# IMPROVED VISUALISATIONS FOR NAPCON IMPROVE DASHBOARDS

Improving the Usability and User Experience of Performance Monitoring Dashboards

Lappeenranta–Lahti University of Technology LUT

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ABSTRACT

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**Improved Visualisations for NAPCON Improve Dashboards: Improving the Usability and User Experience of Performance Monitoring Dashboards**

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Keywords: dashboard, performance monitoring, usability, user experience

This Master's thesis was done to improve the usability and user experience of NAPCON Improve Dashboards, which is a tool used for monitoring the performance of controller and optimizer applications. The literature review focused on the visual aspect of dashboards, usability and user experience. The new dashboards design process was iterative and users were included in the process with usability surveys. The new dashboards design was created based on effective dashboards data visualisation and usability guidelines. Also, user needs, requirements and feedback was considered when developing the new solution. The final feedback from the solution was mainly positive and suggested that the new dashboards design is more intuitive, user friendly and clear compared to the previous one.

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Tämä diplomityö tehtiin NAPCON Improve hallintapaneelien käytettävyyden ja käyttökokemuksen parantamiseksi. NAPCON Improve hallintapaneelit on työkalu, jolla seurataan ohjain- ja optimointisovellusten suorituskykyä. Kirjallisuuskatsauksessa keskityttiin hallintapaneelien visuaaliseen puoleen, käytettävyyteen ja käyttökokemukseen. Uusien hallintapaneelien suunnitteluprosessi oli iteratiivinen ja käyttäjät otettiin mukaan prosessiin käytettävyystutkimuksilla. Hallintapaneelien uusi ulkoasu kehitettiin tehokas hallintapaneelitietojen visualisointi sekä yleiset käytettävyysohjeet huomioiden. Myös käyttäjien tarpeet, vaatimukset ja palaute otettiin huomioon uutta ratkaisua kehitettäessä. Lopullinen palaute ratkaisusta oli pääosin positiivista ja viittaa siihen, että hallintapaneelien uusi ulkoasu on intuitiivisempi, käyttäjäystävällisempi ja selkeämpi kuin edellisessä ratkaisussa.

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ABBREVIATIONS

| | |
|---|---|
| APC | Advanced Process Control |
| CV | Controlled Variable |
| DV | Disturbance Variable |
| HCD | Human-Centred Design |
| KPI | Key Performance Indicator |
| MV | Manipulated Variable |
| MVC | Manipulated Variable Constraint |
| UCD | User-Centred Design |
| UEM | Usability Evaluation Method |
| UX | User Experience |

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Abstract

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# 1 Introduction

Dashboards are well known data visualisation tools that are found everywhere these days. Information can be presented in a powerful and unique way using dashboards, still Toasa et al. (2018) observe that dashboards rarely fulfil their potential as most dashboards do not communicate efficiently and effectively. The cause of inefficient dashboards is not technology, but poorly designed implementations. To create effective visualisations, the purpose and use of a dashboard needs to be understood.

Pappas and Whitman (2011) note that the dashboard design process should be guided by context, user goals, and data constraints for data visualisation to be effective. Therefore, user requirements should be collected to determine the priorities of the dashboard information, how data should be visualised, and what interactions should be available. According to Bach et al. (2023), an iterative user-centred design process can help build consensus on specific design choices. However, as Alhamadi et al. (2022) point out, the problem with user participation in the implementation is the users' constantly changing demands and requirements.

The goal of the thesis is to improve the visualisations of dashboards that monitor the performance of optimizer and controller applications of the case company (NAPCON, Neste). The literature survey aims to find out what type of visualisations are used in different dashboards, how to make effective dashboards and what are the main challenges in dashboard design. The focus of the work is on user interface, user experience and usability rather than focusing on the technical aspect of the dashboards. For this reason, also current usability and user experience standards are investigated. The design process of the new dashboards is iterative and users are included in the process. After the first iteration of the new dashboards design is crafted, user feedback is collected to finalise the new dashboards design according to user needs and requirements.

The new improved visualisations help to bring more value to the case company as the monitoring of the performance of the optimizer and controller applications simplifies and becomes more efficient. So, the long-term effect of the solution is increasing the competitiveness of the optimizer and controller applications of the case company as their performance can be monitored more efficiently.

## Objectives

The main objective of this study is to make the performance monitoring of the case company optimizer and controller applications easier, more user friendly and visually more appealing. The current implementation will be used as a base for the work in which visual elements will then be improved based on literature review and user interviews. For this purpose, following research questions are defined.

Q1: What are the state of the art visualisations and user interfaces used in dashboards?

Q2: What are the current standards and guides on usability and user experience?

Q3: How to improve the visualisations of the case company performance monitoring application?

To reach the objectives, firstly a literature review will be conducted. The review will focus on dashboards and their visual development, and general usability and user experience guides. Next, user interviews will be conducted, in a form that is most suitable for collecting information and feedback about the usability, user experience and development ideas for the dashboard. After literature survey and user interviews, improved visualisations for the performance monitoring dashboard will be created accordingly.

## Structure

The report began with an introduction on the topic and objectives. The next chapter, Chapter 2, will focus on dashboards literature review. In Chapter 3, literature review on usability and user experience is gone through. Chapter 4 introduces the previous dashboard solution and its evaluation process. The improved visualisations for the dashboards are presented in Chapter 5. Chapter 6 discusses the case and the findings. Finally, Chapter 7 will conclude the results of the report.

# 2 Dashboards

This chapter introduces dashboards, dashboard types, dashboards design patterns, effective dashboard data visualisation, and challenges of user-centred dashboard design based on literature review. The aim of this chapter is to provide a holistic view on dashboards, their visualisations and design challenges.

## 2.1 Dashboards Overview

According to Sarikaya, Correll, Bartram, Tory and Fisher (2019), the word “dashboard” is broadly used to describe various entities which challenge the stereotypical dashboard that is well-known in the visualisation community. Dashboards are highly popular data visualisation tools that can be found everywhere. Visualisation dashboards help making decisions based on data and they are used in almost every industry. Individuals use dashboards to follow their health and energy consumption, and students use them to track learning.

The concept of dashboard has developed beyond single-view reporting display. In addition to typical concepts of monitoring and supporting decision making, dashboards can have interactive interfaces including numerous views and objectives, such as learning, communication, and motivation. The expected use of a dashboard guides the decisions in its functionality and visual design. Also, the intended audience, their visualisation and domain experience and their relationship with the data is reflected in the functional and visual features of a dashboard. (Sarikaya et al., 2019)

Sarikaya et al. (2019) categorise three different types of interactivity that can happen with a dashboard: the dashboard can be customised or designed by the user; the data can be faceted through data slicers and filters; and the state of the data and the world can be modified from the data available on the dashboard. These aspects tell about both the functional and visual features of dashboards. Aside from these features, dashboards can also present important semantics about the processes and data that they display.

The biggest challenges of the actual dashboard according to Sarikaya et al. (2019) are analytic and visual literacy, and functional flexibility. Data related to dashboards is also causing many problems: confusion in the selection of metrics, the nature of adjusting views, communicating metadata and poor vocabulary.

Vázquez-Ingelmo, García-Peñalvo and Therón (2019a) note that to enhance data-driven decision making, dashboards should be tailored according to user requirements. However, it is not feasible to involve every potential user in the dashboard development process. As these potential users may have unique qualities, goals and mental schemas, they can request various features that should be considered in the dashboard development process. Due to the complex nature of the dashboards domain, the issue of individualisation is difficult.

Vázquez-Ingelmo et al. (2019a) observe that customisation and personalisation approaches aim to solve the issues of individualisation by providing different tools to tailor dashboards. These tools try to support developers in configuring the dashboards by allowing to reuse components thus decreasing the time spent on development. Several user-friendly dashboard tools exist which allow users without programming knowledge to create and customise dashboards.

Various visualisation tools are used to make custom dashboards. Data visualisation tools frequently mentioned by the literature to make tailored dashboards include Grafana, Tableau, Power BI, Google Analytics, SAS Visual Analytics, Sisense, Zoho Reports, Exploration Views, and QualDash (Bach, Freeman, Abdul-Rahman, Turkay, Khan, Fan, & Chen, 2023; Kruglov, Strugar, & Succi, 2021; Toasa, Maximiano, Reis, & Guevara, 2018).

## 2.2 Dashboard Types

Dashboards are used for many purposes. As Bach et al. (2023) observe, they can be created to help making decisions at an executive level, provide information for front-line workers, and summarise data about departments. They can also help to monitor performance, support communication, facilitate planning and support consistency in organisations key performance indicators. Dashboards can be also divided by their type. Pappas and Whitman (2011) divide dashboards into strategic, operational and analytical.

Strategic dashboards are the most commonly used type of digital dashboards. Its goal is communicating to management the performance of the organisation related to the objectives of the company. Generally, the data can be compared with current target levels or past performance in the strategic dashboard. (Pappas & Whitman, 2011)

Operational dashboards are used for monitoring operations. The dashboard requires data that is timely and it continuously monitors changing activities which may need attention immediately. Similarly to strategic dashboards, a simple view is required in efficient operational dashboards so that off-target metrics that call for intervention can be quickly identified. (Pappas & Whitman, 2011)

Analytical dashboards have the same attributes as operational and strategic dashboards. For operational and analytical dashboards, it is essential to use visual exploration and drill-down to discover trends and patterns in the information. Both analytical and strategic dashboards can have wider timeframes. At the intersection of operational and strategic dashboards can be an analytical dashboard. In addition to looking back and investigating the core reason, analytical dashboards can look forward too, which helps to predict outcomes. By studying present trends, business analysts can model results by modifying variables to suggest activities to get better results. (Pappas & Whitman, 2011)

Bach et al. (2023) divide dashboards into various genres: analytics dashboards, statistics dashboards, infographic dashboards, repository dashboards, magazine dashboards, and embedded mini dashboards. Sarikaya et al. (2019) divide dashboards to visual and functional genres. Visual dashboard displays data with plain charts and sizable numbers in a tiled layout. Functional dashboard is interactive and allows monitoring dynamic data in real-time.

According to Vázquez-Ingelmo et al. (2019b), dashboard solutions differ based on their components, design, interaction patterns, indicators and, most importantly, goals. This creates a need for making solutions that are domain and even user specific, which consumes a lot of time and resources. These custom dashboard solutions are also hard to reuse and adapt to different contexts.

Vázquez-Ingelmo et al. (2019b) describe information dashboards consisting of different interaction methods and visual components. Analysing datasets is easier with information dashboards as they help to recognise patterns and relationships between the displayed

variables. So, information dashboards support making decisions and reaching insights about large datasets which makes them very useful tools.

There are several challenges related to information dashboards. Vázquez-Ingelmo et al. (2019b) note that using the dashboards in various contexts and growing data development makes designing them a complicated task. In addition, different users with various profiles are using the dashboards, which makes it difficult to create a general dashboard solution suitable for everyone, because user requirements vary.

According to Kruglov et al. (2021), information dashboards provide a special method to gain insights into existing data and are important for acquiring information in a variety of contexts. They are used widely in various fields, for example, business process optimisation. These types of dashboards are usually called performance dashboards.

Kruglov et al., (2021) note that performance dashboards help organisations to monitor, manage and measure the performance of their business more efficiently. They are based on data integration infrastructure and business intelligence, and are used for analysis, monitoring and management.

Structuring and displaying essential information so it stands time is a problem for dashboard architects. Lean and agile methods are used by software companies to allow and respond to changes in requirements. Changing requirements for dashboards usually mean tailoring dashboards to different users. Tailored dashboards are dashboards whose functionalities and appearance can change according to the user, context and data requirements. Tailoring dashboards to every user in an organisation is not feasible, which leads to customisable, adaptive and personalised dashboards to gain attention. (Kruglov et al., 2021)

## 2.3 Dashboard Design Patterns

According to Bach et al. (2023), dashboards combine visual and graphical representations and embellishments to simplify and present different layers of abstraction for various data points that are connected. This allows giving the viewers a quick overview of the most relevant or important information. Because dashboards provide information at a glance, they have become widely used in numerous domains, like business, public health, nursing and hospitals, urban analytics, personal analytics, learning analytics, energy and other.

Bach et al. (2023) list high-level guidelines for dashboard design to be reducing information load, advice on visual perception, visualisation literacy and the use of interaction. Nevertheless, little is known about applicable and effective dashboard design and ways of supporting fast dashboard design. Bach et al. (2023) identify various reasons that make designing dashboards a complicated task: multiple data sources can be accessed, and the data can be processed, abstracted or simplified in a way that is seen fit; many visual components are available; and the visualisations can be presented and structured in different ways, to use the screen space on which the dashboards are displayed.

Dashboard design guidelines described by Bach et al. (2023) are that dashboard should avoid visual clutter, should not overwhelm users, should avoid lacking visual design and choose KPIs carefully, should not display too much information, should align with current workflows, should have visual and functional features, should be consistent, interactive and control complexity, should arrange charts symmetrically, group charts based on attributes, separate groups of charts clearly and structure charts by time. These guidelines can provide high-level instructions to designing the dashboard and make use of common knowledge about visualisation, perception and information architecture. Bach et al. (2023) note that the design process should also be user-centred as executives have reportedly rejected dashboards because they have not been included in the process. So, an iterative user-centred design process can help to create shared understanding about the specific design choices.

A design pattern usually explains a general solution for a repeating issue. Bach et al. (2023) analysed 144 dashboards to derive specific dashboard design patterns. Their patterns complement existing visualisation pattern collections. Bach et al. (2023) coded the structure, interactivity and visual design of the dashboards in order to describe the building blocks of the user interface. Their coding resulted in 42 design patterns divided into eight groups: data, meta data, visual representation, page layout, screen space, structure, interaction, and colour. These eight groups were divided into two main groups of design patterns: content dashboard design patterns and composition dashboard design patterns. Table 1 displays content dashboard design patterns.

Table 1. Content dashboard design patterns (Bach et al., 2023).

| **Content dashboard design pattern** | **Examples** |
|---|---|
| Data | Single value, derived values, thresholds, filtered, aggregated and detailed data. |
| Meta data | Data source, disclaimer, data description, update information and annotations. |
| Visual representation | List, table, detailed visualisation, miniature chart, progress bars, gauges, trend arrow, pictogram and number. |

Content dashboard design patterns (table 1) describe abstraction of data, meta information and visual representations. Composition dashboard design patterns are introduced in table 2.

Table 2. Composition dashboard design patterns (Bach et al., 2023).

| **Composition dashboard design pattern** | **Examples** |
|---|---|
| Page layout | Open, table, stratified, grouped and schematic layout. |
| Screen space | Screen fit, overflow, detail on demand, parameterisation and multiple pages. |
| Structure | Single page, parallel, hierarchic, and open. |
| Interaction | Exploration, navigation, personalisation and drilldown. |
| Colour | Distinct, data encoding, semantic and emotive. |

Composition dashboard design patterns (table 2) include components of the page layout, options to fit data into screen space that is available, structuring information over pages, supported interactions, and using colour purposefully. (Bach et al., 2023)

Bach et al. (2023) note that in a dashboard design process, many high-level and low-level decisions need to be made. Usually, high-level decisions are based on sources over which the dashboard designer has little control. These include the devices, data, intended audience, and use cases of the dashboard, or larger team of developers and data analysts helping the creation of the dashboard.

The dashboard genres and design patterns by Bach et al. (2023) provide specific solutions which support the dashboard designers in making lower-level design decisions that they have control over, and which need to be solved to fulfil their requirements. The low-level decisions include colour palettes, dashboard structure, use of screen space, page layout, visual representations and more.

Wu, Tan and Liu (2022) studied how various colour schemes and their harmony can affect cognitive load of dashboards. They concluded that as dashboards require effective decision-making and high information accuracy, harmonising the colour schemes is especially important as it reduces the cognitive load. For example, Wu et al. (2022) found out that in blue-red-yellow colour scheme, yellow and red are suitable for presenting data related to tasks and decision-making whereas blue colour is best for displaying less relevant data.

According to Bach et al. (2023), the goal of the design process is to minimise screen space, abstraction, interactivity and number of pages. Fitting as much information as possible into as little screen space as possible, without interaction, and on one page could be considered the gold standard when designing dashboards. This solution would show all relevant information at a glance, and there is no need for expensive interaction.

Information needs to be prioritised in the layout of the dashboard. For example, information can be shown in different places or sizes, and stratification can be used to place the most relevant information at the start. Table layouts might be optimal for showing repeated/similar information and many facets. Similarly, repetition can be used in each layout component. Repetition supports interpreting and retrieving information and leads viewers' glance. Dashboard designers can also choose more straightforward static dashboards, which concisely display information on a page fit for screen and do not require user interaction. Static dashboards are perfect when interaction is not necessary, desired, or possible. (Bach et al., 2023)

As Bach et al. (2023) observe, interaction allows viewers to use and personalise the dashboard in a manner that fits their requirements. The simplest interactions that help to have more data on the screen that can fit there are navigation buttons, scrolling, links and tabs. These interactions support creating easily responsive dashboards for many screen sizes and they do not interfere with visual encodings such as static images. Parameterisation and detail-on-demand can be effective, even though they call for more precise implementation.

According to Qu and Hullman (2018), visualisations are often displayed in multiples, for example, on a single dashboard or set of dashboards. Still, current guidelines on visualisation design tend to focus on one view instead of multiple views. Following these guidelines alone can result in views that are efficient but inconsistent, leading to error prone and slow interpretation. Therefore, it is important to use visualisations that make the similarities and differences in data recognisable across views.

Each design problem and design process is different. Various parameters need to be studied such as contexts, tasks, users and devices. Bach et al. (2023) describe design trade-offs being unavoidable when there is no optimal solution. That is, when certain design problem parameters have conflicting solutions, heuristics, or guidelines. This knowledge can be used by dashboard designers to inform their process, but other tasks are required such as prototyping and experimentation, reasoning and logic, user-centred design and assessment. Decisions might conflict or influence other decisions, which requires more design trade-offs, causing continuous iteration to reach a usable and effective dashboard design.

## 2.4 Effective Dashboard Data Visualisation

Pappas and Whitman (2011) observe that dashboard effectiveness and the value it brings to users can be increased with aspects such as interactivity, placement, cognitive load, and attention cues. To make visualisations of a dashboard effective, also its use and purpose need to be understood.

According to Toasa et al. (2018), no matter how much information is available, advanced analysis and visualisations that are easy to comprehend are great ways to distinguish meaningful relationships. The terms knowledge, information and data are widely used in

visualisation, usually in related contexts. Often, they are used to specify various layers of understanding, abstraction or truthfulness.

Dashboards can present information in a powerful and unique way, yet Toasa et al., (2018) note they seldom fulfil their potential. Majority of dashboards do not communicate effectively and efficiently, not because of insufficient technology, but because of implementations that have been designed poorly. Toasa et al., (2018) point out that regardless of how good the technology is, the success of the dashboard as a communication tool is a product of design, and an outcome of a display that communicates instantly and clearly.

As Vázquez-Ingelmo et al. (2019b) observe, most of the tailored dashboard solutions focus on a couple aspects, like goals and user preferences, but since all aspects are related, they should be considered. For example, considering the data structure is also important in order to design visualisations well. Merely taking into account user requirements and data structure is also not enough because the user goals must be met too for the dashboard to be effective.

According to Pappas and Whitman (2011), design of the dashboard should be guided by the expected users and data. Knowing the intended audience and their goals is important, so the appropriate dashboard type can be chosen for the design. After collecting information from user requirements and interviews, it can be determined what are the priorities of the dashboard information, what needs to be told with the data, how the data is displayed, and what interactions the dashboard will have.

Pappas and Whitman (2011) note that the users should understand the possibilities of the dashboards, such as what data and technologies are available, how the information can be displayed, and how it can support them in decision making and achieving their goals. The users have to communicate what data is most useful to them and is some information monitored frequently, are they viewing the data from a computer or mobile device, do they prefer detailed tables or graphics that are fast to interpret, and do they need to take actions like look for details or make comparisons.

For the dashboard designer, it is helpful to know how the users are used to looking at information and what visualisations they know in advance so the visuals on the dashboard can be made easily interpretable for the users. The visualisations should display the

information in a clear way so that users can achieve their goal fast. (Pappas & Whitman, 2011)

According to Pappas and Whitman (2011), effective visualisations that allow comparing data quickly in dashboards are bar charts, line graphs and bullet bars. Interactivity can also be included in strategic and analytical dashboards, like drill-down exploration, filtering, and allowing exploring the reasons behind data differences found in comparisons. To provide details related to comparisons, a scatter plot can be also used. A scatter plot shows individual data points patterns, and another dimension can be added with bubble plots that shows other variables that can be behind the variance.

If an operational dashboard is designed, Pappas and Whitman (2011) suggest that the comparison visualisations should show all variations that call for action in an easily and quickly noticeable way. Effective method to display the comparison and highlight action requiring data points is creating a key performance indicator (KPI). A KPI is created to display a certain range where data falls and colour coding is used to highlight the value if it is above or below a threshold. Usually red indicates below target performance, green shows when performance is good, and yellow indicates there is no need for action. If a dashboard uses many KPIs, the colour coding should be consistent between the KPIs.

Pappas and Whitman (2011) note that some dashboard visualisations are not so efficient. These include speedometers, pie charts and dials. These visualisations display little data but take a lot of space as they are round. Using these visualisations can however be a good option when it is required to draw attention to important measurements which could have critical consequences or need action immediately.

In addition to pie charts being large, people may find it difficult to compare their angles. For instance, bar heights of a bar chart can be easier to compare than varying pie slice angles in a pie chart. When selecting visualisations for comparison purposes, bullet bar or bar chart are most effective as they have a common baseline to which users can compare the line lengths against. Showing comparisons with area, angles, colour or volume is less effective. These factors should be considered when selecting dashboard KPIs. (Pappas & Whitman, 2011)

Pappas and Whitman (2011) guide to use the available display space for the dashboard as efficiently as possible. Line and bar graphs are efficient visuals for limited space. Less efficient visuals such as speedometers and dials can be applied if plenty of space is available.

As Pappas and Whitman (2011) observe, colour should not be the only indicator for meaning because some users might be colour blind. Also using too bright or many colours is distracting. Pappas and Whitman (2011) suggest combining colour with border thickness or intensity and labels used to display values. However, text should only be displayed on the dashboard if it is relevant such as data values, category labels or graph titles as visualisation should not need an explanation to be interpreted. Links and more detailed information can be provided in tooltips which show when a mouse pointer is hovered over a graph.

Dashboard should be tested in the environment in which it is intended to be used, as it helps to detect whether visualisations, colour, fonts or terminology need improvement. Information should be relevant, organised, and easy to find. Related visuals should be next to each other with space around different groups. The most important information should be in the top-left corner as people read from left to right. Important information can also be placed in the centre of the dashboard as it will be noticed first. (Pappas & Whitman, 2011)

As Pappas and Whitman (2011) note, there are many options to choose from when visualising data. Still, context, user goals, and data constraints should guide the dashboard design process for data visualisation to be effective.

## 2.5 Challenges of User-Centred Dashboard Design

Data dashboards are everywhere these days, yet Alhamadi, Alghamdi, Clinch and Vigo (2022) mention there have always been difficulties with using and understanding them. Current problems sometimes stem from a difference between developers' expected visual literacy and the real one. The difference is greater in complex fields, like city administration or with users who have poor analytic and visual literacy.

Bresciani and Eppler (2015) reviewed common errors made in designing and interpreting visualisations and formed a classification based on the pitfalls they found in the literature. The causes for pitfalls were based on the user or the designer, and the negative effects were categorised as cognitive, emotional and social. Majority of the visual representation pitfalls

were cognitive disadvantages. Examples of cognitive pitfalls in designing visualisations included ambiguity, confusion, inconsistency, over-complexity, redundancy and more.

Alhamadi et al. (2022) note that challenges that users face with dashboards are related to understanding information and interaction. These challenges are due to visual literacy deficits and information overload, and they are multifaceted and complicated. The challenges seem to be caused partly by dashboard developers who put visual appeal ahead of functional efficiency.

According to Alhamadi et al. (2022), not involving users in the development process can also lead to dashboards that are hard to use. Therefore, intended users' various visual literacy levels, displayed information and layout constraints should be considered by the dashboard developers to improve trust and engagement. Alhamadi et al. (2022) observe that including stakeholders in the design and implementation process of a dashboard has a positive impact on the end result.

Alhamadi et al. (2022) describe another known challenge to be presenting correlations with self-tracking data without overloading users. Some authors require specific instructions on operating dashboards so users can determine which data is important for decision making. There have also been differences between user needs and data that is displayed on learning analytics dashboards.

Dealing with data sources that are incomplete or fragmented is another challenge mentioned by Alhamadi et al. (2022). This challenge is reported frequently as data that is fragmented between multiple information systems is disadvantageous for decision-making. Another challenge is supporting users feature requests, like customisation, comparison functionalities, annotation tasks and data aggregation granularity. Training users is also a great challenge.

According to Alhamadi et al. (2022), the quality of data and the cost of tools are challenges related to implementing dashboards. Problems with dashboard data quality negatively affect the consistency, completeness and accuracy of data.

Alhamadi et al. (2022) divide dashboard challenges by involving users in development, data, addressing user needs, adoption, onboarding and training. When developers misunderstand user requirements and needs, the result is implementation misalignment. Users have difficulties in identifying and expressing their requirements. This problem can be solved by

giving users a list of KPIs, so they can better understand their own needs. For example, when Aginsha and Noranita (2021) designed a performance dashboard as a monitoring tool, they determined the business needs of users and the most important company KPIs for the dashboard. This resulted in a performance dashboard that met the information criteria of its users and displayed valuable information for them.

As Alhamadi et al. (2022) observe, data challenges can be about access, performance, metadata, currency and provenance. Data quality issues are data unavailability or requirements for processing data before use. The unavailability of data worsens when data is siloed and fragmented between multiple information systems and when users are in charge of collecting their own data. Often users complain if the information displayed on a dashboard is not updated at the speed required by them. Since the amount of data pulled affects the rendering speed of visualisations, providing more granular data compromises dashboard performance. The dashboard performance can be improved with data caching techniques. Data verification is also important so it can be confirmed that dashboards show the information expected by users.

New information is requested frequently by dashboard users which makes it difficult for developers to fit everything on one display. Having too much data on a single dashboard causes ineffective decision making and information overload. Also, even considering the visual literacy of users, accommodating all users can be problematic since everything cannot be presented with simple diagrams. Additionally, in order to effectively present data, developers have to understand KPIs across multiple domains and industries. (Alhamadi et al., 2022)

While users may be eager to use dashboards, Alhamadi et al. (2022) note that communicating data through visualisations can be challenging because some users are accustomed to common table reports. Users may have difficulty understanding why certain graphs are shown or what the dashboard is displaying even if the dashboard is plain with minimal interaction.

According to Alhamadi et al. (2022), some users are willing to learn but the learning resources may be insufficient or the users do not know where they are stored. So, tutorials or training may be required when new visualisations are introduced. The dashboard can be built to include training in the form of tutorials and tips that can pop up for users to review

when they encounter issues. Also, “hand holding” training can be organised to reduce visual literacy issues. During the training developers slowly guide users multiple times to interpret the visualisations.

Alhamadi et al. (2022) findings show that direct user involvement makes developers notice a lot of issues that users face with dashboards. If users do not report problems to developers, they think there are no issues. Alhamadi et al. (2022) describe the most common problem to be that the advanced and complex visualisations and artefacts of dashboards are not aligned with users’ visual literacy. Other issues mentioned are data quality problems, ineffective information presentation, lack of trust, functionality usage problems and finding reasons to carry on using the dashboard. The most prominent problem with involving users in the implementation are the constantly changing user demands and requirements.

# 3 Usability and User Experience

This chapter introduces general concepts of usability and user experience. The goal is to get a better understanding of current standards and guides on usability and user experience, so these guides can be followed when developing the dashboard. Also, methods to study usability are investigated, to find out proper ways to conduct usability study with the dashboard users.

## 3.1 Introduction to Usability and User Experience

Ritter and Winterbottom (2017) describe user experience (UX) as an extensive subject with a complex set of components that are linked together which add to the general user experience of a digital product, but the main focus is on usability. Usability is a core component of creating a pleasant user experience.

The International Organization for Standardization (2018), describes usability as:

> "The extent to which a system, product or service can be used by specified users to achieve specific goals with effectiveness, efficiency and satisfaction in a specified context of use."

Jakob Nielsen describes usability as a quality attribute that evaluates the ease-of-use of user interfaces. Five most important quality components that define usability are learnability, efficiency, memorability, errors, and satisfaction. (Nielsen Norman Group, 2012)

Learnability means the ease of performing basic tasks when first encountering the design. Efficiency refers to the speed at which tasks are completed after learning the design. Memorability determines how easy it is to re-establish competency when returning to the design after not using it for a while. Errors are measured by amount, severity and recoverability. Satisfaction describes the pleasantness of using the design. (Nielsen Norman Group, 2012)

Another important quality attribute is utility, which means the functionality of the design, and more specifically, whether it fulfils user needs. Utility and usability combined describe the usefulness of something. The system should provide the required features and also be easy to use in order to be considered useful. (Nielsen Norman Group, 2012)

Ritter and Winterbottom (2017) mention UX to be rooted in user-focused disciplines that include design thinking, human-centred design (HCD), and user-centred design (UCD). Design thinking is a method to solve creative problems and create valuable outcomes. The method consists of five steps which are empathise, define, ideate, prototype and test. Figure 1 displays the design thinking approach.

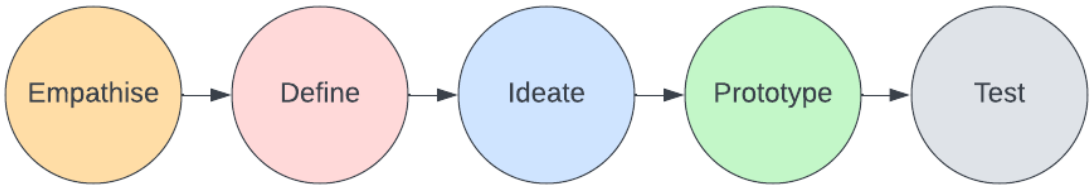


Figure 1. Design thinking approach. Adapted from Ritter and Winterbottom (2017).

In the design thinking process, empathising is understanding the users who the design is created for. Defining includes defining the need of the user starting from the research. Ideating means generating as many ideas as possible to be able to find innovative solutions to solve the problem. Prototyping consists of illustrating and testing the idea with a prototype. In the testing phase the idea is tested with real users using the prototype. (Ritter & Winterbottom, 2017)

Ritter and Winterbottom (2017) note user-centred design principles to be based on design thinking. Design thinking aims to create workable and practical solutions to users by focusing on human-centred innovation. In dashboard design context, Cahyadi and Prananto (2015) suggest that design thinking approach could be used as a basis for solving design-related problems in dashboard creation.

The terms UCD, HCD and design thinking are often seen as the same thing and used interchangeably. However, they are different even though they have many similarities. HCD is a usability standard based on general features of people, whereas UCD focuses more on a segment of people and their unique behaviours and personality traits. The user-centred design philosophy gives instructions in the software development process to aim to develop the best possible end product for the user by constantly focusing on the needs, wants and limitations of the user. (Ritter & Winterbottom, 2017)

Ritter and Winterbottom (2017) describe the steps of the UCD approach to include research, concept, design, develop and test. After completing the steps, a new iteration is made according to the user feedback so the end product can be improved. Therefore, UCD focuses on including the user in the development process instead of leaving the user outside the process.

## 3.2 Usability Guidelines

This chapter introduces usability heuristics and web accessibility which are common usability guidelines. These guidelines are relevant to dashboard design and development as they help to create usable and accessible dashboards.

### 3.2.1 Usability Heuristics

Most often used usability heuristics were developed by Jakob Nielsen. These 10 principles help to find common usability problems with user interfaces. The principles are visibility of system status, match between system and the real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, help users recognise, diagnose, and recover from errors, and help and documentation (Nielsen Norman Group, 2020). The principles and their descriptions are listed in table 3.

Table 3. 10 usability heuristics (Nielsen Norman Group, 2020).

| **Heuristic** | **Description** |
|---|---|
| 1. Visibility of system status | System status should be visible for users |
| 2. Match between system and the real world | Design should use language that is familiar to users |
| 3. User control and freedom | System should have actions such as undo, redo and cancel |
| 4. Consistency and standards | Design should be consistent and follow industry standards |

| | |
|---|---|
| 5. Error prevention | Design should help to prevent errors with confirmation buttons and warnings |
| 6. Recognition rather than recall | System actions, elements and options should be recognisable for users |
| 7. Flexibility and efficiency of use | System should cater novice and expert user needs with shortcuts, customisation and personalisation options |
| 8. Aesthetic and minimalist design | Design should only contain information that is relevant for the user |
| 9. Help users recognise, diagnose, and recover from errors | Design should make recognising, diagnosing and recovering from errors straightforward for users |
| 10. Help and documentation | System documentation should be provided easily if additional explanations are needed |

The status of the system should be always visible for users, which can be achieved by giving feedback to users in reasonable time and communicating the state of the system clearly and continuously. There should be a match between the system and the real world, which means that the design should use language that is already familiar to users. (Nielsen Norman Group, 2020)

Users should have control and freedom in the system. There should be a clear way for the users to undo, redo and cancel actions, to help them to be in control and avoid making unwanted actions or getting stuck. The design should be consistent and follow industry standards. This improves the learnability of the system and decreases the cognitive load of users. (Nielsen Norman Group, 2020)

Displaying clear error messages is important, however the design should also help the users to prevent making problems. Making errors can be prevented by adding confirmation options, giving warnings to users and supporting undo actions. Actions, elements and options of the system should be recognisable for the users, so they don't have to memorise how the system works. Help can be given in context, instead of offering lengthy tutorials that users have to remember. (Nielsen Norman Group, 2020)

The system should be flexible and efficient to use, so the needs of novice and experienced users can be catered. Shortcuts can allow expert users to make actions quicker and options

for customisation and personalisation of the system can be provided. The design should be aesthetic and minimalist, so the interface should only contain relevant information and focus on what is essential for the system and fulfilling user goals. (Nielsen Norman Group, 2020)

Recognising, diagnosing and recovering from errors should be straightforward for users. Error messages should explain the problem and possible solution in plain language with traditional visualisations that help the users to recognise and notice the error. Help and documentation should be provided if the system needs additional explanation. The documentation should be easily available and provide concrete steps to help users in completing their tasks. (Nielsen Norman Group, 2020)

### 3.2.2 Web Accessibility

According to Ritter and Winterbottom (2017), web accessibility is essential for user experience. It means making an inclusive design, so the digital product can be used by everyone. This includes removing obstacles from the user interface so that users with special needs, such as colour blindness, can interact with it. Since the dashboard solution is used only internally in the company, other defects affecting accessibility will not be covered here, as they are not relevant to consider for the solution.

Various colour blindness types exist, which makes it important to consider a few factors while making a design for user interface. Ritter and Winterbottom (2017) advice using sufficient contrast so text is visible from its background. Also, colour should be used as a support and not as the only indicator for relevant information. Visual elements, icons and text can be used to reinforce colour in the user interface.

## 3.3 Usability and UX Evaluation Methods

Fernandez, Insfran, and Abrahão (2011) conducted a systematic mapping study on usability evaluation methods (UEMs) for the web. They found that user testing is the most widely used UEM, as users were included in the testing process in more than half of the studied papers. Inspection methods, such as heuristic evaluation, were the second most popular UEM. The third most popular UEM was inquiry methods, including questionnaires and

interviews, which were used to gather subjective data from users. Inquiry methods were often used together with other testing methods to produce a more thorough evaluation.

The rest of this chapter introduces heuristic analysis and usability testing in more detail, which are widely known methods to evaluate the usability and user experience of user interfaces. Usability testing method will be used in the evaluation of the case dashboard, which will be presented in Chapter 4.

### 3.3.1 Heuristic Analysis

Ritter and Winterbottom (2017) describe heuristic analysis as a UX research method where the evaluation is done by a UX expert based on heuristics. Heuristic analysis can be performed on a prototype or live website. This allows using them already in early phases of evaluating the design of a web project.

Heuristics, such as Nielsen's 10 usability heuristics, are based on established criteria and act as practical guidelines for the work. Ritter and Winterbottom (2017) note that heuristic analysis should not be the only testing method for user interface as one expert cannot find all usability problems. It is still valuable for enhancing research. The heuristics are useful to know when performing usability tests as they act as usability guidelines.

Ritter and Winterbottom (2017) observe that heuristic analysis can help to find issues with usability. As there may not be enough time or resources to fix all of the problems, severity and frequency ratings can also be assigned to manage fixing the issues. Heuristic analysis can also point out positive aspects from the interface, like the parts that work well.

### 3.3.2 Usability Testing

Usability testing is a UX research method that is used to discover issues and improvement ideas for designs. Usability testing sessions are done on one or more specified user interfaces. In a testing session participants are asked to perform tasks on these interfaces while the facilitator observes the session, collects feedback and asks follow up questions for more information. The terms “user testing” and “usability testing” are used interchangeably. (Nielsen Norman Group, 2019)

Most common goals of usability testing are to recognise problems in the design, uncover opportunities to improve the design, and learn about the target users' preferences and behaviour. Usability testing and iterative design process is required to create a great user experience that is guided by real users' interactions and observations with the design. (Nielsen Norman Group, 2019)

Usability testing can be qualitative or quantitative. In qualitative usability testing findings, insights and anecdotes are collected from users about how they use the product. Qualitative usability testing is a better method for uncovering issues with user experience. In quantitative usability testing metrics describing the user experience are collected. (Nielsen Norman Group, 2019)

Ritter and Winterbottom (2017) note that metrics of usability tests are based on the description of usability which often includes effectiveness, efficiency, satisfaction, memorability, learnability and error proneness. The metrics can be quantitative or qualitative and measure for example errors or frustration during a task. Table 4 describes examples of tasks and metrics used to measure various usability components.

Table 4. Example tasks and metrics to test usability (Ritter & Winterbottom, 2017).

| **Usability component** | **Metrics** |
|---|---|
| Effectiveness | Task success<br>Task completion |
| Efficiency | Time on task<br>Steps to complete task |
| Satisfaction | Rating scale for enjoyment, ease of use, usefulness<br>Expression of satisfaction / frustration |
| Discoverability | First clicks<br>First impressions<br>Expressions of satisfaction / confusion |

| | |
|---|---|
| Learnability | Time on task for repeat tasks<br>Task success for repeat tasks<br>Number of errors for repeat tasks<br>Expressions of mastery / confusion |
| Error proneness | Number of errors<br>Severity of errors |

In addition to the usability test, interview questions can be asked in the beginning and end of the test to provide insights into user reactions and actions. Interview questions can be about the user's experiences with the subject area, their background, or relationship with the technology. These questions help to produce the usability rapport with the user. (Ritter & Winterbottom, 2017)

Ritter and Winterbottom (2017) mention that questions during or after the usability test can be measured with a rating scale. With Likert scale agreement or disagreement of a participant can be measured with 5- or 7-point scale. Statement can be for example “I find the dashboard solution easy to use”, where 1 indicates “strongly disagree” and 5 “strongly agree”. The responses can be compared across tests and between participants using this method.

### 3.3.3 Heuristic Evaluation vs. User Testing

Tan, Liu, and Bishu (2009) studied the differences in heuristic evaluation and user testing and concluded that the methods complement each other. User testing is often organised in a scenario-based environment, and it depends on the comments and experience of the users. Therefore, user testing often evaluates what is already existing instead of what is possible.

Heuristic analysis on the other hand relies mostly on the knowledge of experts, who evaluate the website against heuristics. Potential usability problems could be reflected with heuristic analysis, which is a quality that user testing is missing. In their study, Tan et al. (2009) found more problems with heuristic analysis than user testing. Heuristic analysis allows exploring the interface more freely when user testing is done in a more controlled environment with specific tests.

According to Tan et al. (2009), heuristic analysis could be done first, and then the design of the user interface could be improvement based on the findings. After improving the design based on heuristic analysis findings, user testing should also be conducted as these methods find different problems. With user testing, the usability issues that are most relevant to users can be assessed directly. Tan et al. (2009) suggest that the feedback from user testing can be beneficial for fine-tuning the user interface, which is often done later in the design process.

The study of Tan et al. (2009) concludes that both heuristic analysis and user testing are necessary in usability evaluation. To get most out of these user interface evaluations, they are recommended to be used in different stages of the design process. Tan et al. (2009) believe that the early stages of the design process benefit from heuristic analysis, whereas the later stages of the design process benefit from user testing. The findings of Tan et al. (2009) are consistent with other studies on numerous usability evaluation methods and their different strengths; applying various evaluation methods leads to the best usability evaluation of a user interface.

# 4 NAPCON Improve Dashboards Evaluation

The previous solution of NAPCON Improve Dashboards is evaluated before the new design for the dashboards is done. Firstly, the background section of this chapter introduces the case company, dashboards solution and motivations for renewing its visualisations. Next, the usability survey section describes the dashboards evaluation survey. The evaluation of the dashboards is performed with usability testing which was introduced in the previous chapter. The goal of the evaluation is to identify problems with the current solution and opportunities to improve the solution. Finally, the usability survey results section presents the feedback and results of the survey. New evaluations are done with the improved dashboard visualisations later to find out whether the usability and user experience was improved.

**Background**

The case company of this work is Neste and the performance monitoring dashboard is called "NAPCON Improve Dashboards". NAPCON is part of Neste that focuses on creating, delivering and maintaining innovative solutions for learning and optimisation purposes in the process industry (Neste, 2023). NAPCON Improve Dashboards is used to monitor Advanced Process Control (APC) applications.

APC applications are automation tools that make use of multivariable predictive control for continuous control in plants. It automates the control and optimisation by sending remote set points to manipulated variables, in order to control the controlled variables within the predetermined constraints. APC applications are widely used and effective in industry as they require low capital investment and they can be used via integrating process automation in daily operations, optimisation and decision making.

Even though an APC can be designed and commissioned perfectly in a plant, with time it can be constrained due to operational needs and the models can get old. The performance of these tools are monitored daily by engineers, so that they are used as efficiently as possible. When there are many APC models in operation in a factory, the performance tracking can be hefty. Therefore, striking visual tools that show the performance of each and every model is very beneficial for easy performance tracking and getting the most out of the APC's. The

dashboards that are based on calculated performance indices are widely used in industry to monitor APC performance.

NAPCON Improve Dashboards displays various calculated performance indices of optimizer and controller applications. Based on these indices the performance and overall status of optimizer and controller applications can be monitored. The data is displayed in numeric form in different tables. Red, orange and green background colours are used in the table cells to indicate the status of the calculated performance indices.

The current solution has gotten feedback from users that it contains too many numbers and is very technical. Based on the user feedback the visualisations should be improved to include more graphical elements so the performance can be monitored easier. The improved visualisations could include for example diagrams, trends or charts, based on what would be the most suitable way to present the different calculated performance indices. To find out how to improve the visualisations to answer user needs, user interviews were conducted.

**Usability Survey**

Usability testing was done with the dashboard users with a survey that consisted of closed and open-ended questions. The closed-ended questions measured the usability of the dashboard in different areas. The open-ended questions aimed at collecting additional comments and feedback to improve the solution and they were related to visualisation types, performance measurements and indicators. All feedback was collected anonymously.

Likert 5-point scale was used to measure the agreement or disagreement of a participant against usability related statements about the dashboard. Values of the scale ranged from “strongly disagree” to “strongly agree”. Table 5 presents all options used in the scale.

Table 5. Answer options to statements used in the usability survey.

| Value | Description |
|---|---|
| 1 | Strongly disagree |
| 2 | Disagree |

| | |
|---|---|
| 3 | Can’t say |
| 4 | Agree |
| 5 | Strongly agree |

The closed-ended questions were formed as statements, each related to some component of usability. The measured usability components were effectiveness, efficiency, learnability, memorability, errors, and satisfaction. The usability statements are listed in table 6.

Table 6. Statements used in the usability survey.

| **Usability Component** | **Statement** |
|---|---|
| **Effectiveness** | 1. Monitoring the performance of controller and optimizer applications is easy and effective with the dashboard. |
| | 2. Information in the dashboard is relevant, organised and easy to find. |
| | 3. The dashboard is too technical and contains too many numbers. |
| **Efficiency** | 4. Displaying the data only in numeric form gives enough insights on the performance levels. |
| | 5. I can quickly get an overview of the controller and optimizer performance statuses from the dashboard. |
| | 6. Detecting controller and optimizer performance issues is easy. |
| **Learnability** | 7. The dashboard includes helpful tips on how to use it or what the information means. |
| **Memorability** | 8. Using the dashboard is intuitive. |
| **Errors** | 9. The dashboard reports errors and the error messages are helpful. |
| | 10. The dashboard recovers from errors. |
| **Satisfaction** | 11. The user interface is pleasant and modern. |

| | |
|---|---|
| | 12. The dashboard is user friendly. |
| | 13. Overall, using the dashboard is productive. |

In addition to the statements, few open-ended questions were included in the survey. The open-ended questions allowed collecting more feedback that could be used to improve the solution according to user needs. The final questions are presented in table 7.

Table 7. Open-ended questions used in the usability survey.

| **Question** |
|---|
| 14. What type of visuals would you like to see on the dashboard (graphs, trends, tables, plots, charts)? |
| 15. In what form would you prefer to see the performance measurements (scores, points, grades, percentages, visuals, plain data)? |
| 16. What are the performance indicators that you would like to track daily/weekly? |
| 17. How would you prefer seeing everything (on the same page, several subsections, other)? |
| 18. Any other comments or ideas for developing the dashboard? |

**Usability Survey Results**

The usability survey was sent to five users out of which four responded. So, the response rate of the survey was good. The users had different experiences with the dashboard which affected their answers. Still all of them had experience working with APC solutions which made contacting them relevant. Table 8 presents the answers of the users and the mean answer value for each statement.

Table 8. Answers of users to usability related statements.

| Statement | User 1 | User 2 | User 3 | User 4 | Mean |
|---|---|---|---|---|---|
| 1. Monitoring the performance of controller and optimizer applications is easy and effective with the dashboard. | 2 | 4 | 3 | 3 | 3 |
| 2. Information in the dashboard is relevant, organised and easy to find. | 2 | 4 | 3 | 4 | 3,25 |
| 3. The dashboard is too technical and contains too many numbers. | 5 | 3 | 3 | 2 | 3,25 |
| 4. Displaying the data only in numeric form gives enough insights on the performance levels. | 1 | 2 | 3 | 4 | 2,5 |
| 5. I can quickly get an overview of the controller and optimizer performance statuses from the dashboard. | 1 | 4 | 3 | 3 | 2,75 |
| 6. Detecting controller and optimizer performance issues is easy. | 2 | 4 | 3 | 4 | 3,25 |
| 7. The dashboard includes helpful tips on how to use it or what the information means. | 3 | 3 | 3 | 1 | 2,5 |
| 8. Using the dashboard is intuitive. | 1 | 3 | 3 | 3 | 2,5 |
| 9. The dashboard reports errors and the error messages are helpful. | 2 | 3 | 3 | 1 | 2,25 |
| 10. The dashboard recovers from errors. | 1 | 3 | 3 | 2 | 2,25 |
| 11. The user interface is pleasant and modern. | 1 | 3 | 3 | 3 | 2,5 |
| 12. The dashboard is user friendly. | 1 | 3 | 3 | 3 | 2,5 |
| 13. Overall, using the dashboard is productive. | 2 | 4 | 3 | 4 | 3,25 |

From table 8, we can see that the users had quite different opinions on the statements. Also, some users were likely not as familiar with the solution as they answered the “3: Can’t say” option more than others. From the mean values the highest score was 3,25 and the lowest 2,25. Based on the mean values of the answers, it is clear that there is room to improve the user experience and usability of the dashboard.

Based on the mean values from statements, the information in the dashboard was agreed to be relevant, organised and easy to find. Yet, the users felt that the dashboard was too technical and that it contains too many numbers. The users agreed that detecting controller and optimizer performance issues is easy from the dashboard. The dashboard errors seemed to be an issue as users felt that the dashboard does not report errors and the error messages are not helpful. Moreover, the dashboard does not seem to recover from errors. Finally, the users thought that overall using the dashboard is productive.

In addition to the statements, feedback was collected with open-ended questions that were related to the visualisations, performance measurements and indicators (table 7). The open feedback questions turned out to be useful as users could describe their ideas on developing the dashboard freely. Users hoped for visuals that help to quickly and efficiently understand the performance data of Controller and Optimizer. Bar and pie charts, speed metres, trends and simple line graphs, and different plots were suggested, whichever would simply present the data in an easily readable way.

The data that users wanted to see was controlled variable (CV) targets and measurements together with associated manipulated variables (MVs) and manipulated variable constraints (MVCs) for a certain time frame such as the previous week. This information was said to be the most important as it often opens up the situation of the controller to the user. Also, not many control loops are more complicated than this in an APC solution so this provides a solid overview.

Seeing thresholds in a graphical way, points in time when thresholds were exceeded, and corresponding variables responsible for their breaching would be useful in users' opinion. Separate tables for MVs and CVs could also be used to display various KPIs. From existing visualisations, colour indicating the goodness of values was considered to be a good feature.

The suggestions for performance measurements visualisations included visual and metric data display, percentages for comparing performance measurements, and general scores displaying how well the controller is performing. Visualisations in other internal systems were mentioned to be nice, where speed metres with numeric values and threshold colours are used. However, one user mentioned that a NAPCON specific system that requires a lot of usage instructions should be avoided.

Users also hoped for a feature to change the selection of displayed variables. One example was visuals presented graphically with the option to choose manipulated variables and disturbance variables (DVs) individually, collectively and display the behaviour in time when values have breached. The ability to look into the reasons for the breaching using visual parameters would also be beneficial.

The performance indicators that users considered useful in a performance dashboard are general scores and indicators, such as the uptime (percentage of the time the controller is on since commissioning or other predefined interval), available MVs divided and total number of MVs, measure how close CVs and MVs are to optimisation limit. Also, trends of the most critical controlled variables with their control targets were mentioned a couple of times. For example, how well CV measurements have been following their targets and constraints, MVC constraints have been respected and how often and close MVs have been to their optimal values over selectable timeframe.

Users would prefer seeing everything on one page if the application is very small. In case of a bigger application, a main page would be preferred for selecting different subsections or dashboards of the controller to view.

The last open-ended question allowed collecting any other ideas or comments about developing the solution. Users hoped that the dashboard would include a lot of plots and general scores. Table could present the most important indices or variables, but it shouldn't be too crowded. Also, the dashboard should be developed together with the end users so user needs are reflected. One user had an idea about using the tool also as a service for some customers that don't have APC engineers as the tool is currently only used by APC engineers. In this case, NAPCON experts could show and demonstrate to the customer how well the controller is performing and produce some reports (such as monthly). These need to be very easy to understand because the person receiving this information doesn't necessarily understand APC terms and therefore may prefer a simpler explanation of the performance (for example visual pictures of targets and their measurements).

To summarise the survey results, the usability statements were inconclusive. However, when looking into the open-ended questions, there were a lot of comments which describe new features and visualisations in detail that could benefit the existing solution. So, the open-ended questions turned out to provide very valuable feedback towards improving the

solution and the usability statements results were not as useful. The feedback from open-ended questions was considered when the new dashboards visualisations were developed. The improved visualisations for the dashboards are presented in the next chapter.

# 5 Improved Visualisations for the Dashboards

The new design for NAPCON Improve Dashboards includes improved controller status dashboard and an advanced trending and data export dashboard. These dashboards are displayed on separate pages. The other tables of the NAPCON Improve Dashboards were not included in the new solution. So, this solution would enhance the controller status dashboard and allow custom trending of variables.

New usability survey was done with the new dashboards. This survey was also sent to people who were not familiar with the previous dashboards solution, as the new one was simpler and the survey included a demo video explaining the dashboards. The goal of the survey was to get feedback and improvement ideas on the new dashboards. Only open-ended questions were included in the survey. Close-ended questions were left out as in the previous survey they did not provide clear results but the open-ended questions provided a lot of useful ideas.

The feedback from the new dashboards was taken into account when the dashboards were developed further. The structure of this chapter goes as follows; first the new improved visualisations for NAPCON Improve Dashboards are presented, then the survey of new dashboards design and its results are gone through, lastly refined dashboards design is presented.

## 5.1 First Iteration of New Dashboards Design

**Controller Status Dashboard**

Controller status dashboard page displays multiple scores of the controller with speed meter and timeline visualisations. The page also includes different time range selection buttons to quickly adjust the timeframe of the visualisations. It should be noted that mock data is used in the design and the values between different visualisations are not aligned so that the speed meters could be demonstrated with various values. The controller status dashboard is presented in figure 2.


Figure 2. Controller status dashboard.

The speed meters have thresholds colouring which indicates how well the value is in target. Green means good, yellow neutral and red bad. Being in target is displayed as a percentage over selected timeframe. The low and high thresholds of the variables could be defined in the database by APC engineers if required.

As Pappas and Whitman note (2011), speed meter visualisations are good for drawing attention to important measurements which may need taking immediate action, which is why they were selected for this view. Furthermore, as there was plenty of space available for the page, these visualisations could be selected as the available display space for dashboards should be used effectively.

The colours for being in target were selected based on the user survey and literature. From the user survey, speed meter visualisations were mentioned as an option to display values with threshold colouring. The threshold colouring was also used because KPIs are created to display a certain range where data falls and the colour coding helps to highlight if the value is above or below threshold. Often, red is used to indicate below target performance, green good performance and yellow that there is no need for action. (Pappas & Whitman, 2011)

The timeline visualisation presents how these scores have behaved over time. For example, how long they have been false or true within the last 60 minutes. The timeline visualisation was selected because it is similar to table layout, which is optimal for displaying repeated information. Repetition supports retrieving and interpreting data and leads viewers' glance

(Bach et al., 2023). Pre-calculation could be used to calculate the scores for months, weeks, years or so, in the background. Using pre-calculated scores makes loading of the dashboards instant. The need for implementing this feature should be investigated further based on how heavy the dashboards are to load for certain time frames.

The scores in the controller status dashboard are named as descriptively as possible. Green and red colours are used in the timeline to highlight whether the value has been true or false. Also, text is used together with colouring to display the respective state, so it is clearer what the actual value is. According to Pappas and Whitman (2011), colour should not be the only indicator for meaning as some users might be colour blind. Instead, colour should be combined with labels to display values.

**Advanced Trending and Data Export Dashboard**

In the advanced trending and data export page NAPCON Analytics tag query panel is used to query controller tags from the database. From the queried list, tags can be searched and selected for trending. Selected tags are displayed in the bottom of the panel. The trend can be updated from the green update trend button in the upper right corner. The selected list of tags can also be saved as a tag group which makes future trending of these tags faster as they don't have to be selected individually each time. The tag groups can be edited, for example, named descriptively. The time range of the trend can be adjusted with time selector tools. The tag query panel also has a feature to download data for selected tags and time range. This feature can be useful for creating reports of how some variable has changed over time.

Figure 3 shows an example of using the tool with mock data. Tag group "Debutanizer column temperature TC11118" has been saved and selected. In the trend we can see the targets and measurement over the selected time range. Here we can see that the measurement has been within the upper and lower target limits.


Figure 3. Example usage of advanced trending and data export dashboard.

Based on user feedback the presented solution would be useful for APC engineers or other advanced users who wish to see how the selected variables have behaved in various time ranges. The solution could be also used to trend ready-made groups to see how measurement has been within target.

## 5.2 New Dashboards Design Evaluation

### Dashboards Design Survey

The new dashboards design survey includes demo video describing the new dashboards designs, screenshots of dashboards and questions about the usability of the new design. No close-ended usability questions are included. In the previous survey close-ended questions did not provide much value since people answered very differently to those so no clear conclusions could be made. Also, from the first survey it was clear that more feedback and ideas were collected through the open-ended questions so this approach was taken in the new survey. The open feedback was also similar among many respondents so it was clearer what needed improvement.

This survey was done so that people who did not answer the previous survey could answer. This way we can reach out to more people and hopefully get more input on the design. The idea of the demo video was to describe the dashboards and their usage as clearly as possible so the users will get an idea how the dashboards are used and if they would be useful in their opinion. Also, screenshots of the new dashboards were included in the survey before the questions. The questions are presented in table 9.

Table 9. Open-ended questions in the new dashboards design survey.

| **Question** |
|---|
| 1. What do you think about the user interface of the controller status dashboard? |
| 2. What do you think about the scores on the controller status dashboards? (For example, should some variables be added/removed/combined) |
| 3. What do you think about the time interval selections? (For example, are they enough, should there be more) |
| 4. Any other comments or ideas for developing the dashboard? |
| 5. What do you think about the user interface of the advanced trending and data export dashboard? |
| 6. What do you think about the usability of the trending? (For example, is it useful in your opinion, do you see use cases for it, would you use it) |
| 7. What do you think about the usability of the data export? (For example, is it useful in your opinion, do you see use cases for it, would you use it) |
| 8. Any other comments about the advanced trending and data export dashboard? |

**Dashboards Design Survey Results**

The survey was sent to eleven people with APC applications experience. Eight of them responded, so the response rate was good. Overall the feedback was really positive, but some ideas were presented on how the solution could be improved. The feedback was considered when the next iteration of the dashboards was made. The finalised new dashboards design is presented after the survey results.

The feedback about the controller status dashboard user interface suggested that the controller name should be clearly visible. Also, selection for controllers could be added. The metrics of the dashboard could be combined and named better. Some controller specific metrics could be added, like custom performance and quality indicators. There were different ideas on what these custom metrics could be, so the metrics should be customisable for each controller. Couple users commented that the scores about controller status should be flexible and editable. One user suggested that an overall page displaying high level information on each controller performance could be useful as the detailed page only shows information on one controller at a time.

Showing controller variable states below the controller performance indicators would be useful. The states could show for example on, off, or other custom states that the variables have over the selected time frame. The predefined time interval selections were mostly considered good and enough. However, there was a wish to include custom time interval selection as well for more specific needs to view controller states. Also, predefined calendar months and weeks, e.g. June 2023, could be added.

The next part of the survey was about collecting feedback on the advanced trending and data export dashboard. The users agreed that the dashboard interface was user friendly, clear and intuitive. They thought that the trending was decent, and the option to save tag groups for future trending was good. One development idea was to have a tree-like structure in the variable listing to firstly display controllers, then their variables and finally the parameters of variables.

The trending feature was considered useful as it allows digging deeper into controller performance issues and finding the root causes of different situations. For example, investigating why some scores are low can be done with the trending. However, the users are used to using different systems for trending these variables, so they were not sure what added benefit this additional trending tool could provide. Some thought that the user interface of this trending tool was better and the tool seemed also quicker compared to the solutions they have used before. But for the tool to be used widely, it should be clearly superior to the other systems with trending tools. For improvement ideas on the trending tool, a couple users suggested scaling feature for y-axis as it may be needed when investigating process issues from trends.

With the data export feature, users had similar thoughts than with the trending feature. It was mentioned that there are other tools they are using for data export where the data parameters can be widely adjusted, so there may not be much need for this feature. The option to create automatic reports for predefined intervals, like monthly and weekly, was seen as one idea to improve the data export tool.

So, the trending feature was considered to be more useful than the ability to export data, at least with the current options on data parameters. Yet, having the trending and data export features in the same application as the controller status dashboard can reduce the amount of going back and forth between different systems for using these features. Overall, the new dashboards designs were considered clearer than the previous ones and the feedback was mainly positive.

## 5.3 Finalised New Dashboards Design

Based on the feedback from the new dashboards design survey, the dashboards design was improved. Firstly, a home page was added, which includes navigation links to the dashboards and scores displaying the uptime of all controllers. The home page makes navigating between the new dashboards easy and provides an overview on controllers' performance. The home page is presented in figure 4.

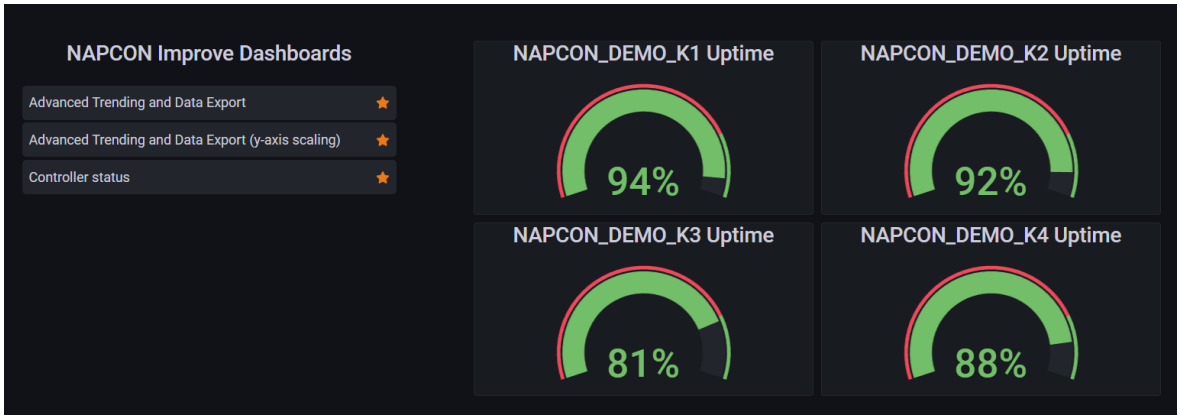


Figure 4. NAPCON Improve Dashboards home page with navigation and controller performance visualisations.

On the home page, similar speed meter visualisations were selected as are used in the controller status page. The aim with using similar visualisations is to create consistency between the pages and make similarities between the pages recognisable. According to Qu and Hullman (2018), same visualisations should be used to keep multiple views consistent.

On the controller status page, controller selection and custom time range selection options were added. Selected controller name was made more visible and the naming of scores and dashboards on the page was improved. Some of the controller performance scores were combined to avoid showing repetitive information. Two custom scores were added since there were many ideas from users' side to display other useful metrics on the page as well. The custom scores could be, for example, quality and performance indicators defined by APC engineers. Figure 5 displays the improved controller status page.


Figure 5. Improved design of controller status dashboard.

Below the speed meter scores and controller status timeline dashboard, two new visualisations were added. These dashboards show the states of CV and MV variables of the controller in the selected time frame. The CV and MV dashboards are also using the timeline visualisation type. These dashboards help to get an overall view on the states of controller variables.

The same visualisations for CV and MV states as controller status timeline were selected because they follow the guides on using similar visualisation elements for consistency. Also, related visualisations should be next to each other (Pappas & Whitman, 2011) which is why speed meters are next to each other and the timeline visualisations as well. To summarise, using as many of the same types of visualisations as possible helps to provide consistency and allow faster interpretation of the information (Qu & Hullman, 2018).

For more detailed metrics and investigations on variables, the advanced trending and data export tool is suggested to be used. The usage of the advanced trending and data export dashboard is demonstrated in figure 6.


Figure 6. Advanced trending and data export dashboard with y-axis scaling.

In the advanced trending and data export page, no changes were made. However, since a couple users hoped for y-axis scaling, another advanced trending and data export page was added, which includes the option to scale y-axis. Since this tool is still under development, and not offering as pleasant user experience on the trending, the original trending tool was kept as well. These tools use the same data, so the tag groups made on the other can be used on the one as well. The only difference is that the added page offers the option to scale the y-axis of the selected variables.

# 6 Discussion

The aim of this study was to improve the performance monitoring of the case company optimizer and controller applications by improving the visualisations of the performance monitoring dashboards. To improve the visualisations of the dashboards, state of the art visualisations and user interfaces used in dashboards were studied. In addition, current standards and guides on usability and user experience were investigated, to improve the usability and user experience of the performance monitoring dashboards. So, the literature survey of the thesis was focused on dashboards, usability and user experience. After the literature survey was completed, usability studies were conducted to find out how to improve the visualisations of the performance monitoring dashboards according to user needs, requirements and feedback.

The literature survey on dashboards explained dashboards, dashboard types, dashboard visualisation and challenges of user centred dashboard design. From the literature review it was advised to include users in the design of a new dashboard, which is why user surveys were conducted two times during the thesis work. The first usability survey focused on collecting feedback on the existing NAPCON Improve Dashboards, so improvement ideas could be collected from the users. It was clear from the survey that close-ended usability questions did not provide much value as users answered so differently to the various statements. However, from the open-ended questions some valuable feedback was collected as users described what kind of visualisations they would like, what metrics are most important for them and how the solution could be improved.

Based on the literature review and user survey, the new dashboard design was drafted. During the development process, there was no opportunity to view the existing dashboard solutions in a working environment as they are only used on client premises. Therefore, only screenshots and a user manual were referred to when drafting the new dashboards designs. Demo data was used in the dashboards, and they were developed in a local environment. Based on the user feedback, the focus was on improving the controller status dashboard and providing a trending visualisation for viewing how variables have been in target.

For the advanced trending page NAPCON Analytics advanced trending and data export tool was used. The reason for selecting this tool was to avoid making a tool that is specific for

just this use case, which would require more development and user onboarding. As one user suggested in the feedback, complex NAPCON specific systems should be avoided.

After the new dashboards were drafted and functioning in the local development environment, a demo video was recorded explaining and showing how the dashboards work, what they include and why. The demo video was done because time constraints would not have allowed deploying the work-in-progress onto some simulated environment. For the survey purposes though, the local environment proved enough as then demo video was able to be done and questions drafted based on it. Also, since the demo video explained the new dashboards thoroughly and as they were less complex than the previous solution, there was a possibility to send this survey also to people not familiar with the previous solution. The aim of sending the survey to more people was to get more opinions on the usability of these new dashboards. The response rate of the new dashboards design survey was good and feedback mainly positive. Some improvement ideas were picked from the survey feedback. The improvement ideas were selected based on their repetitiveness among respondents and the ease of implementation given the time constraints.

The new dashboards design was improved to include a home page that included navigation to the dashboards and uptime indicators of all controllers. The controller status page was improved to include controller selection and dashboards displaying CV and MV states of the selected controller. The controller performance metrics displayed as speed meters on the page were also refined, so that there would be less repetitive information on controller performance. Also, at least two custom performance metrics are added, which are to be assigned by the end user. The need for customisable indicators stem from the second user survey as various users had different ideas on what metrics could be useful to show.

In the advanced trending and data export page, user feedback suggested a need for scaling the y-axis of the trend. For this purpose, another trending dashboard was added which included this feature. The trending dashboard which includes the scaling option is not as good on other functionalities, which is why the original trending dashboard was also kept. To improve the dashboard with the scaling option, more research and development work is required.

Overall, the user surveys provided valuable feedback and insightful improvement ideas for the dashboards. The most repeating and feasible feedback ideas were considered and

implemented in the dashboards design. The rest of the feedback can be beneficial for future development of the NAPCON Improve solutions. So, the results of this thesis can be used to continue the development of the dashboards further.

This thesis provides an overview on dashboards, usability and user experience, which can be referred to when developing or designing new dashboards. It is important to keep in mind that including the target audience in the design process is essential for dashboard visualisations to be effective. Even though this thesis included users in the process, there still seemed to be room for improvement, which just shows how important it is to keep up the communication with the users.

# 7 Conclusions

This study focused on improving the usability and user experience of performance monitoring dashboards by improving its visualisations. The motivation and need for new dashboards stem from the fact that the previous solution was too technical and contained too much information as a lot of data was presented using various tables. For the new solution, it was hoped that the user interface would include visualisations that are user friendly and provide better user experience and are more intuitive to use.

The research included a literature review, which focused on dashboards and their visualisations, and usability and user experience guidelines. Dashboard, dashboard types, dashboards design patterns, effective dashboard data visualisation, and challenges of user-centred dashboard design were studied. The aim of the dashboards literature review was to get a holistic view on dashboards, their visualisations and design challenges.

Dashboard design process should be iterative and user-centred, so shared understanding about the design choices can be achieved. User goals, data constraints and dashboard context should guide the design process for data visualisation to be effective. The most common problem in dashboard design was aligning dashboard visualisations with users' visual literacy. The main problem of involving users in the implementation of dashboards is the ever-changing user requirements and demands.

The second part of the literature review introduced widely known usability and user experience concepts. The goal of the usability and user experience study was to get an understanding of the current standards and guidelines, so they could be considered when developing the new dashboards. To find ways to conduct usability study with the dashboards users, some common methods to study usability were investigated.

The core component in creating a pleasant user experience is usability. The most important components of usability are learnability, efficiency, memorability, errors, and satisfaction. A system can be considered useful if it provides the required features and is easy to use. Design thinking can be used in problem solving to create valuable outcomes. The method includes empathising, defining, ideating, prototyping and testing.

Usability heuristics help to find common usability problems with user interfaces. The heuristics by Jakob Nielsen are widely used and include visibility of system status, match between system and the real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, help users recognise, diagnose, and recover from errors, and help and documentation.

The previous performance monitoring dashboards were evaluated with usability testing. The goal of the usability testing was to discover issues and improvement ideas for the dashboards. Based on the literature review and usability testing, improved visualisations for the performance monitoring dashboards were created. To get feedback on the improved visualisations, another user survey was held. The dashboards design was finalised based on the feedback from the new dashboards design survey. Including users in the dashboards development process was beneficial, as it allowed collecting feedback on the solution and understanding user needs and requirements.

The new dashboards design received mainly positive feedback. It was agreed that before developing the solution further, it should be tested in a customer environment. So far the solution has only been tested in a local development environment with demo data. Therefore, the next step is to deploy the solution in a customer environment and test it live with real data. More feedback from users should be collected once the solution is up and running in a real environment. After feedback collection, the solution can be developed further together with the users.

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