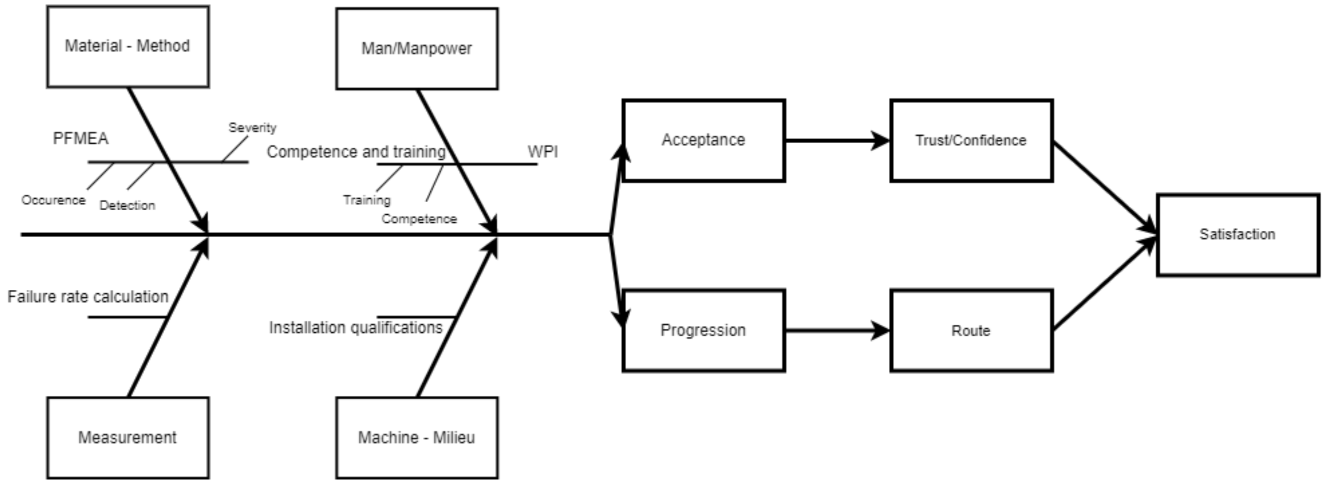



*Figure 16: Cause-effect diagram between NPI subjects and satisfaction*

**Scales:**

Another decision has to be made about the number of scales to use for the progression level and the acceptance level. The scales for the progression level are simple, as there are four in total. The first two indicate whether a subject is non-existent or finished, the other two are in between, since a subject can be in an initial or update state. Thus, the levels are non-existing, initial, update, and final for progression.

The acceptance levels are a little more difficult since it is matter of difficulty or accuracy. The higher the number of levels, the higher the accuracy but also more difficult. For a small number of levels, the opposite is true. Since accuracy is difficult to determine for qualitative subjects, the decision is made to have five levels. Undoubtedly, there is discussion about the difficulty of the determination because each subject is different.

However, it is more beneficial to use one certain number of levels for the clarity and homogeneity. The levels are as follows, unacceptable, slightly unacceptable, neutral, slightly acceptable, and acceptable.

The Ishikawa diagram shows the relationship between the relevant NPI subject and the satisfaction level, but it does not show how the relationship is. In the next section, I will recommend an approach to produce a satisfaction level considering the NPI subjects and their respective acceptance and progression levels.

**Manpower/man:**

A product's WPI is made by a manufacturing engineer and used by the operators for that kind of product. As earlier explained, it is difficult to quantify a WPI, because it consists of instructions. Therefore, the employees who can assess the WPI's are the manufacturing engineers and the operators. A discussion between the manufacturing engineer, quality engineer, and operator, should lead to a grade on how good the respective WPI is. These grades vary from 5 till 1, with 5 being excellent quality and 1 low quality. Consequently, these grades are converted to acceptance levels as follows in Table 11.

| Grade: | Acceptance level: |
|---|---|
| 5 | Acceptable |
| 4 | Slightly acceptable |
| 3 | Neutral |
| 2 | Slightly unacceptable |
| 1 | Unacceptable |

*Table 11: Grades and corresponding acceptance levels WPI*

Competence and training will be expressed in the training requirements (Opleidingsmatrix) and the skills requirements (Inzetbaarheidsmatrix). Since these two requirements can be expressed in percentages, since it is easy to quantify them. Using the general scoring matrix, or later a specialized matrix, a certain percentage can be assigned to an acceptance level, Table 12. The percentage of the training requirements is computed by the number of employees fulfilled training requirements divided by the total number of employees per product. The percentage of the skills requirements is computed by the number of employees T (can work independently) divided by the total number of employees per product.

| Range (%): | Acceptance level: |
|---|---|
| X >= 80% | Acceptable |
| 60% =< X < 80% | Slightly acceptable |
| 40% =< X < 60% | Neutral |
| 20% =< X < 40% | Slightly unacceptable |
| X < 20% | Unacceptable |

*Table 12: Percentages and corresponding acceptance levels Training and Competence*

**Material – Method:**

To be consistent with Benchmark's current PFMEA procedures, it is not possible to alter severity. In that case, Benchmark has some specific ways to take this into account in their PFMEA and prioritisation process. Namely, two other factors are calculated, first, severity * occurrence (S*O), which sets the limits for immediately necessary action that determines the priority for continuous improvement. Secondly, severity * detection (S*D) determines the limits for immediate action required for high-impact items. In addition, failure modes with a severity of 10 must be corrected immediately. So, to know how these two calculations can be converted to acceptance levels, first the ranges should be determined with the consideration of the severity constraint.

Each failure mode has a value for detection, occurrence, and severity, this value can vary between 1 and 10. This means that both S*O and S*D can have a minimum value of 1 and a maximum value of 50. Using a linear scale gives the following Table 13,

| Range: | Acceptance level: |
|---|---|
| 1 < X < 10 | Acceptable |
| 10 =< X < 20 | Slightly acceptable |

| | |
|---|---|
| 20 =< X < 30 | Neutral |
| 30 =< X < 40 | Slightly unacceptable |
| 40 =< X < 50 | Unacceptable |

*Table 13: Values and corresponding acceptance levels S*O and S*D*

Then the question is which value should be taken for severity, occurrence, and detection of a PFMEA. The answer is the average of each respective value.

**Machine – Milieu:**
The installation qualifications consist of 13 test cases. Once the test cases are determined, each case must meet the acceptance criteria. So, my advice is to use the following levels from Table 14,

| Installation qualifications | Count (Number of test cases accomplished * 5/13) |
|---|---|
| Acceptable | 5 |
| Slightly acceptable | 4 |
| Neutral | 3 |
| Slightly unacceptable | 2 |
| Unacceptable | 1 |

*Table 14: Count test cases and corresponding acceptance levels Installation Qualifications*

The scales is determined as follows, since there are 5 acceptance levels, the 13 installation qualifications dimension has to transformed to 5 dimension. So, to calculate the respective acceptance level, the number of test cases that are accomplished have to be count and multiplied by 5/13. This number should be rounded up and result in a number from 1 to 5, where 1 is unacceptable and 5 is acceptable.

**Measurement:**
The scale Table 12 can also be used for the test coverage. Since the calculation is ( # of testers reaching their theoretical test coverage / total # of testers) expressed in percentages, it will automatically fall within the ranges of Table 12.

**Progression:**
The progression of a subject could be in four possible states, namely, not existing, initial, update, and final. Determining the progression is different from determining the level of acceptance. In fact, quantifying a state of progression is virtually impossible and is very abstract. However, there is one easily quantifiable state of progression and that is non-existent. For example, a subject is in the non-existent state, if the subject does not yet exist.

Determining the other progression states is much more difficult, because there are two different ways to determine them. The first method is that the progression is time related to the product development where it situates in a certain Benchmark’s design step. For instance, steps one and two can only have not-existing or initial, three to five updates, etc. This means that subjects have fixed progression states in each design phase. Table 15 show the relationship between the progression states and Benchmark's 7-step process based on how now the NPI process is organized. The relationships of the WPI, the training and skill matrices, and the PFMEA are the same.

Except the installation qualifications which only has the final progression state defined by Benchmark. This means that the progression states of the other steps are open for discussion and own interpretation.

| Benchmark's 7-step process: | WPI: | Training: | Competence: | Test coverage: | PFMEA: | Installation qualifications: |
|---|---|---|---|---|---|---|
| 1. Concept<br>2. Design<br>3. Prototype | Initial | Initial | Initial | Initial | Initial | X |
| 4. Design verification | Update | Update | Update | Update | Update | X |
| 5. Preproduction | Final | Update | Update | Final | Final | Final |
| 6. Qualification | Final | Final | Final | Final | Final | Final |

*Table 15: Progression states for each NPI subject*

The other way is that subjects can move to a different progression state no matter what stage the product is in, but for that they must first have reached a certain level of acceptance. For instance, the WPI can move from the initial to the update state if it has reached the acceptance level in the initial state.

Both ways have advantages and disadvantages. The crucial factor is the product development. The first method goes with the flow of product development which ensures that workers are working efficiently. They are working with the latest current state of the product. In the other method, it is possible that a topic is completed while the product is still changing. This means that all the work to get the subject to that state might be used inefficiently. So, what is the advantage for the one method is a limitation for the other. However, the advantage of the second method is that it can achieve a higher satisfaction and thus yield faster, because it is not limited in time but in work effort. This is also directly the limitation of the first method. Thus, it is up to Benchmark which method they prefer.

**Satisfaction calculation:**
Below is an example to show how the satisfaction report works, where the values are hypothetical. If a value has a green background that means that it can be changed. As earlier mentioned, the satisfaction evaluation report is structured so that it can be easily adapted to the needs of the user. This is no different for the yield numbers associated with the acceptance levels and progression states.

In general, the satisfaction is calculated as follows, $Satisfaction = \frac{\sum_{j=1}^{4} Satisfaction_j}{j}$, where $Satisfaction_j = \sum_{i=1}^{7}(Acceptance_i * Progression_i)$. In Table 16 shows all the variables with each respective definition.

| Variable: | Definition: | Variable: | Definition: |
|---|---|---|---|
| j=1 | Man/Manpower | i=1 | WPI |
| | | i=2 | Competence |
| | | i=3 | Training |
| j=2 | Measurement | i=4 | Test coverage |
| j=3 | Milieu – Machine | i=5 | Installation qualifications |
| j=4 | Method – Material | i=6 | Severity * Occurrence |
| | | i=7 | Severity * Detection |

*Table 16: Satisfaction table*

There are two standard tables for acceptance and progression with satisfaction values that are the same for each subject. In addition, these satisfaction values are based on a linear basis to make it as easy as possible. Table 17 is as follows,

| **Satisfaction values** | | | |
|---|---|---|---|
| **Level** | **Weight** | **State** | **Weight** |
| Unacceptable | 20% | Not existing | 0% |
| Slightly unacceptable | 40% | Initial | 33.33% |
| Neutral | 60% | Update | 66.66% |
| Slightly acceptable | 80% | Final | 100% |
| Acceptable | 100% | | |

*Table 17: Satisfaction values acceptance and progression*

This is the easiest way, but the question is how this method can be adapted to more specific needs. For example, it may be that the WPI has different satisfaction values than the other subjects. In my opinion, it is up to Benchmark to change these parameters, either based on experience or on the preference of staff responsible for the subjects. The following is an example of how to proceed and obtain an actual satisfaction value. Table 18 shows the filling form where each subject has an acceptance level and progression state attached.

| **Filling form** | | | |
|---|---|---|---|
| **Production** | **Subject** | **Select level** | **Select state** |
| Man/Manpower | WPI | Slightly unacceptable | Update |
| | Competence | Neutral | Update |
| | Training | Neutral | Final |
| Milieu - Machine | Installation qualifications | Neutral | Update |
| Measurement | Test coverage | Slightly acceptable | Update |
| Method - Material | Severity * Occurrence | Neutral | Update |
| | Severity * Detection | Acceptable | Final |

*Table 18: Filling form*

| **Result matrix** | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Man/Manpower** | | | **Milieu - Machine** | **Measurement** | **Method - Material** | |
| | WPI | Competence | Training | Installation qualifications | Test coverage | Severity * Occurrence | Severity * Detection |
| | | | | | | | |
| **Level** | 40% | 60% | 60% | 60% | 80% | 60% | 100% |
| **State** | 67% | 67% | 100% | 67% | 67% | 67% | 100% |
| **X** | 27% | 40% | 60% | 40% | 53% | 40% | 100% |
| **Total** | 51% | | | | | | |

*Table 19: Result matrix*

Table 19 shows the results matrix of the satisfaction value and works as follows. The first two rows of percentages are the rewritten weights of Table 18 in percentages, X is the multiplication of these weights. The final step is to calculate the average of Man/Manpower, Milieu and Machine, Measurement, and Method - Machine, which yields a total satisfaction value.

**Advice guidelines:**
The main advantage of this method is that the input values can be easily changed without changing the entire approach, the input values can be adjusted to the preference of Benchmark, or my advisory guidelines can be followed. Finally, the method can be easily extended by, for example, using different yield values for specific subject. Hence, management can make the method as customized as it wants.

**Evaluate and conclude current satisfaction performance:**
As already discussed, the best way to visualize the performance of the satisfaction is through a line chart, together with the predicted values and a trendline. This gives the ability to evaluate the satisfaction changes from week to week and to conclude the overall performance using the trend and comparison with the predicted values. The black arrow is indicating where change in the process or improvement in the satisfaction was expected.

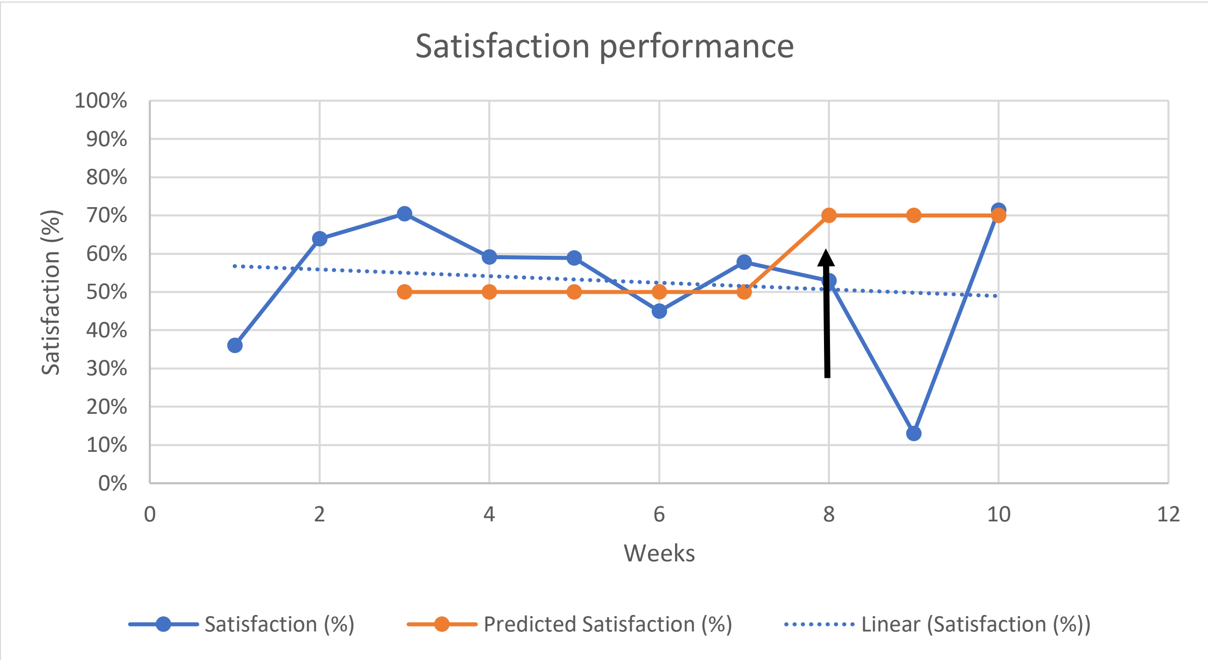



*Figure 17: Visualization satisfaction performance*

For the satisfaction contribution of each subject, an Ishikawa diagram is useful to show all the values and how the total satisfaction is established, see Figure 18.

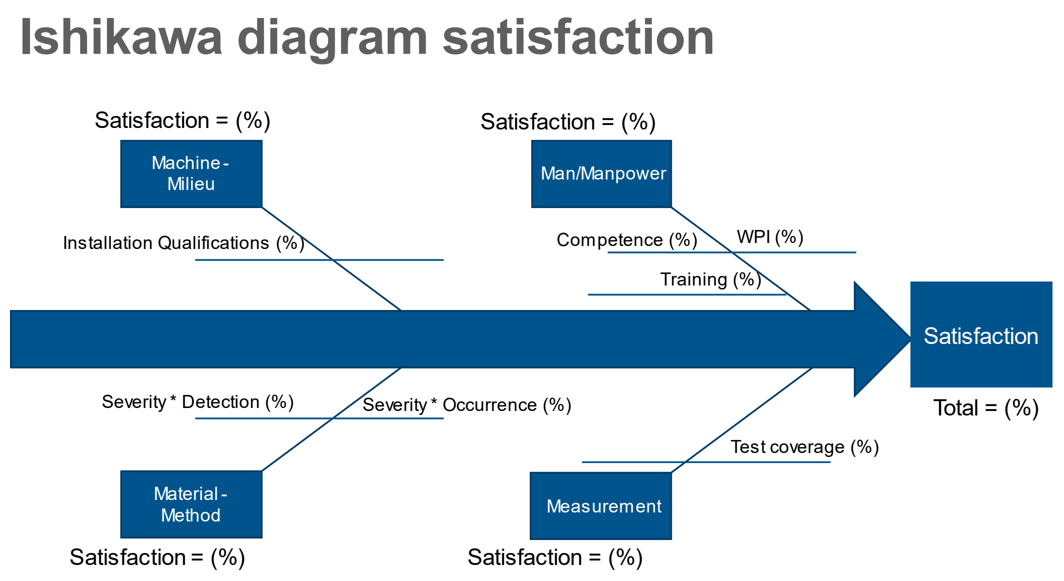



*Figure 18: Ishikawa diagram satisfaction*

### 6.2.2: Do

The Do phase has a similar structure as the previous chapters, in contrast to the Plan phase, where for each report objective the solution is described. The Do phase has two report objectives: Identify new opportunities for improvement and draw up an action or problem-solving plan.

**Identify new opportunities for improvement:**

The main difference with the yield evaluation reports is that here is the focus on identifying and setting up action plans for opportunities of improvement. It is already mentioned that it is not possible that the subjects are defect, but only low quality.

- Identifying opportunities

Section 5.2.1 decided that the Ishikawa diagram is the best method to identify and visualize opportunities. Since, it finds out several root causes or improvement opportunities which can be prioritised in the next section.

- Visualizing opportunities

Figure 19 shows an example of an Ishikawa diagram that can be used as a visualizing and identifying method of improvement opportunities for each subject to improve the satisfaction.

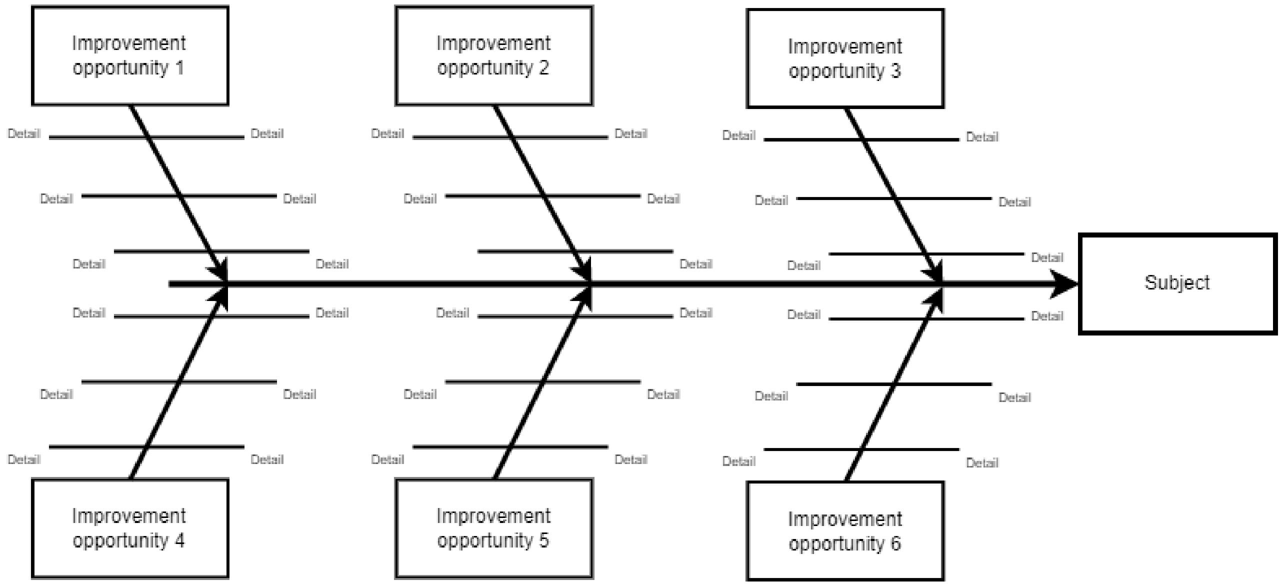



*Figure 19: Ishikawa diagram identification opportunities per NPI subject*

- Comparing subject change

Figure 20 and Figure 21 show that by comparing two pareto charts from previous week and the current week, it shows the differences in contribution in terms of satisfaction by subject. This gives insight into which subject has seen improvement or reduction. Moreover, it shows which subject still has great potential for improvement. The values in the Pareto charts are the X values from the result matrix in Table 19.

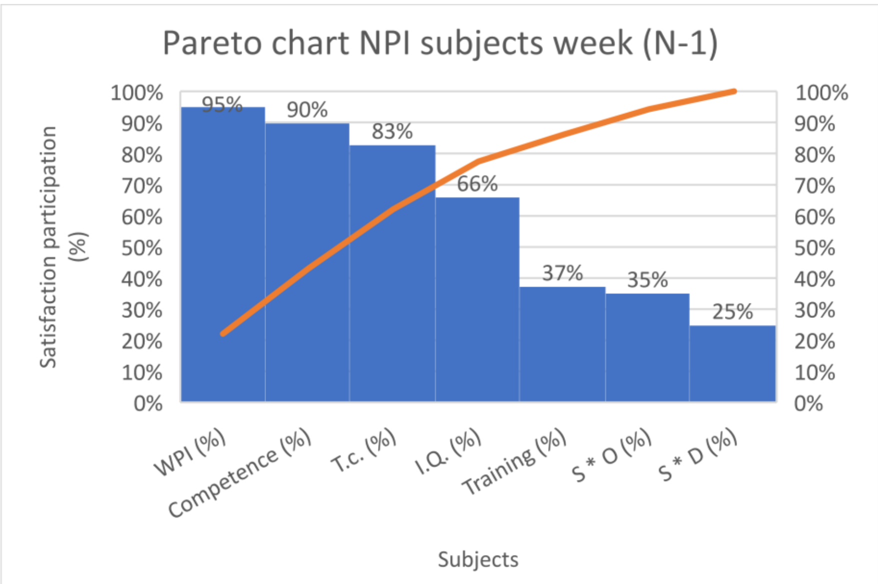



*Figure 20: Pareto chart NPI subjects previous week*

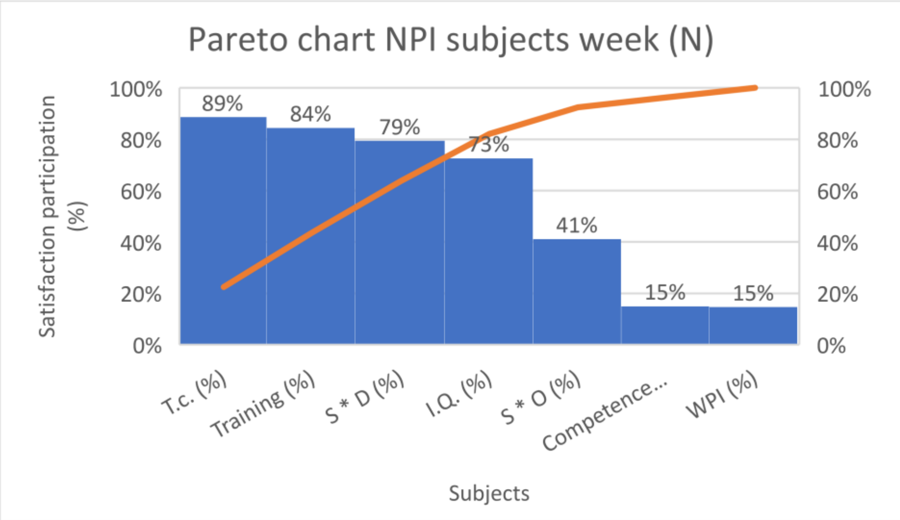



*Figure 21: Pareto chart NPI subjects current week*

**Draw up an action or problem-solving plan:**

The establishment of sub-objective, an action or problem-solving plan and the report objective of the check phase, track progress of problem-solving plan, uses the same two tables. These two tables incorporate both the respective report objectives and sub-objectives.

- Draw up problem-solving steps

So, the main aim of problem-solving steps is to have a step-by-step approach that ensures improvement. However, there are more crucial factors that are attached to a problem and needs to be added otherwise it is not a legit problem within Benchmark. This means the documentation of the CAPA Issue ID, Work Issue ID, a description, and responsible employee. In Figure 22, the improvement steps are clearly visualized and are as follows, 1. A detailed description, 2. The Root Cause Analysis, 3. An Action list, 4. Solution finding, 5. Verification, and 6. Implementation. An important thing to keep in mind is that each Issue ID represents a subject and not an improvement opportunity from a subject. This will be discussed in the next sub-objective.

| CAPA Issue ID | Work Issue ID | Description | Responsible | Improvement | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Detailed description | RCA | Action list (QIT) | Solution finding | Verification | Implementation |
| #.... | JIRA: SA.. | | | | | | | | |
| #.... | JIRA: SA.. | | | | | | | | |
| #.... | JIRA: SA.. | | | | | | | | |
| #.... | JIRA: SA.. | | | | | | | | |
| #.... | JIRA: SA.. | | | | | | | | |
| #.... | JIRA: SA.. | | | | | | | | |
| #.... | JIRA: SA.. | | | | | | | | |
| #.... | JIRA: SA.. | | | | | | | | |

Legend: In progress , Done

*Figure 22: Management report overview*

- Prioritizing improvement opportunities

In the prioritization, each improvement opportunity from a subject is prioritized and documented. This becomes clear in Figure 23, since the first column represents an Ishikawa diagram from a subject. The action column is the action to ensure the improvement. The prioritization is incorporated through the estimation of effort and satisfaction increase estimate. Further aspects that are documented are the problem owners, start date, due date, status, and registrations.

| Ishikawa ID (Work Issue ID) | Action | Effort Estimate (Low 5, Medium 3, High 1) | Satisfaction Estimate (High 5, Medium 3, Low 1) | Priority (Effort * Satisfaction) | Owner | Start date | Due date | Status | Registrations |
|---|---|---|---|---|---|---|---|---|---|
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |

Legend: Overdue In progress Done Original action lists: (Source)

*Figure 23: Action tracker satisfaction report*

### 6.2.3: Check

The main of the check phase is to track progress of the problem-solving plan. Therefore, it is necessary that the action plan for each improvement opportunity is included, as well, as the visualization of it.

**Track progress of problem-solving plan:**

The monitoring of the problem-solving or action plans did include three report objectives: problem description per improvement opportunity, action plan per improvement opportunity, and visualization tracking progress.

- Problem description per defect and problem-solving plan per defect

For both the problem description per opportunity and problem-solving plan per opportunity, the current method was already adequate. Hence, the aim for the report was to provide space and clarity so that it could be visualized and put in the report. The problem description and problem-solving plan are both incorporated in Figure 23.

- Visualization tracking progress

In Figure 22 can be seen that each problem-solving step of every CAPA Issue ID can be in progress (yellow) or done (green). In the case of the prioritization, see Figure 23, each work issue ID can either be overdue (red), in progress (yellow), or done (green). It is overdue if the due date has passed.

### 6.2.4: Act

The act phase aims at evaluating the reflection for the next report. This means that it sets the overall focus of where the satisfaction is going to be improved, predict the satisfaction change for the next reports, and standardizes the satisfaction gains from previous reports.

**Prediction yield performance for next report:**

The prediction of yield performance for the next report includes two report sub-objectives: prediction satisfaction changes and satisfaction improvement focus.

- Prediction satisfaction change

Figure 24 visualizes the incorporation of the satisfaction's prediction. Interesting directions that have to evaluated are topics such as where is a change in satisfaction expected. Hence, when will a subject be improved.

In addition, by comparing the trendline and the predicted satisfaction values, it gives a sense about how necessary it is to make improvements, since it shows what logically will happen with the satisfaction if the current way of work is maintained. Hence, a major difference means high demand for improvement.

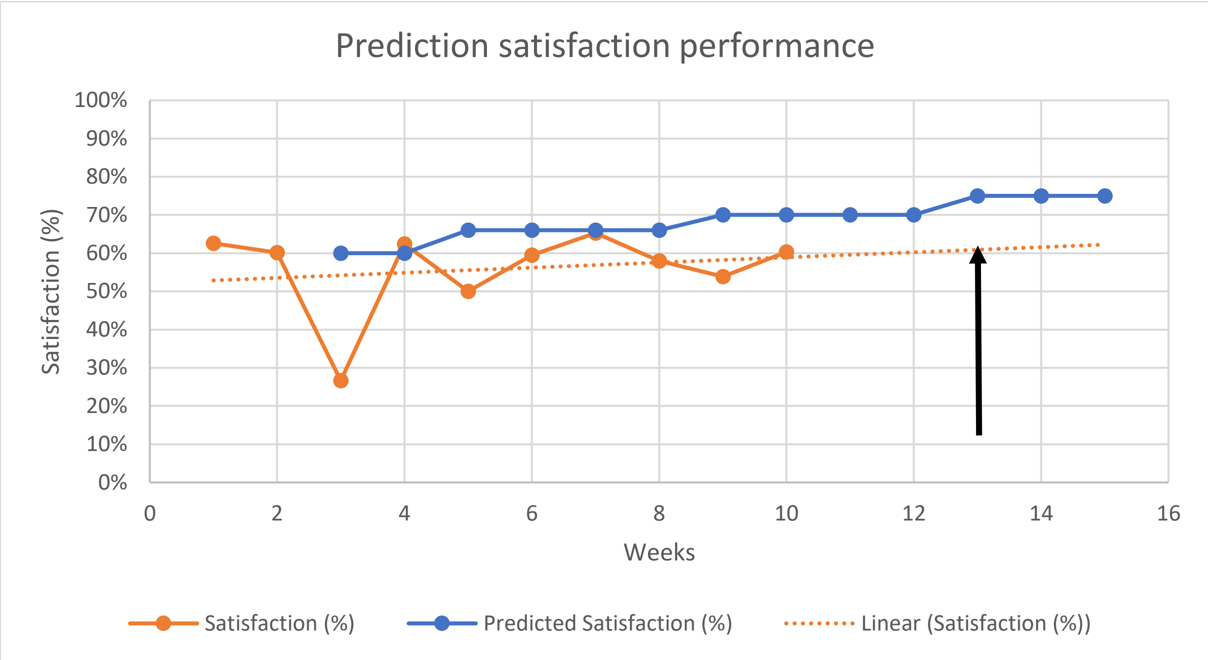



*Figure 24: Prediction satisfaction performance*

The prediction of the satisfaction is based on the change of subject's satisfaction. This is visualized by means of an Ishikawa diagram, see Figure 25.

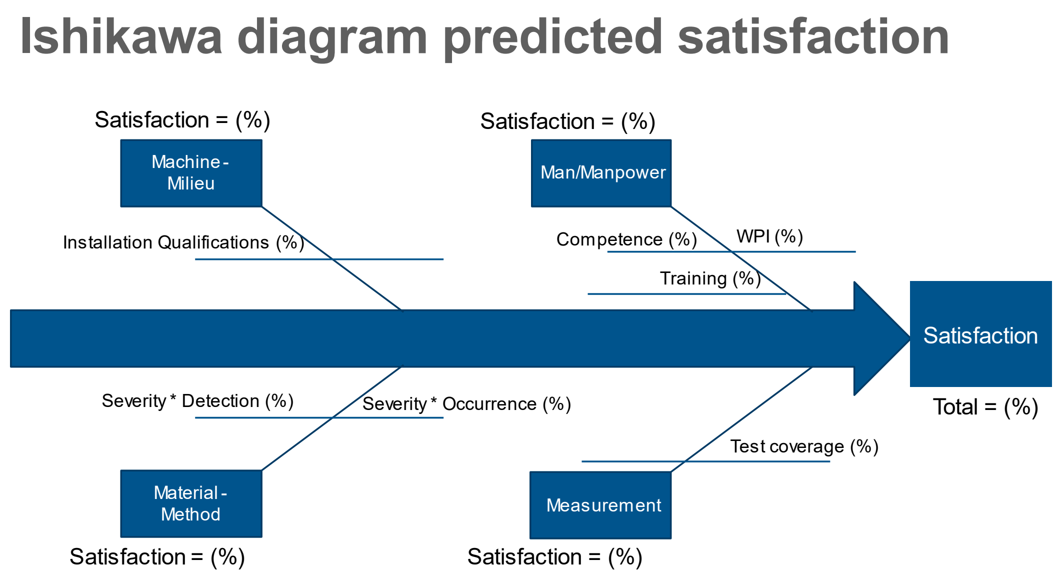



*Figure 25: Ishikawa diagram prediction satisfaction*

- Satisfaction improvement focus

The satisfaction improvement focus is a macro-overview or summary that shows where improvement is initiated. Figure 26 is the visualization of this overview in the PowerPoint template. It includes every subject and a legend for clarity.

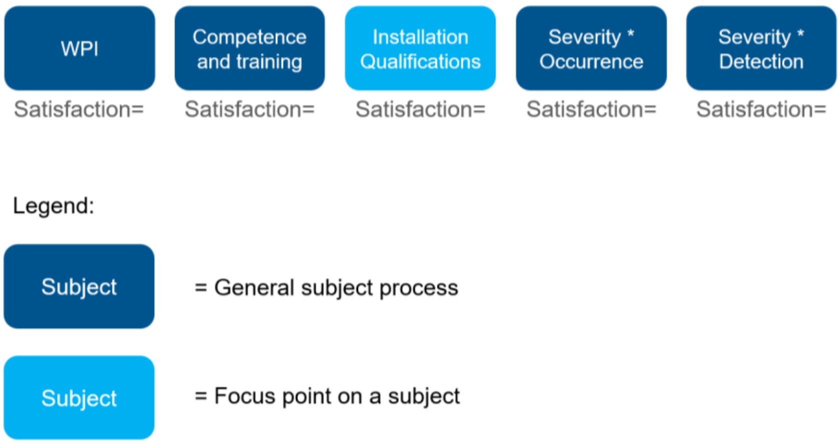



*Figure 26: Process flow satisfaction improvement focus*

## 6.3: Yield improvement evaluation

As in Figure 15 can be seen, the yield improvement evaluation report is responsible for steps 5 and 6 of Benchmark's 7-step process. The yield improvement evaluation report is the most like the current reports.

### 6.3.1: Plan

In contrast to the satisfaction evaluation report, the plan phase includes the evaluation and conclusion of the current yield performance, in terms of process yield (RTY) and test yield (FPY).

**Evaluate and conclude current yield performance:**

The main two limitations of the current reports were that the entire processes' yield was not incorporated, and that the data had the intention to be goal on its own rather than a supporting tool. How this is solved, can be seen in the following report objects.

- Rolled Throughput Yield performance

The visualization of the yield performance starts off with the visualization, see Figure 27, of the yield of the entire process, RTY. This gives the overall evaluation of the yield and is not only beneficial since it was not even included in the previous reports but also shows the most accurate yield value. The RTY of a process can be calculated by the multiplication of the FPY's of each tester. If testing processes are parallel, then the path with the lowest FPY is taken forward.

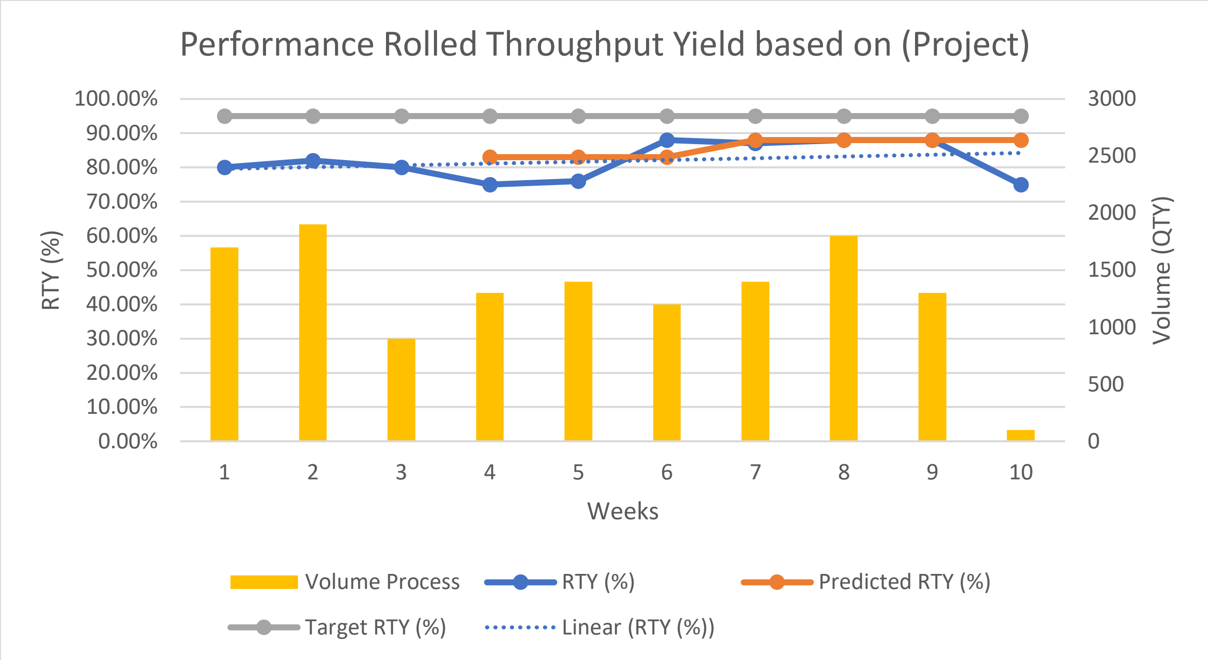



*Figure 27: Visualization RTY performance*

The next step is different, as the next visualisation method is the comparison of Pareto charts between the current and previous week in tests that are part of the process, see Figure 28 and Figure 29. The reason for this is that the RTY is not designed to detect defects or failures, but to understand yield performance. From this point of view, Pareto charts evaluate where the most yield is gained or lost and can therefore conclude which tester to focus on in the report.

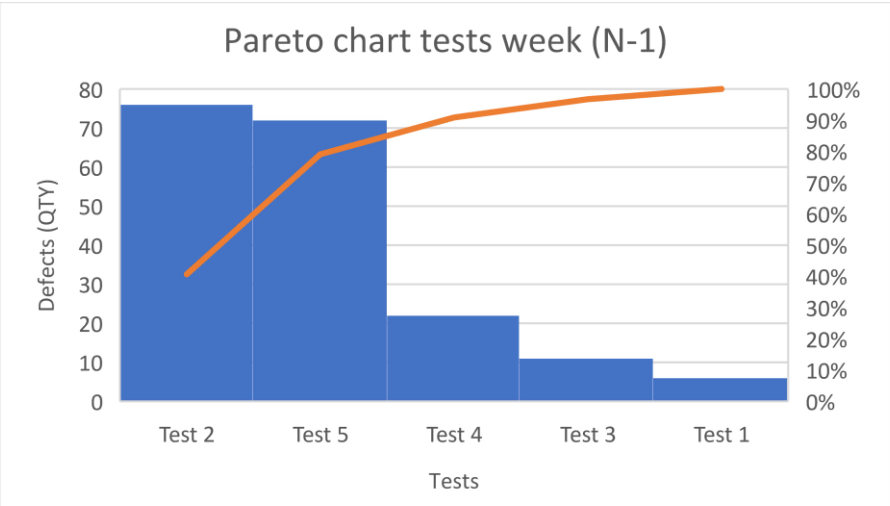



*Figure 28: Pareto charts defects per tests previous week*

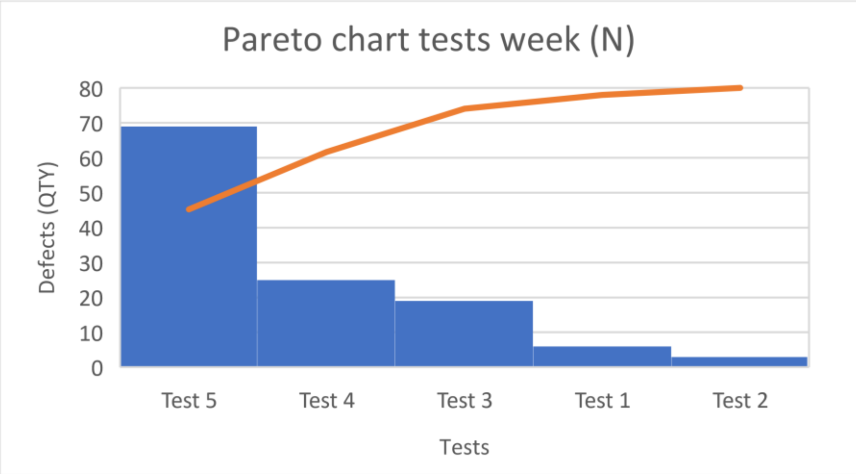



*Figure 29: Pareto charts defects per tests current week*

- First Pass Yield performance

The combination of the RTY's evaluation, conclusion, and the Pareto charts will result in a decision on which tester to focus on. The next step is the visualization of the yield performance from that respective tester. This is mostly the same as the previous visualizations of the performance, since it includes a target, yield values, predicted yield values, volume quantities, and a trendline. The FPY is calculated as follows, it is the percentage of number of passed items with cycle number 1 for a test divided by the total number of items that has gone in for that specific test.

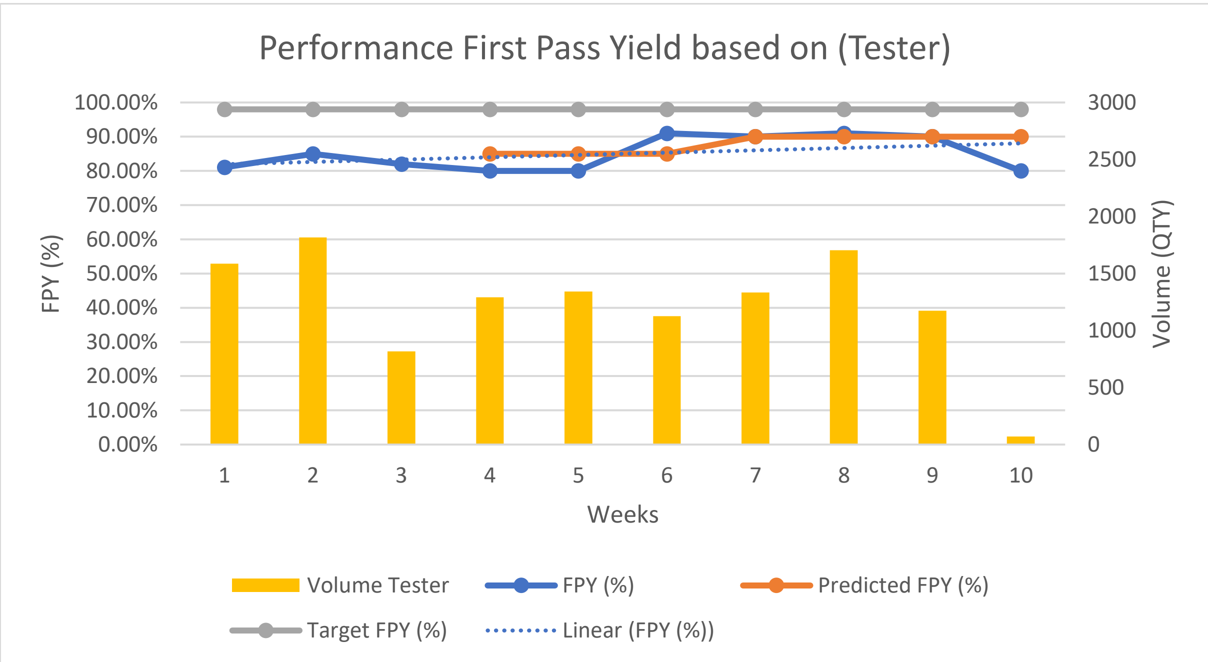



*Figure 30: Visualization FPY performance*

### 6.3.2: Do

Th Do phase aims at accomplishing the desired results from the plan phase. Therefore, where the Plan phase the failures of the yield performance concludes, is it up to the Do phase to solve these failures. The Do phase has two report objectives: Identify new opportunities for improvement and draw up an action or problem-solving plan.

**Identify new opportunities for improvement:**

In contrast to the satisfaction evaluation, products or components can have defects. It includes the following sub-report objectives: identifying defects, visualizing defects, and comparing defect change.

- Identifying defects

Section 5.2.1 decided that the Ishikawa diagram is the best method to identify and visualize defects. Since, it finds out the root causes of the early formed buckets which can be prioritised in the next section.

- Visualizing defects

Figure 31 shows a general visualization of potential root causes from a bucket. The decision is made to put such an Ishikawa diagram not directly in the report, but as a link. The reason for that is because there are several buckets and putting them all together in the report will make it unclear for the reviewers.

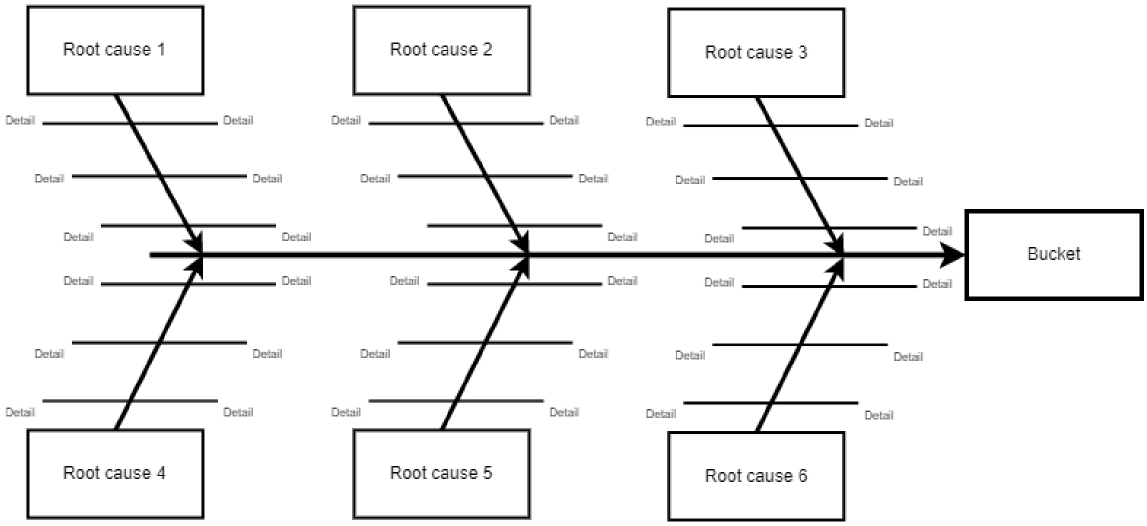



*Figure 31: Ishikawa diagram identification defects per bucket*

- Comparing defect change

For both the RTY and the FPY, the comparison of defects between weeks is best visualised by two Pareto diagrams. As already mentioned in the Plan phase, there is a difference in usage between the Pareto diagrams of the RTY and the FPY. For the FPY, it is decided which buckets to focus on to solve the defects. Examples of these Pareto diagrams can be seen in the following Figure 32 and Figure 33.

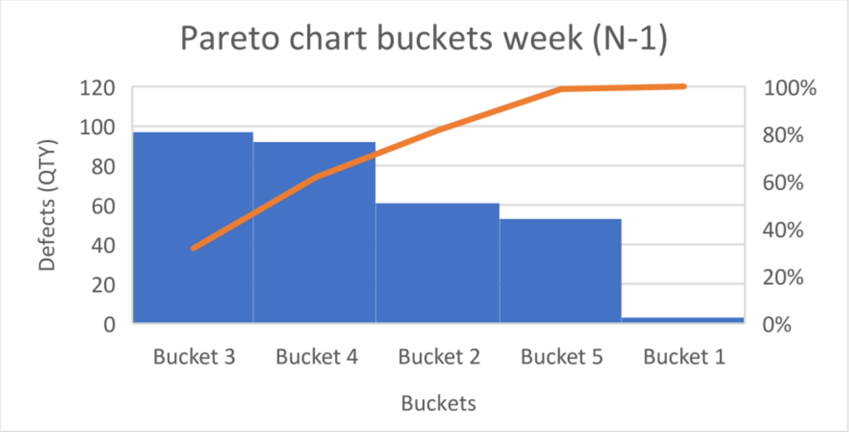



*Figure 32: Pareto chart defects per bucket previous week*

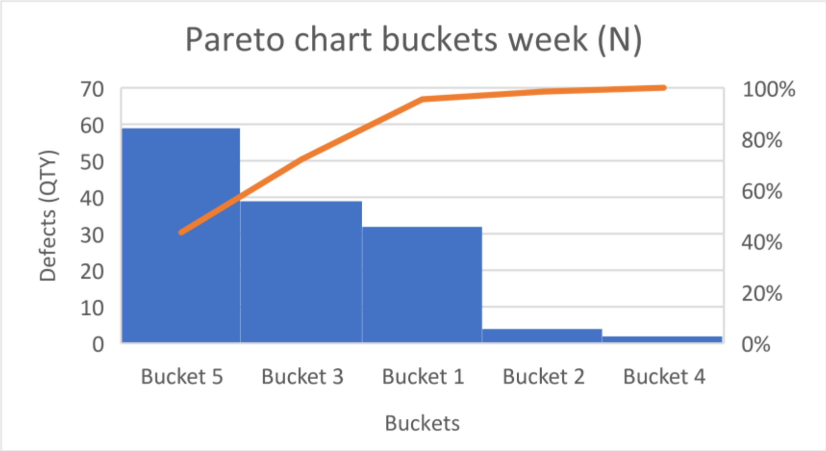



*Figure 33: Pareto chart defects per bucket current week*

**Draw up an action or problem-solving plan:**

The establishment of sub-objective, an action or problem-solving plan and the report objective of the check phase, track progress of problem-solving plan, uses the same two tables. These two tables incorporate both the respective report objectives and sub-objectives.

- Draw up problem-solving steps

So, the main aim of problem-solving steps is to have a step-by-step approach that ensures improvement. These steps are the same as for the satisfaction report. This means the documentation of the CAPA Issue ID, Work Issue ID, a description, and responsible employee. In Figure 22, the improvement steps are clearly visualized and are as follows, 1. A detailed description, 2. The Root Cause Analysis, 3. An Action list, 4. Solution finding, 5. Verification, and 6. Implementation. There is no need for further explanation of these problem-solving steps as these are known procedures by the employees within Benchmark.

- Prioritising defects

The prioritizing defects is the same idea as for the satisfaction report, since each defect or root cause from a bucket is prioritized and documented. This becomes clear in Figure 34, since the first column represents an Ishikawa diagram from a bucket. The action column is the action to ensure the improvement. The prioritization is incorporated through the estimation of effort and chance estimate of occurring. Further aspects that are documented are the problem owners, start date, due date, status, and registrations.

| Ishikawa ID (Work Issue ID) | Action | Effort Estimate (Low 5, Medium 3, High 1) | Chance Estimate (High 5, Medium 3, Low 1) | Priority | Owner | Start date | Due date | Status | Registrations |
|---|---|---|---|---|---|---|---|---|---|
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |
| SA.. | | | | | | | | | |

Legend: Overdue In progress Done Original action lists: (Source)

*Figure 34: Action tracker yield improvement report*

### 6.3.3: Check

The main of the check phase is to track progress of the problem-solving plan. Therefore, it is necessary that the problem-solving plan for each defect is included, as well, as the visualization of it.

**Track progress of problem-solving plan:**

The monitoring of the problem-solving or action plans did include three report objectives: problem description per defect, action plan per defect, and visualization tracking progress.

- Problem description per defect and problem-solving plan per defect

For both the problem description per defect and problem-solving plan per defect, the current method was already adequate. Hence, the aim for the report was to provide space and clarity so that it could be visualized and put in the report. The problem description and problem-solving plan are both incorporated in Figure 22.

- Visualization tracking progress

In Figure 22 and Figure 34 can be seen that each problem-solving step of every CAPA Issue ID can be in progress (yellow) or done (green). In the case of the prioritization each work issue ID can either be overdue (red), in progress (yellow), or done (green). It is overdue if the due date has passed.

### 6.3.4: Act

The act phase aims at evaluating the reflection for the next report. This means that it sets the overall focus of where the yield is going to be improved, predict the yield change for the next reports, and standardizes the yield gains from previous reports.

**Predict yield performance for the next report:**

The prediction of yield performance for the next report includes two report sub-objectives: prediction yield change and yield improvement focus.

- Prediction yield change

The prediction of the yield change is almost the same as the satisfaction prediction. The main difference is that the predicted yield is calculated differently. Both Figure 35 and Figure 36 include predicted values of the yield in the upcoming weeks based on predicted changes in the future.

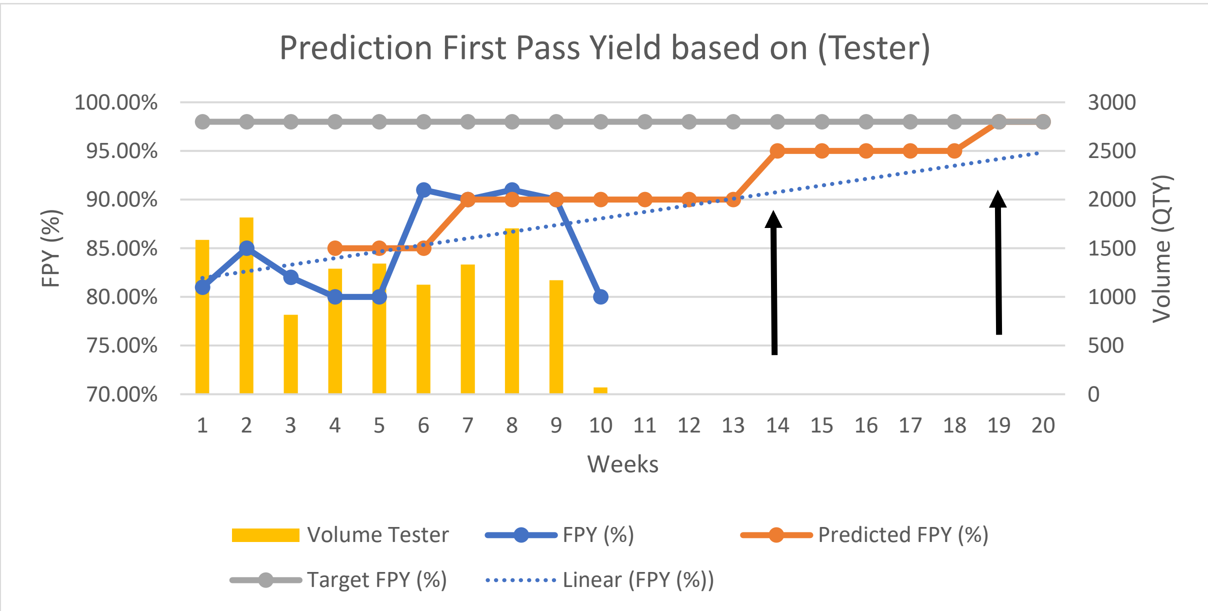



*Figure 35: Visualization prediction FPY performance*

The reason a tester's prediction comes before the entire process is that it is important to understand what the result of a tester's improvement will be on the yield of the entire process. Therefore, the last step is seeing what a tester's potential improvement will bring to the RTY.

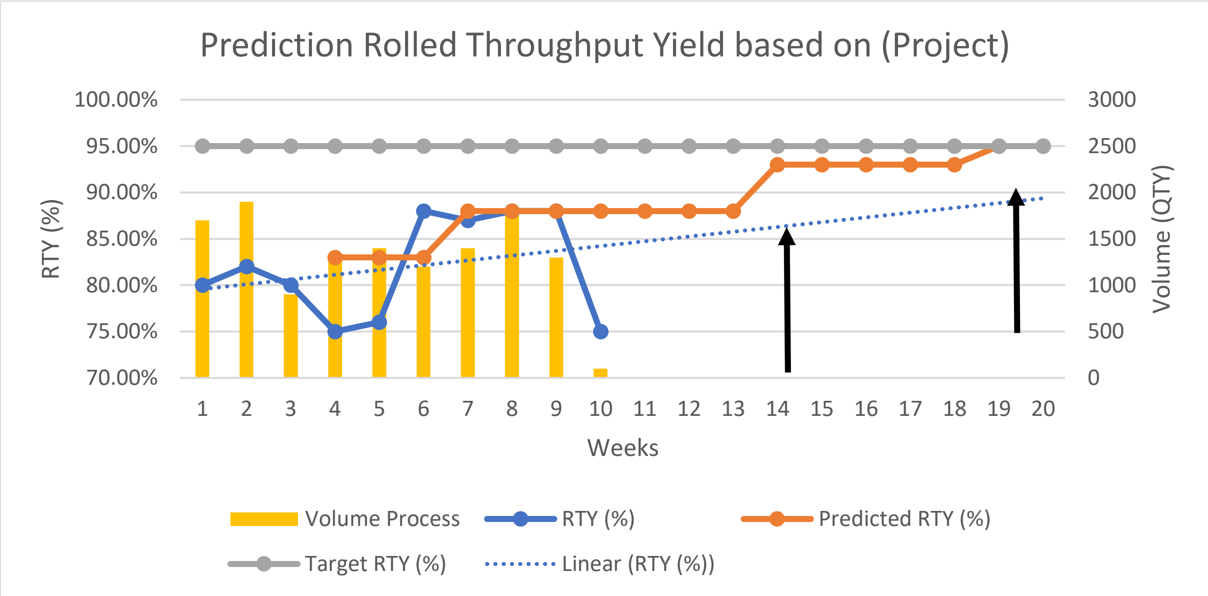



*Figure 36: Visualization prediction RTY performance*

- Focus yield improvement

The yield improvement focus is a macro-overview or summary that shows where improvement is initiated. Figure 37 and Figure 38 are the visualization of these overviews in the PowerPoint template for both a tester's FPY and a processes' RTY. It includes every bucket, test, and a legend for clarity.

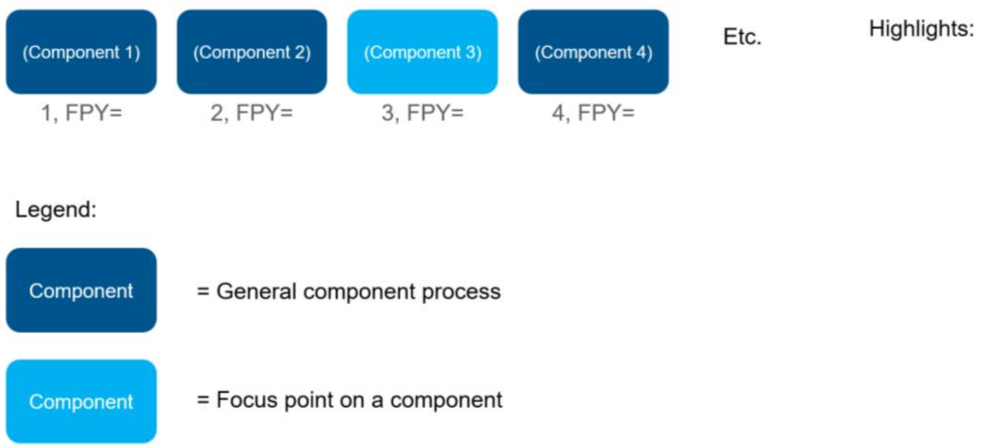



*Figure 37: Process flow FPY improvement focus*

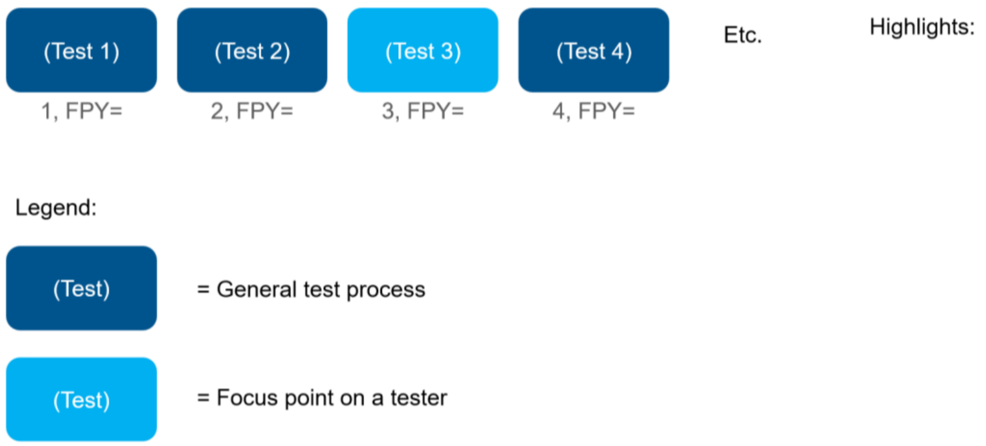



*Figure 38: Process flow RTY improvement focus*

## 6.4: Templates

**Objective:**

The previous parts of sections 6.2 and 6.3 were important to show what the final solution should look like. However, this section also contains the implementation part, which ensures that the solutions can be incorporated into the daily use of Benchmark. To make this possible, it is necessary to see how these evaluations are sent from one employee to another. This is done using PowerPoint for which Benchmark has a generic template.

**Other remaining requirements Benchmark template:**

There are also aspects in the model that were not explicitly discussed in the solutions section. These aspects are requirements from the Benchmark, which should be included but did not fall under the objectives of the report. These requirements ensure proper implementation of the templates.

First, the title page was missing information from the client or the item number. Second, several slides were missing conclusion, commentary, or legend sections. Conclusion sections contain clues that can be made based on the information provided by a visualisation. An example of a comment section is the priority section, which describes which buckets have priority and an explanation. Finally, the legend was added because it makes certain aspects much clearer, such as the states of the improvement steps per problem-solving plan.

**Excel documents:**

For Benchmark, I have created for each report an own excel document that includes all necessary computations, guidelines, and visualizations to make the reports.

Moreover, it also contains a summary section, see Table 20, where each subject is visualized with corresponding advice calculation and Benchmark's document number. This makes it easier for employees to determine each subject's acceptance level, since they see where to look and how to calculate it.

| Subject | Calculation | General documents |
|---|---|---|
| **WPI** | A grade from 1 to 5 | (Collaboration between manufacturing and quality engineer) |
| **Competence** | (# of employees who are T or I / total # of employees) (%) | ANF - 08100 |
| **Training** | (# of employees completed the trainings / total # of employees) (%) | ANF - 08300 |
| **Installation qualifications** | Count # of test cases accomplished * (5/13) | ANF - 30102 |
| **Test coverage** | (# of testers reaching their theoretical test coverage / total # of testers) (%) | ANW - 13650 |
| **Severity * Occurrence** | (Average Severity * Average Occurrence) | ANW - 13500 |
| **Severity * Detection** | (Average Severity * Average Detection) | ANW - 13500 |

*Table 20: Guidelines calculation for each NPI subject*

## 6.5: Conclusion

The conclusion of chapter 6 will answer two research questions, which were as follows: **"How should the final solution look like?"** and **"How can the proposed solution optimally be implemented?"** The first question targets the solution in general, while the second question targets the solution's implementation.

The final solution consists of two different reports, responsible for different parts of the seven-step process. Both reports have the same structured approach and the same report objectives. Moreover, the same visualisation methods and outputs of data quality are pursued, to make it as efficient as possible. The first report focuses on satisfaction, as it solves the wait-and-see response of employees to evaluate yield. In contrast, the second report focuses on improving yield to meet the yield target agreed with the client.

The reports can optimally be implemented by using supportive documents and easily usable templates. This is done by providing two excel templates which includes guidelines on how to get the desirable results that should be in the report. The PowerPoint templates are made as simple as possible by already providing all visualization methods with the corresponding data outputs. For instance, for the evaluation of the current yield performance, an employee can directly see how the visualization should look like and what it should contain.

# Chapter 7: Solution evaluation

This chapter's aim is to evaluate the two solutions based on whether they are data consistent. If the solutions are data consistent, then they are valid solutions for the core problems. This chapter's research question is: **"How can the proposed solution be evaluated?"** This is the final check of whether the practical solutions improve the efficiency of the yield evaluation reports and eventually taking away Benchmark's discomfort.

Section 7.1 compares Benchmark's to-be situation with Benchmark's as-is situation, section 7.2 describes the questionnaire, section 7.3 provides the questionnaire's answers, section 7.4 describes the adjustments to the solutions based on the answers of the questionnaire, and section 7.5 ends with the conclusion of this chapter.

## 7.1: Proposed solutions

To evaluate the proposed solutions, it is necessary to compare Benchmark's as-is situation with Benchmark's to-be situation. This is the comparison of the current situation with the desired situation, what the proposed solutions of this study should comply with.

**Structured approach:**
The most suitable solution for a structured approach for each report, is the PDCA cycle. In general, it was the best solution since each phase scored the best for each requirement. This means that the aim of a PDCA's phase and the order of phases suited the best the Benchmark yield evaluation reports. The requirements were as follows and in the following order, 1. Evaluate and conclude current yield performance, 2. Identify new opportunities for improvement, 3. Draw up an action or problem-solving plan, 4. Track progress of problem-solving plan, and 5. Predict yield performance for the next report.

For the first requirement, the Plan phase is perfectly aligned with the evaluation and conclusion of the current yield performance. Since this is based on the evaluation of this performance, it can be concluded on where to improve the project or product so that the yield reaches its target. This focus, on where to improve, is on a bucket or buckets from a tester where the most fails or defects can be solved. For the satisfaction report, instead of focusing on a tester to improve a bucket, it concentrates on a NPI subject to improve the satisfaction.

The second and third requirements align with the Do phase. The main reason is that the Do phase is the practical implementation of the aspects from the Plan phase to achieve the desired results, aiming to be in line with the predicted yield or satisfaction so that the goal is achieved. Identifying new opportunities or defects for improvement and drawing-up the problem-solving plans, are the actions required to achieve improvement.

The fourth requirement relates to the Check phase, as tracking the progress of the problem-solving plan is the same as checking whether everything is going according to the plan. This also includes the observation of challenges and obstacles that hinders the progress of the problem-solving plans. This is included in both reports, since each step or action must be labelled with a status and noted with a comment for corresponding obstacles and challenges.

The fifth requirement ties in with the Act phase because the Act phase should ensure that the improvements made in the cycle are standardised. This means that the improved yield or satisfaction must remain at its level. This is shown if the predicted change in improvement matches the actual measured yield or satisfaction.

**Visualization methods:**
To achieve efficient yield and satisfaction reports, the visualization methods should be as standardised as possible, which could desirably result in data consistency. This is done for each report objective (the same as the requirements for the structured approach) and sub-report objectives for the yield and satisfaction report. So, by comparing both reports, it can be concluded whether they are the same and thus standardised.

1. Evaluate and conclude current yield performance

For both reports, it starts with an overall performance overview. The satisfaction report aims at which NPI subject to focus. On the other hand, the yield improvement report uses the overall process yield to decide on which tester to focus. Table 21 shows that the visualization methods that are the same are line charts and conclusion sections.

| **Satisfaction report:** | **Yield improvement report:** |
|---|---|
|   |   |
|   |   |
| - |   |

*Table 21: Comparison between satisfaction and yield improvement report part 1*

2. Identify new opportunities for improvement

Both reports have two Pareto charts showing the situations of the current and previous weeks, see Table 22 The satisfaction report shows the change in the contribution to satisfaction. The yield improvement report, on the other hand, shows the difference in the number of defects or failures per bucket. Furthermore, both include a prioritisation, a conclusion, and a legend section that gives or provides information to employees. The Ishikawa diagrams are also part of the objective of this report but are not directly part of the templates as it would be repetitive once adopted. In conclusion, for this report objective, the visualization methods are mostly the same and hence standardised.

| **Satisfaction report:** | **Yield improvement report:** |
|---|---|
|  |  |
|  |  |

*Table 22: Comparison between satisfaction and yield improvement reports part 2*

3. Draw up action or problem-solving plan

Since core problems 3 and 4 have the fewest slides, it is chosen to put them in one table.

4. Track progress of problem-solving plan

The report objectives draw up action or problem-solving plan and track progress of problem-solving plan are taken together, since both visualizations are mixed in the templates. Table 23 shows that the action or problem-solving plans are visualized and managed through tables where each problem-solving step in the management report, or action in the action tracker can be in progress, done or overdue. In conclusion, for both reports, the visualization methods are almost the same and thus standardised.

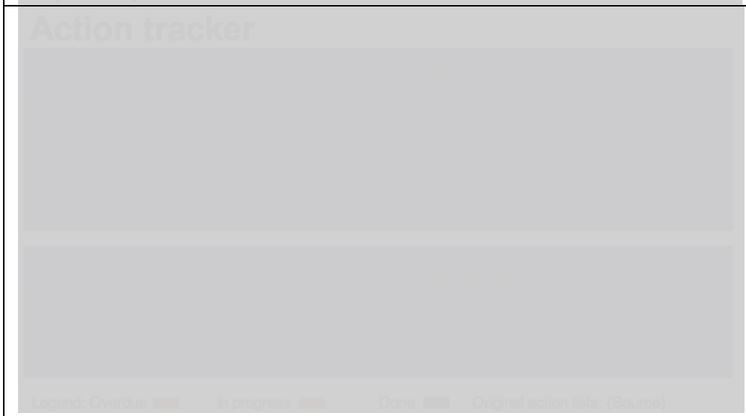
| Satisfaction report: | Yield improvement report: |
|---|---|
|   |   |
|   |   |

*Table 23: Comparison between satisfaction and yield improvement reports part 3*

5. Predict yield performance of the next report

In the case of the last report objective, the visualisation methods are almost the same. Table 24 shows that the key variable of both reports is visualised using a line graph and both reports include a conclusion section and a process flow diagram. All these help employees understand and make the reports their own. So, also for this report, the majority is the same and so the visualisation methods are standardised.

| Satisfaction report: | Yield improvement report: |
|---|---|
|   |   |

<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>-</td><td>
</td></tr>
<tr><td>-</td><td>
</td></tr>
</table>

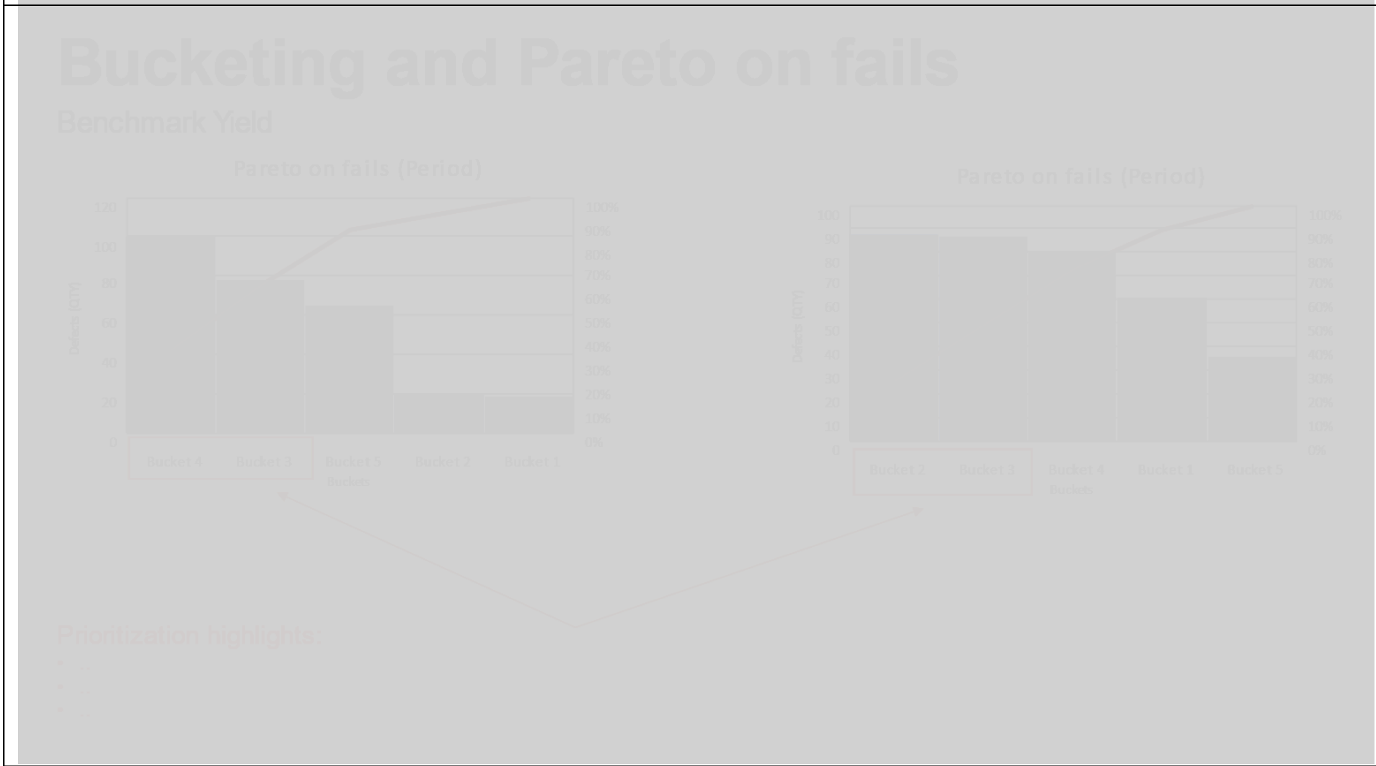
*Table 24: Comparison between satisfaction and yield improvement reports part 4*

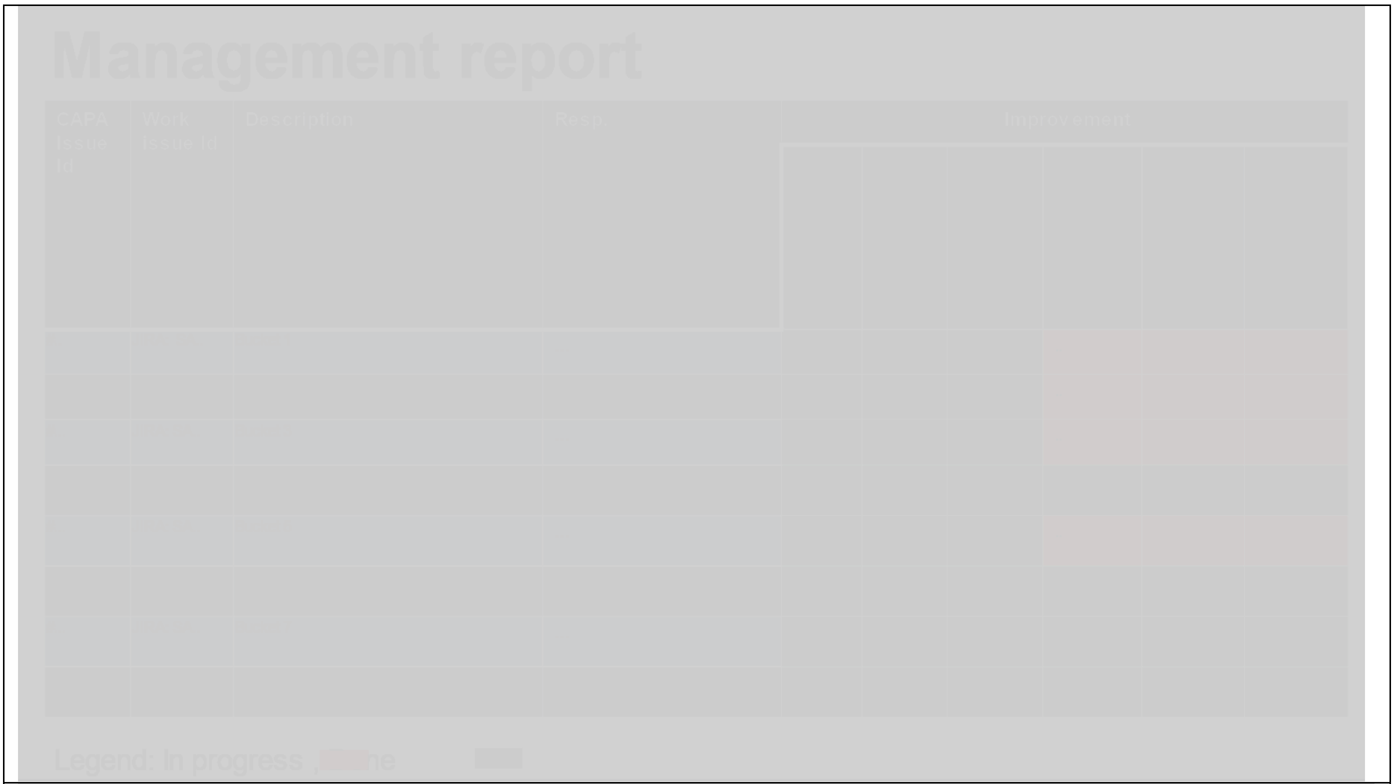
**Data quality output:**

The question if the data output of the new reports is consistent, is true, if the new reports are in line with the report objectives and its requirements. The final step is to compare the satisfaction and yield improvement reports with the two reports that are examined in Chapter 3, see Table 25. The second report only has one figure, since it may have other components that were evaluated, for the evaluation only one is enough to show the data quality output.

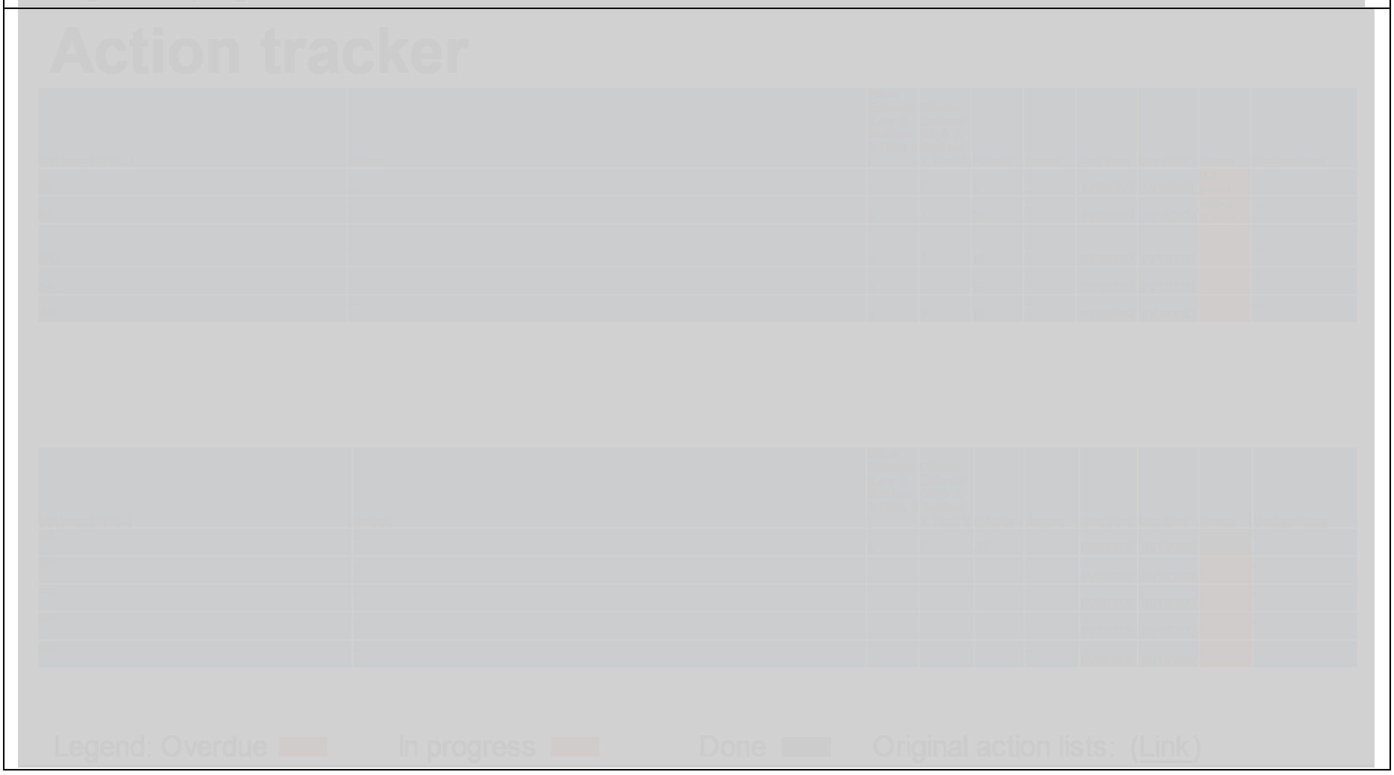
**1$^{st}$ report:**


Bucketing and Pareto on fails
Based on Weekly information YTD (Functional test):


Bucketing and Pareto on fails
Benchmark Yield
Pareto on fails (Period)
Pareto on fails (Period)
Prioritization highlights:



Management report
CAPA Issue Id
Work issue Id
Description
Resp.
Improvement
Legend: In progress , ne

Action tracker
Legend: Overdue
In progress
Done
Original action lists: (Link)

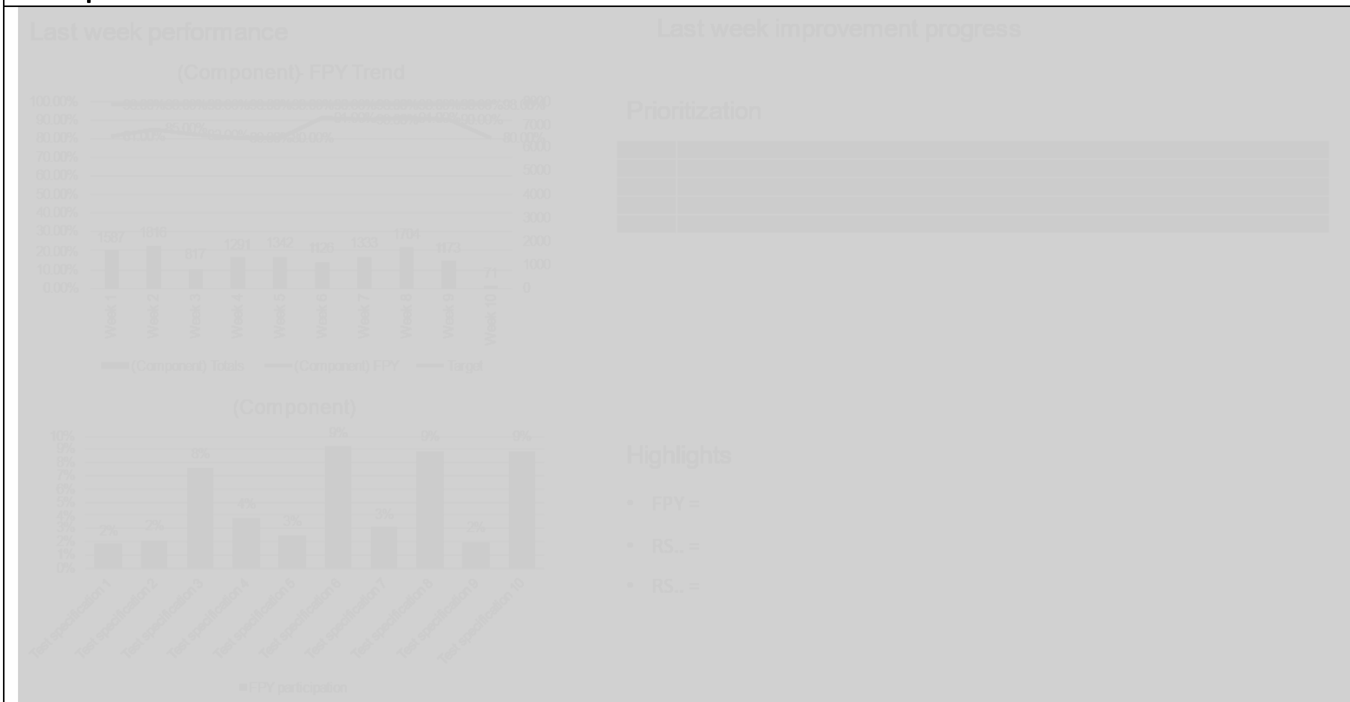
| |
|---|
|  |
| **2nd report:** |
|  |

*Table 25: Reviewed reports from current situation*

Since the satisfaction report is a completely new solution, it cannot be compared with Benchmark's as-is solution. Fortunately, this is not the case for the yield improvement reports. Another advantage is that since standard reporting is sought as much is possible because that creates data consistency, resulting that both reports are similar. For this comparison, Table 21, Table 22, Table 23, Table 24, and Table 25 are used for each report objective.

1. Evaluate and conclude current yield performance

The requirements of the yield improvement reports were as follows: measurements of RTY and FPY values, predicted values of RTY and FPY, targets for RTY and FPY, displays of process changes for RTY and FPY, production volumes per process and per tester, trendlines for RTY and FPY, and at last the Pareto of defects per tester. As can be seen in Table 21, these requirements are all included in the yield improvement report.

Considering the first and second reviewed reports, the entire concept of RTY is new. This means that the overall process was not looked at all and so it was assumed that most of the defects lay with a particular tester, without actually confirming it. Furthermore, it does not include supportive metrics that could help the conclusion, in this case a trendline for the RTY and FPY.

2. Identify new opportunities for improvement

The requirements of the yield improvement reports were as follows: the identification of buckets, sort the buckets using a Pareto chart, and comparing these buckets between the current and previous week. The yield improvement report contains all these requirements, which can be seen in Table 22.

The first report complies with all the requirements, except for the identification of buckets. The proposed reports also do not include the Ishikawa diagrams with the buckets in the report but contains a link of the source. The first report lacks this requirement. The second report fails to comply with all requirements.

3. Draw up an action or problem-solving plan

The requirements of the yield improvement reports were as follows: the use of the current standard problem-solving steps (1. Detailed description, 2. RCA, 3. Action list (QIT), 4. Solution finding, 5. Verification, 6. Implementation), and the prioritization of buckets based on the buckets that occurring the most, and on the defects within the buckets based on effort estimate and chance of occurring.

The first current report complies with all these requirements, while the second report only includes a prioritization section where it is not clear exactly how the prioritisation took place and on what it was based. So, in this case the new reports have acquired the way of the first report.

4. Track progress of problem-solving plan

The requirements of the yield improvement reports were as follows: including a problem description per bucket, tracking progress of the problem-solving plans per bucket and actions against each defect, and including bucket documentation by adding related procedures, such as the CAPA Issue ID, Work Issue ID, and responsible Employee. As earlier mentioned, the first reviewed report functioned as the role model, since it was found satisfactory at the review sessions with the company's supervisor.

5. Predict yield performance for the next report

The requirements of the yield improvement reports were as follows: the same requirements as the first report objective, prediction for RTY and FPY values in the future, and showing production changes in the future. These aspects are included in the yield improvement reports, as can be seen in Table 24.

This section already described the shortcomings of the reviewed reports regarding these requirements. However, both reports also lack at predicting possible improvements or declines in RTY or FPY in the future.

## 7.2: Questionnaire

Only comparing Benchmark's as-is and Benchmark's to be situation is not enough for a proper evaluation. The solutions need also be validated by the stakeholders that are actually working with them. For this purpose, a questionnaire has been prepared where employees can assess the solutions by answering the different questions.

**Structure:**
To start off, the questionnaire is divided in six sections. These are as follows, the introduction, general evaluation, focus on data consistency indicators, implementation, connection to efficiency, and remaining remarks. The questions are explained in this section.

The questions methods are either text answers or multiple grids where a choice can be made from a Likert scale. This questionnaire uses a five-scale with as possible answers, starting from the bottom, strongly disagree, disagree, neutral, agree, and strongly agree. The decision is made to use these choices, since it asks the professional opinion of employees who will collaborate with it in the future.

Finally, there is only one template that includes all the questions, since the two reports should tell the same story in their own way. As already mentioned, this results that all the report objectives are in both reports and therefore the questionnaire should hold for both.

**Introduction and general evaluation:**
The introduction has two questions, namely, first question is about the employees' name and the second questions is about his/her function within Benchmark.

**Indicators:**
In general, the questionnaire must show that this study's solutions will help Benchmark to reach their desired situation. Therefore, the norm of this study is that if each core problem's solution should be data consistent. This means that the desired situation with the solutions of each core problem can include all the three respective indicators.

- Accomplishment: "What is Benchmark trying to accomplish with these yield evaluation reports?"
- Decisions: "What decisions can be made supported by the yield evaluation reports?"
- Insights: "What insights will help Benchmark achieve its goals of the yield evaluation reports?"

These were the original indicators, but they need to be updated to reflect the changes of this study. So, for the first indicator, Benchmark wants to solve core problems by improving the processes of yield assessment reports. Second, the decisions Benchmark wants to make depend on the content or output of the reports. The same goes for the insights to help achieve its goals, which also depend on the content or output of the reports. So, these are three points that should undoubtedly include in the questionnaire. The questions are: are the following objectives accomplished in the report template, does the information from each slide ensure that the right decision can be made, and does the insights from each slide help Benchmark to achieve yield/satisfaction improvement? The first question has the report objectives that need to be responded, while the second and third question has each slide's title as that need to be answered.

**Implementation:**
For a proper implementation, it is always useful to ask for feedback. This is the aim of this question to stimulate the process of receiving feedback to ensure that the solutions are good implemented. The question is if the employee has any suggestions for a better implementation.

**Efficiency:**
It is known that by solving the core problems, the efficiency of the yield evaluation reports and thus the efficiency of the yield improvement process will be improved. It strengthens my research if it is also confirmed by other sources. Therefore, the question is provided as a statement with as options the core problems. So, the statement is, “I think the report template is a more efficient solution that the current reports because,”. An important thing to note is that it is not known by the respondents that those options are my core problems.

**Conclusion:**
The conclusion is an overall evaluation of the reports in terms of quality. This flows from the employee's opinion, as everyone has their own perception of quality, and the same applies to templates. The employee's opinion may be partly shaped by the previous questions, but also by possible other issues such as clarity or flexibility, etc. Finally, there is a slight difference in the possible answers, as the question is about the level of quality, the answers are: very poor, poor, average, good and very good.

**Remaining remarks:**
The two questions regarding the remaining remarks are both about if there are any negative or positive remarks left about the report. These remarks can remain if there are not topics discussed that should have been discussed according to the employee.

## 7.3: Results

The results of the questionnaire are described below.

Question 1:

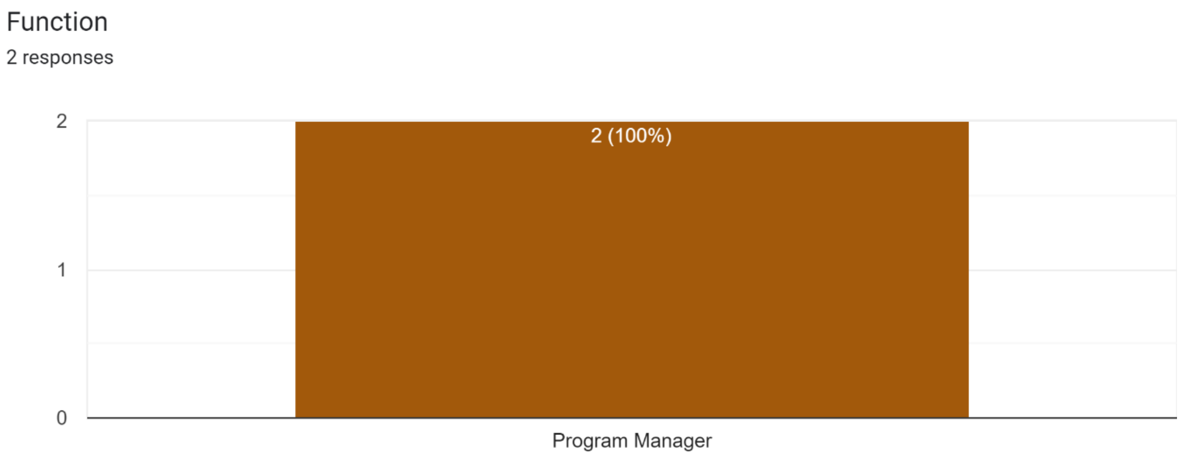



*Figure 39: Question 1 Questionnaire*

Question 2:

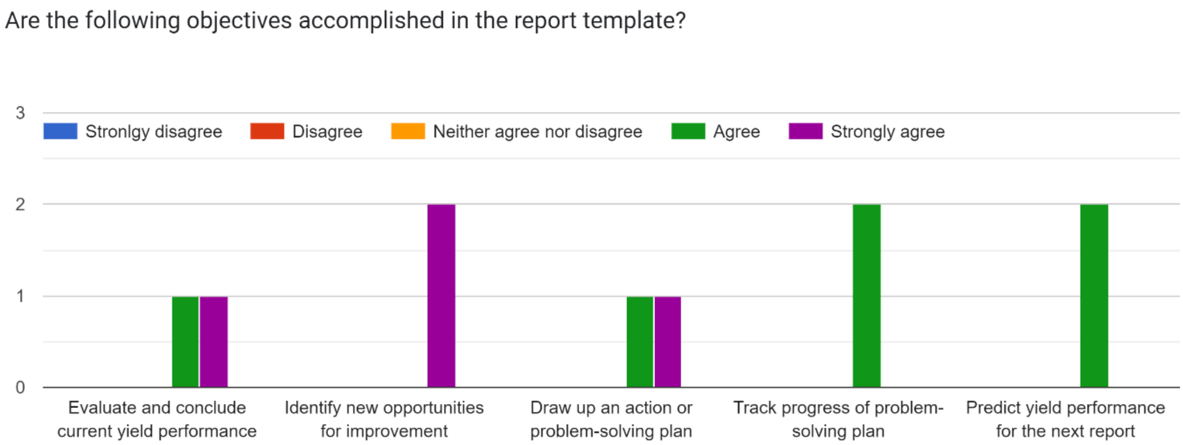



*Figure 40: Question 2 Questionnaire*

Question 3:


*Figure 41: Question 3 Questionnaire*

Question 4:

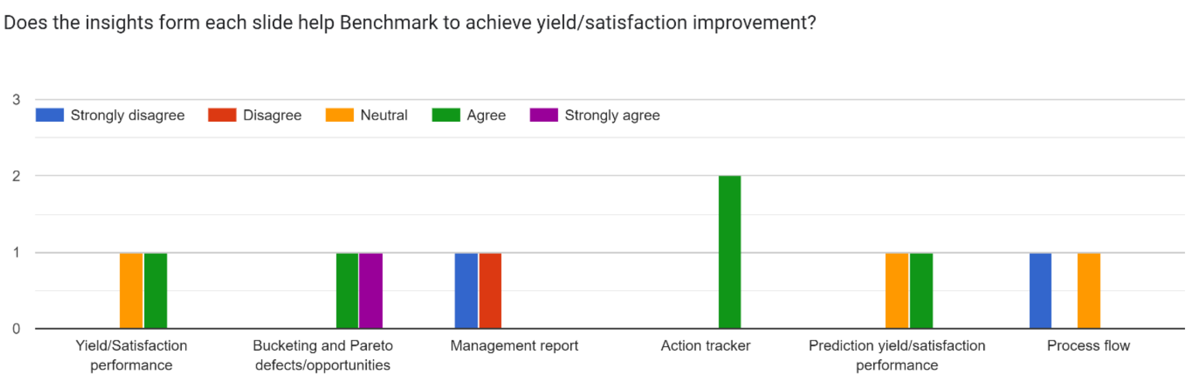



*Figure 42: Question 4 Questionnaire*

Question 5: Do you have any suggestions for a better implementation?

First response was: *I consider the report concerning yield (phase 6 and further) as very useful. It contains the info I would expect, is easy to be generated, reports in a clear and structured way and doesn't need too much explanation.*

*I consider the report concerning satisfaction (phase 1 - 5) more difficult to create and understand. I get the general idea of its purpose (which I think is good) but also have some doubts. First of all, the name "satisfaction" is somewhat confusing to me. I would have expected something like "manufacturing readiness". Secondly the parameters used as input are partly unclear (example "Installation Qualifications").*

*What I would expect: throughout the project phases 1 - 5 (part of BM 7-steps) there are several "NPI" deliverables. The maturity of those deliverables directly contributes to what I would call "Manufacturing readiness" (or "satisfaction"). Examples are Work Instructions, Training, but also FC, P-FMEA, CP (test coverage), tester maturity, supplier readiness, custom made component status (proto, pre-production, released, etc.) and many more. Those deliverables can all be placed into the Ishikawa diagram and used as input parameter. It could be that "Installation Qualifications" is exactly doing that, but this is not clear to me.*

*Another comment is regarding the Process Flow. For the yield report (phase 6 and further) it is very clear and is a great help for an even better understanding of the report (just put it in front). But for the satisfaction (phase 1 - 5) this is not a flow chart. It is just summarizing the parameters that are used to come to an overall percentage. But that is redundant since already in the Ishikawa.*

*General remark for both yield and satisfaction: the real management report is in the first few slides, not in the slide that is called "management report". The latter is good for background information during a report out, but I would not use it as a management report.*

Second response was: *It would be good to have a 'How-to-guidance' to have a better understanding of the slides for someone new*

Question 6:

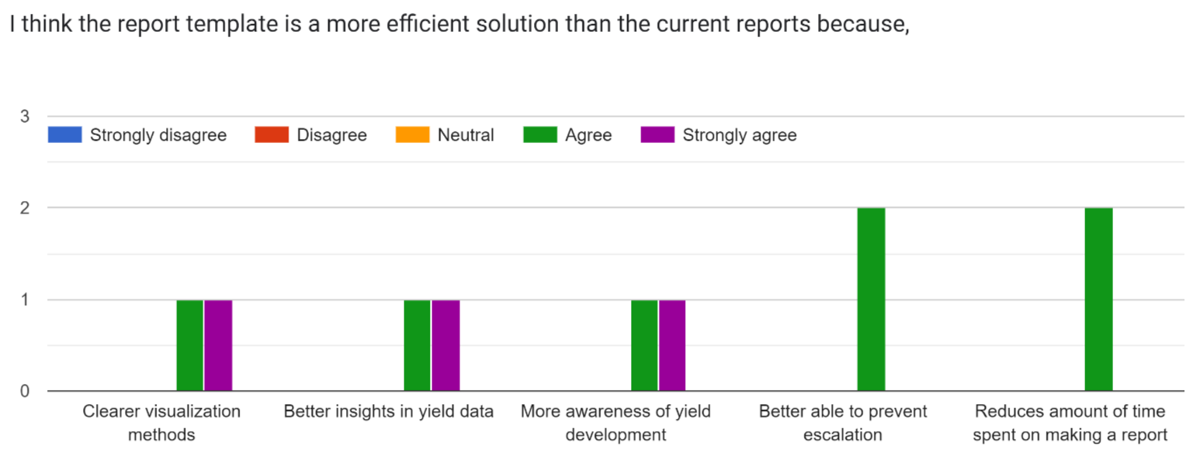



*Figure 43: Question 6 Questionnaire*

Question 7:

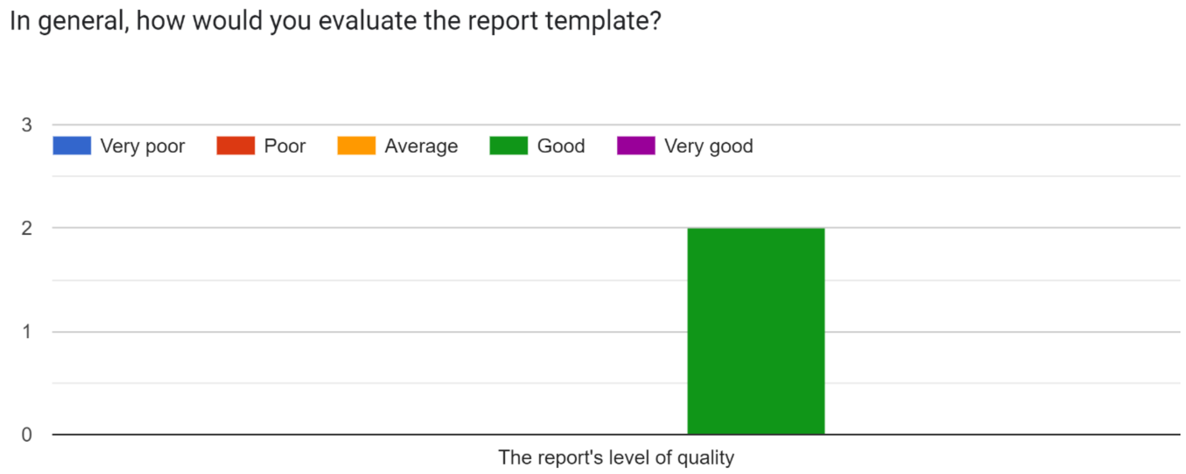



*Figure 44: Question 7 Questionnaire*

Question 8: Do you have any negative remarks about the report template?

First response: *The yield report (phase 6 and further) is clear. The general idea of the satisfaction report is good, but it requires more inputs and explanation.*

Second response: *The template is not self-explaining so a training/ how-to document is needed.*

Question 9: Do you have any positive remarks about the report template?

First response: *The general idea of the satisfaction report is really good. I believe (when using in the right way and with the right parameters) it is really helpful for getting a good impression of the status of any NPI project in just a few slides.*

Second response: *Plan-do-act approach is part of the template*

## 7.4: Feedback adjustments

Adjustments based on the results of the questionnaire are the use and position of the process flows in the templates, and the management report slide. Since, these two slides are graded the lowest compared to the other slides.

The main issue with the process flow is that it should be in an earlier stage of the yield improvement report and can be removed from the satisfaction report. The feedback says that now the yield improvement report does not show where in the process the yield will be improved. Another argument was that it was still unclear which yield was involved where in the process and with which tester. It lacked a schematic and visual overview. This could be solved by adding to the process flow slide of the RTY, the diagram of the project's process flow. Benchmark's NPI process obliges that each project contains a process flow. This new slide can be seen in Figure 45.

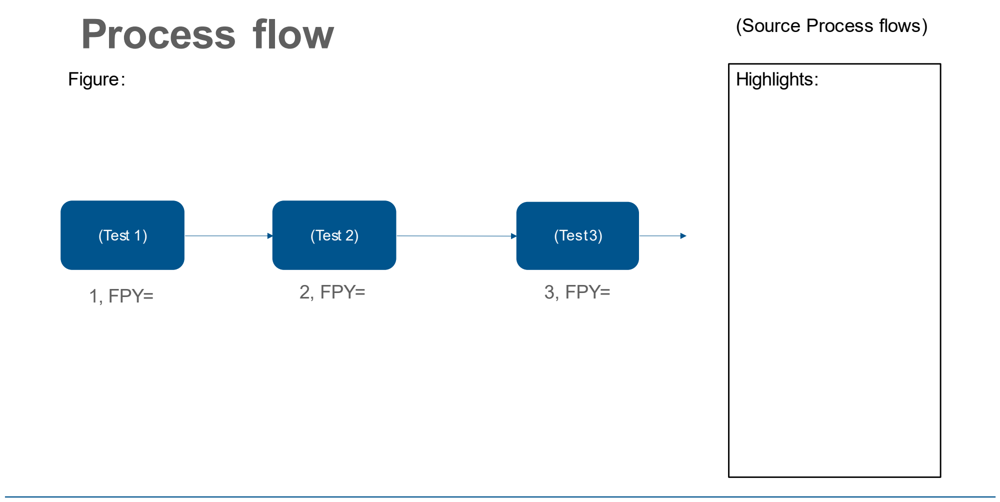



*Figure 45: New process flow slide*

To improve the visual overview on which tester the RTY is improved, the process flow of the RTY has been changed to an information slide about the tester. This slide provides a summary about the tester in question. This summary consists of an image, the buckets that can be tested and a highlights section. The changes can be seen in Figure 46.

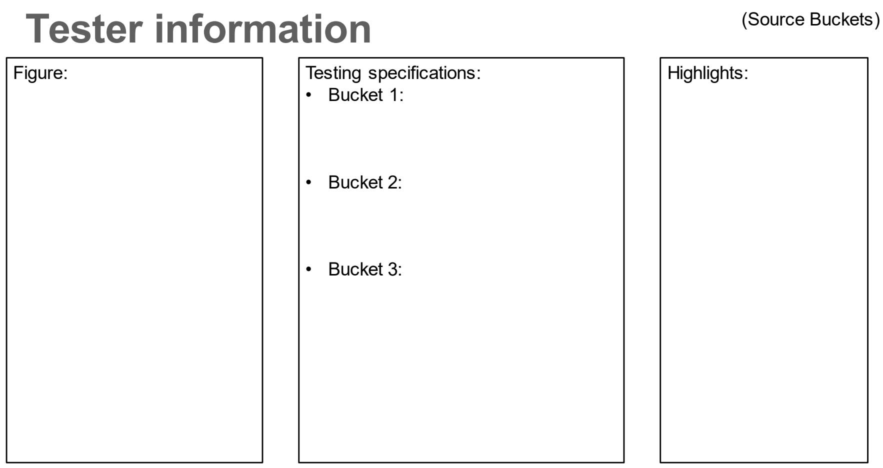



*Figure 46: New slide tester information*

The final change is to move the positions of these slides. The process flow is best placed after the performance evaluation of the RTY and the image of the tester after the performance evaluation of the FPY.

The second issue concerns the slides of the management report. However, after a discussion with the management, considering the reasoning of this feedback and the overall purpose of this slide, it was decided not to change it. The main purpose is to provide an overall picture of the status of the bucket, which the supervisor believes is achieved.

## 7.5: Conclusion

The conclusion is concentrated on answering this chapter's research question: **"How can the proposed solution be evaluated?"** The answer on this question should be able to validate whether the solutions improve the efficiency of the yield evaluation reports. The first step of the evaluation is the comparison between Benchmark's as-is and Benchmark's to-be situation. Main aspects that are compared are the satisfaction report and the yield improvement report to see whether the structured approach, in terms of a PDCA cycle, and the visualization methods are the same.

The second part is the validation of the reports by extern stakeholders. In this research, the validation is a questionnaire filled in by two different employees. The questionnaire includes the examination of the three indicators of data consistency: accomplishment, decision-making and insights, for both reports. Furthermore, the questionnaire also includes questions on whether the efficiency of yield evaluation reports can be increased by solving the core problems. This study already proved that these links exist, but with employee confirmation, the argument becomes even stronger.

In the questionnaire, there were three questions connected to the data consistency indicators, with each one. The main result for accomplishment was either agree or strongly agree (6 x agree, 5 x strongly agree). The insight indicator was more distributed (2 x strongly disagree, 1 x disagree, 3 x neutral, 5 agree, 1 x strongly agree). The last indicator was also more distributed (2 x strongly disagree, 1 x disagree, 3 x neutral, 5 agree, 1 x strongly agree).

In conclusion the main feedback, was to improve the process flow and place it earlier in the template, was also responsible for 2 x disagree. The main comment for any suggestions for a better implementation was to improve the how-to introduction of the satisfaction template, since it is more difficult to understand. At last, the question regarding a more efficient solution that the current reports were also considered positively since the results were: 7 x agree, and 3 x strongly agree. In overall, both responses graded the templates as good.

# Chapter 8: Conclusions and recommendations

Chapter 8 includes the conclusions and recommendations of this study. Section 8.1 draws up the conclusions, section 8.2 provides the recommendations, and section 8.3 will give advice for future research.

## 8.1: Conclusion

In this section, the conclusions are provided of this research. The major conclusion is the answer on the main research question, which was: ***"How to increase the efficiency of Benchmark's approach to its yield evaluation reports?"*** The main methodology to increase the efficiency of Benchmark's approach to its yield evaluation reports, was by validating the report objectives in the satisfaction and yield improvement reports, this would result in solving the core problems and thus improving the efficiency of the yield improvement process.

In general, yield refers to the percentage of non-defective items of all produced items. One of the procedures to ensure yield improvement are the yield evaluation reports. However, these yield evaluation report, and its process encountered some issues, which were, unstructured approach per report, reporting differs per project, and wait-and-see response to evaluate yield. The reporting differs per project could be further levelled down into visualization methods reporting differs per project and data quality reporting differs per project. The other issue could be divided in lack of preventive thought to increase yield, and lack of awareness of yield development during the design phases.

The main finding of this study is that there is a difference in the approach to yield. The moment where the project or product stands in Benchmark's 7-step process is a very important factor. Namely, the value behind measured yield in the early NPI process is does say much, since it is very unpredictable. This is since the production process is constantly changing resulting in that the testing processes also changes and hence the yield changes. Consequently, these respective steps in the NPI process needed another metric, which is satisfaction expressed in terms of NPI activities that are observed as important factors that could influence yield.

To make yield evaluation reports more efficient, the reports should have been data-consistent. Data consistency could be achieved through standardised reporting. This affects the solutions of the core problems. Therefore, the solutions of the core problems should also be standard. Moreover, some core problems are the same but occur at different stages of Benchmark's 7-step process. For example, the lack of preventive thinking to increase yield is similar to the unstructured approach for each report. The lack of awareness of yield development during design phases corresponds to data quality reporting that differs for each project. Finally, using the same visualisation methods for reporting for each project will lead to standardised reporting.

However, finding solution for these core problems is difficult and thus this study includes report objectives that should be met in de evaluation reports. By connecting the report objectives with the core problems, consequently, solutions for the report objectives are automatically also solutions for the core problems. The report objectives are as follows, 1. Evaluate and conclude current yield performance, 2. Identify new opportunities for improvement, 3. Draw up action or problem-solving plan, 4. Track progress of problem-solving plan, and 5. Predict yield performance of the next report.

The most suitable solution for a structured approach for each report and preventive thinking to increase yield, is the PDCA cycle. Figure 47 shows the overall overview of the PDCA implemented in Benchmark’s 7-step process.

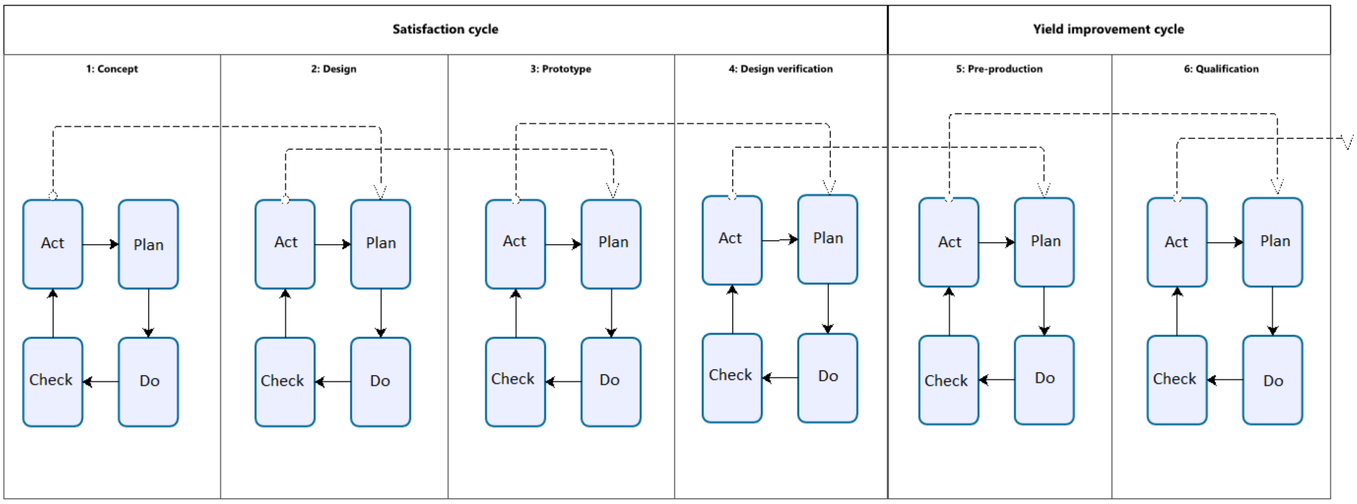



*Figure 47: General solution conclusion*

In general, it was the best solution since each phase scored the best for each requirement. This means that the aim of a PDCA’s phase and the order of phases suited the best the Benchmark yield evaluation reports. The requirements were as follows and in the following order, 1. Evaluate and conclude current yield performance, 2. Identify new opportunities for improvement, 3. Draw up an action or problem-solving plan, 4.Track progress of problem-solving plan, and 5. Predict yield performance for the next report.

## 8.2: Recommendations

Based on this research, this section includes a summary of all the recommendations per core problem. Each core problem describes how it affects both the satisfaction and yield improvement reports by solving or meeting the report objectives.

This study recommends using the PDCA cycle as a structured approach that also builds in a preventive thought for related employees to increase yield. Advice on how to implement the PDCA cycle in the reports, is by ensuring that each report includes the report objectives. An employee can make sure that the report objectives are included by considering the sub-report objectives and the respective requirements, which are visualized in **Error! Reference source not found.** and **Error! Reference source no t found.**.

The solution of the visualization methods is that each phase of the PDCA cycle in the reports have both the same visualization methods. **Error! Reference source not found.** recommends all the visualization m ethods per report objective.

| **Report objective:** | **Satisfaction report:** | **Yield improvement report:** |
|---|---|---|
| Evaluate and conclude current yield performance | - Line chart<br>- Ishikawa diagram<br>- Conclusion section | - Combination of line chart and bar chart<br>- Conclusion section<br>- Process flows |
| Identify new opportunities for improvement | - Pareto charts<br>- Ishikawa diagram<br>- Prioritization section<br>- Conclusion section | - Pareto charts<br>- Ishikawa diagram<br>- Prioritization section<br>- Conclusion section |
| Draw up action or problem-solving plan | - Management report<br>- Status defined by a colour | - Management report<br>- Status defined by a colour |
| Track progress of problem-solving plan | - Action tracker<br>- Status defined by a colour | - Action tracker<br>- Status defined by a colour |
| Predict yield performance of the next report | - Line chart<br>- Ishikawa diagram<br>- Process flow diagram<br>- Conclusion section | - Combination of line chart and bar chart<br>- Process flow diagram<br>- Conclusion section |

*Table 26: Recommendations visualization methods*

So, there are some slight differences, but the majority is the same. This is beneficial, since both reports strive for as much standardised reporting as possible to achieve data consistency. However, there are differences such as the visualization of the performance for both current and prediction. This is because of the yield improvement reports have apart from the yield only one other metric visualized in the graph, namely, the volume. In contrast to the satisfaction report, since these has multiple subjects that contribute to the satisfaction. If this was the same visualized as the yield improvement report, then it would be unclear and unorganized. Therefore, the contribution of these subjects would be recommended to use an Ishikawa diagram. In conclusion, this study recommends using in most situation the same visualization methods, but there are exceptions based on clarity and structure. The recommendation for better data quality and increase of awareness is visualized in **Error! Reference s ource not found.** for each report objective for the two reports.

| Report objective: | Satisfaction report: | Yield improvement report: |
|---|---|---|
| Evaluate and conclude current yield performance | - Measured satisfaction<br>- Predicted satisfaction<br>- Previous changes in process<br>- Trendline satisfaction<br>- Contribution each subject satisfaction | - Measured RTY and FPY<br>- Predicted RTY and FPY<br>- Target RTY and FPY<br>- Previous changes in process for RTY and FPY<br>- Volume per process and per tester<br>- Trendline RTY and FPY<br>- Pareto defects per tester<br>- Process flow<br>- Tester information |
| Identify new opportunities for improvement | - Pareto satisfaction contribution per NPI subject<br>- Comparison between week N and week N-1 | - Identification buckets<br>- Pareto defects per bucket<br>- Comparison between week N and week N-1 |
| Draw up action or problem-solving plan | - Action plan steps (1. Detailed description, 2. RCA, 3. Action list (QIT), 4. Solution finding, 5. Verification, 6. Implementation)<br>- Prioritization based on effort estimate and satisfaction increase | - Problem-solving steps (1. Detailed description, 2. RCA, 3. Action list (QIT), 4. Solution finding, 5. Verification, 6. Implementation)<br>- Prioritization based on effort estimate and chance of occurring |
| Track progress of problem-solving plan | - Problem description per opportunity<br>- Action plan per opportunity<br>- Bucket documentation by adding related procedures (CAPA Issue ID, Work Issue ID, Description, Responsible) | - Problem description per defect<br>- Problem-solving plan per defect<br>- Bucket documentation by adding related procedures (CAPA Issue ID, Work Issue ID, Description, Responsible employee) |
| Predict yield performance of the next report | - (Same as 1st report objective)<br>- Prediction satisfaction<br>- Prediction changes in the future | - (Same as 1st report objective)<br>- Prediction RTY and FPY<br>- Prediction changes in the future |

*Table 27: Recommendations data quality output*

Once again, the majority of aspects from both reports are the same. There are slight differences, such as a defect in the satisfaction report is called an opportunity. Moreover, where the satisfaction report only focuses on one metric, the yield improvement report focuses on two metrices, the RTY and the FPY.

## 8.3: Future research

The main discussion point is that the report templates are not tested in practice for long periods of time due to the limited time available. This affects the satisfaction report more than the yield improvement report because the satisfaction report is completely new, and the yield improvement report has only improved. So, there is already some experience of working with the yield improvement report. Thus, this study cannot say with 100 per cent certainty whether the satisfaction report removes Benchmark's discomfort about the efficiency of their yield improvement process. Future research is needed to confirm the use of this report.

The second point is about that this study's advice for values, ranges, calculations, and NPI activities of the satisfaction report needs revisions through experience of employees. The report is still in its infancy and will certainly come across issues that are not generalisable but need a more specific approach. For instance, for certain project, the values for yield/or yield loss for the satisfaction report, are not linearly but exponentially distributed, etc.

Another direction of future research is the inclusion of activities that could have been further useful but did not take place due to time constraints. For example, further verification of NPI activities that affect yield early in the NPI process. Further verification could include, for example, observing other NPIs with these NPI activities in mind. To ultimately get a more refined picture and better research.

Furthermore, I would have liked to have tested the current problem-solving steps (1. Detailed description, 2. RCA, 3. Action list (QIT), 4. Solution finding, 5. Verification, 6. Implementation). This study has assumed that these steps are sufficient from the start, but this is not obvious because there is no strong evidence as to why it works. But as mentioned earlier in this report, this is a thesis in itself.

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