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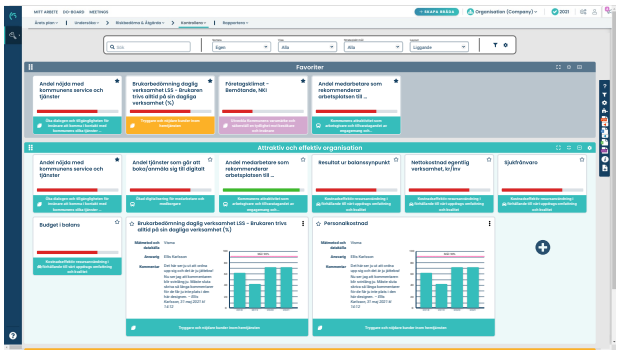

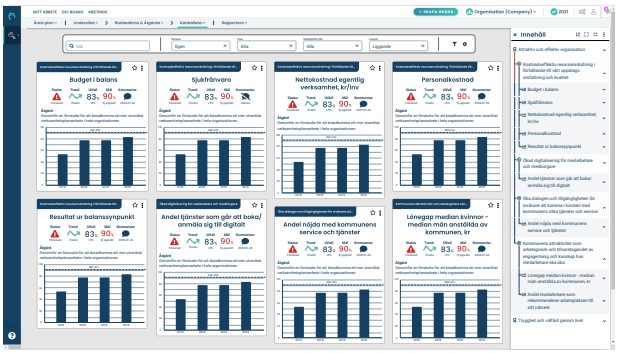

Designing Information Visualizations for Strategic Planning Platforms

An Iterative Research Project Generating Information Visualization Design Guidelines and Concepts By Investigating the User Experience

Master's Thesis in Computer Science and Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover: Images of two concepts developed during the project. The concepts are further described within the report. More images can be found in appendix.

Typeset in LaTeX
Gothenburg, Sweden 2021

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Abstract

In strategic planning software, one of the problems is how to visualise the great amount of data available in a manner that provides an overview and increases the user experience. In this project, we have attempted to find new ways of visualising the data in Stratsys, a company providing a strategic planning software to several Swedish municipalities and companies. Through literature studies, user research and iterative work with ideation, prototyping and evaluating of concepts, we have found two proposed concepts for new visualizations to be used within Stratsys platform, as well as a compiled list of information visualization design guidelines to be used while designing for a strategic planning platform. The compiled design guidelines are based on the takeaways from the evaluations conducted throughout the project and they serve to answer the research question: *Which design principles, leaning on novel and well-known research on information visualization and transitions, can support overview and comprehension of large amounts of data in a strategic planning platform?*. Thereby, we provide a set of guidelines on designing information visualizations for strategic planning platforms with a focus on finding, understanding and getting an overview of large amounts of data.

Keywords: information visualization, qualitative data, strategic planning, innovation, user research, design principles, design guidelines

Acknowledgements

We would like to thank our supervisor, Beata Stahre Wästberg, for all support and feedback during the report writing, as well as aiding with her great expertise during the design process. We would also like to thank her for being supportive and showing a great interest in the project.
We would also like to thank our mentor at Stratsys, Carin Andersson-Sarning, for all support during the project. We would especially like to thank her for aiding in finding participants for user research, as well as guiding us through the project. Furthermore, we would like to thank her for supporting us to become better designers.
We would like to thank the participants in the user interviews and questionnaires that gave their time to give the valuable feedback that was the backbone of this project.
And we would like to thank the Stratsys employees and consultants that also took their time to give us deeper insight into Stratsys.
There is also a number of people that we are very thankful to that we can not mention with names here, due to promised anonymity. If they read this, they know who they are.

Tove Ekman & Alexander Nordgren, Gothenburg, May 2021

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Dictionary

Definitions and descriptions of select words and phrases used throughout the report. The definition of the word and phrase is a description of what we mean when we use that word.

Word	**Meaning**
Activity	Type of qualitative data within Stratsys, usually within a goal.
Blank space	See white space.
Check list	Set of data within Stratsys, usually posed as questions and responses.
Child element	See child node.
Child Node	Node that are below another in the hierarchy.
Connecting Thread	A type of visualization within Stratsys
Data	See information.
Data Structure	Connections between data and layout of data.
Details	Information that is not needed to provide an overview. High level information.
Element	See Node.
Goals	Type of qualitative data within Stratsys, usually at the top level.

Word	**Meaning**
Gross list	Set of data in Stratsys.
Guidelines	See Principles.
Information	An uncountable set of facts or details that can be used to explain a thing, person or situation.
Information Visualization	the act of making facts and details able to be seen by the eye or making facts and details form a picture in the mind
Measurement	Type of quantitative data within Stratsys, usually within a goal or activity.
Node	Type of data that has some kind of connection to other data.
Object	See Node.
Overview first principle	Overview first, zoom and filtering, then details on-demand
Parent element	See Parent node.
Parent node	Top level node, has nodes connected lower in the hierarchy to it.
Pilot	A test run to validate the planning.
Plan Do, Review	Type of strategic planning.
Principle	Fact based statement of how design should be implemented.
Regulation	Set of data within Stratsys, usually posed as a list.
Scorecard	Set of data in Stratsys.

Word	Meaning
Strategic goal	See Goal.
Strategic planning	A planning process commonly used in larger corporations.
Subelement	See Child node.
Visualization	A visual representation of something.
White space	Blank area of screen that is not being used.
Stratsys	The collaborative company, providing a strategic planning platform.

Style Definition

Style	Meaning
Small Caps	Internal names, such as name of prototypes
Bold	Table headers

Abbreviations

Abbreviation	Meaning
AI	Artificial Intelligence
AR	Augmented Reality
CPM	Critical Path Method
HMW	How Might We
KPI	Key Performance Indicator
PDR	Plan, Do, Review
PERT	Project Evaluation and Review Technique
SWOT	Strengths, Weaknesses, Opportunities, Threats
SWUN	Strengts, Weaknessess, Use cases, Novelties
UX	User Experience
VR	Virtual Reality
W/N Analysis	Wants / Needs Analysis

1

Introduction

This project was conducted in collaboration with Stratsys [1], a Gothenburg based software company that supplies a type of strategic planning software that they call a *Plan, Do, Review* platform. This software allows the users to create, store and access large amounts of data. Stratsys' platform is used by 198 000 people at companies and organisations in 102 countries. The customers, which include several Swedish municipalities and public utilities, use the platform to plan and organise workflows [5].

This project aimed towards finding new interactive ways of presenting large amounts of data to the users. The users need to be able to interact with the data, such as edit, add, remove and present the data. Furthermore, the users should be able to choose in which way the data is presented.

The intention was to create guidelines for a new type of visualization with increased user experience, rather than making adjustments to the current interface. Increased user experience includes: a better overview of the data, easier to understand the data, easier to find the relevant data, as well as suitable transitions between different types of data and visualizations. User experience also includes a focus on the emotional state of the users, not only usability [6].

In this project, we explored the latest research in the field of information visualization and also looked into other designers' contributions in the field. The target group for the proposed designs in this project was users with administrative roles within their organisation.

1.1 Stakeholders

In this project, Stratsys and its customers were the main stakeholders. However, stakeholders such as other designers that may utilise the produced principles as well as programmers that may implement the designs also needed to be taken into consideration. Furthermore, the project had to be adapted to the course requirements of the master thesis course at Chalmers University of Technology [2].

[1] https://www.stratsys.com/

[2] https://www.student.chalmers.se/sp/course?course_id=13580

1.2 Problem Statement

At the time of this project, one of the main challenges in Stratsys' platform was to make large amounts of data easy for the users to understand and overview. According to Stratsys, the form of visualization had not changed much in recent years and they wanted to investigate new ways of visualising and working with data.

The users of Stratsys' platform commonly work with a lot of information that needs to be accessible and understandable.

Stratsys suggested that the users of their platform sometimes struggle with getting a sense of the structure and finding where data is located. Furthermore, Stratsys suggested that transitions, when the user changes the layout may facilitate keeping track of the data location.

1.3 Research Question

The project aimed to find new information visualizations that could aid the users in finding, understanding and getting an overview of the large amounts of data as requested by Stratsys. To yield a more generalisable result, a set of guidelines could be compiled as well to aid while designing for this niche field. To narrow the scope of the project as well as to guide it towards the wanted outcome, the research question was defined to: *Which design principles, leaning on novel and well-known research on information visualization and transitions, can support overview and comprehension of large amounts of data in a strategic planning platform?*

1.4 Aim and Goal

This project aimed to find new ways of visualising the data model of Stratsys, to make working with the data model a more pleasant experience for the users. We intended to find new ways to visualise the data model, to give the users a better understanding of how the information is connected within the system. This should result in visualization concepts, as well as a set of guidelines.

The main goal of the visualizations was to allow the users to get a deeper understanding of the data, as well as a better overview. We wanted to enable the users to interact with their data and dig deeper into it. Additional goals were to facilitate the users in transitioning between views and supporting the users in finding the data that they are looking for.

The main goal of the guidelines was to provide a set of recommendations that could be beneficial for designers that are working on similar tasks, with a focus on visualizations in strategic planning platforms.

1.5 Planned Result

The planned result was a set of design guidelines that could be used while designing new visualizations and transitions between visualizations in a strategic planning platform, to aid users in finding, understanding and getting an overview of large amounts of data. The design guidelines should aim towards the latest research in the field of data and information visualization. The result should contribute to the specific field of information visualizations within strategic planning platforms and thereby be less general than information visualization design guidelines found in current literature.

1.6 Limitations and Context

At the time of the project, the Covid-19 pandemic resulted in recommendations of limiting social contacts [7]. Thus, contact with users and other stakeholders mainly had to be done remotely. Furthermore, we planned for design methods that avoid or could be adapted to avoid, meeting the users face to face. According to recommendations from the Swedish authorities, work should be conducted from home if possible. However, working in co-location was still allowed if deemed necessary [7]. Hence, this project would be conducted using a mix of remote and co-located work. In the context of the Covid-19 pandemic, we experienced that it was becoming more common that people work remotely, usually from home, where the conditions might be largely different than in the office. At home, users might be working on their laptops, which could affect the size of the display and the number of distractions around the users. The access to colleagues might be reduced, which could harm the amount of help available for interpreting data. The dislocation from the common office might also make it harder to get an overview of what colleagues within the organisation are working on. This might increase the need for, and demands on, a strategic planning platform.
The text in the prototypes constructed throughout this project has Swedish as the main language. This was because the main language used at Stratsys is Swedish, and all user research was planned to be conducted with Swedish speaking users. Furthermore, as the target users mainly have Swedish as their first language, user evaluation of the prototypes was planned to be conducted in Swedish.
Algorithm implementation was out of scope for this project. Some consideration might however be made towards system performance, but only to the extent of ruling out solutions that require an unreasonable amount of computer power.
In this project, we focused on visualizations within an existing web-based platform, which made us restricted to the existing web interface that is not adapted for virtual reality (VR) and augmented reality (AR). Thus, we will not dig deeper into the subject of VR and AR visualizations.

2
Background

This chapter will discuss and define the term visualization as well as discussing strategic planning platforms and how visualizations can be used within them. There will also be an introduction to Stratsys' platform and data model. This chapter will provide the outline and basis of this project.

2.1 Visualization

In this section, we will define what we mean by the word visualization, and which fields within visualization this project will be concerned with. We will also briefly describe a number of visualization techniques that are of relevance to this project.
Ware states that the term visualization was earlier concerned primarily with mental representations, but that it increasingly has come to mean something like *"a graphical representation of data or concepts"* [8, p.2]. Ware talks about the visualization process as something that happens between the data presented and the human, a cognitive process where the visualization works as an extension of the human mind. In this process, the human uses the graphical representation to get a deeper understanding of the data presented.
As Spence notes, the word visualisation does not necessarily involve computers, but might as well be done for instance with pen and paper [9, p.2].
Traditionally, visualization techniques have been largely focused on images. In recent years, visualization has had a possibility to expand to incorporate more of our senses in perceiving visualizations [10]. According to Roberts et al., data can be mapped to colour, size, loudness, frequency, temperature or other variables that can be perceived by the different human senses. A technology that has become increasingly popular in recent years is virtual reality (VR), which aspires to involve as many senses as possible. However, in this project, we define visualizations to only include the visual representation of data and information.

2.1.1 Information Visualization

Oxford Learner's Dictionary defines the word visualization as *"the act of forming a picture of somebody/something in your mind"* and *"the act of making something able to be seen by the eye"* [11]. The same dictionary defines the word information as *"facts or details about somebody/something"* [12]. Combining the two definitions leads to information visualization being defined as *the act of making facts and details able to be seen by the eye or making facts and details form a picture in the mind.*

Spence claims that information visualization is a tool to facilitate the user in creating a mental model of data and information, and the choices made by the designer of the visualization greatly influences this [9, p.14]. Spence states that information visualization design is heavily influenced by human factors, such as the visual system and the cognitive capabilities of the users [9, pp.15-16]. Lastly, Spence states that *"the purpose of information visualization is to amplify cognitive performance, not just create interesting pictures. Information visualization should do for the mind what automobiles do for the feet"* [9, p.16]. Later in this report, the term information visualization and the term visualization may be used interchangeably.

2.1.2 New Visualization Techniques and the Visualization Gap

A study conducted by Schmidt concludes that there exists a large number of visualization techniques that have been developed in the last years and have been proven useful. However, in her study, she could not find any example of tools and applications that uses these newer visualization techniques [13].

Schmidt states that visualizations are primarily being used when it comes to presenting or reporting data, and not that much while working with the data and analysing it. Schmidt presents studies that show that utilising information visualizations earlier in the process while working with data may be beneficial [13]. This gap in usage and benefit of visualizations is called the *interactive Visualization Gap* by Batch and Elmqvist [14]. Batch and Elmqvist's study on the field finds that professional data analysts rarely utilises visualizations in their analysis work, but rather use them as a communication tool. The reasoning behind this is largely due to the visualization software being separate from the computational software and requires extensive data-wrangling while using.

2.1.3 Visualising Time

Time planning tools of today largely stem back to planning systems introduced in the early 20th century, before the digitalisation of society [15]. This implies that the systems have a solid base as a part of how we are used to interpreting time, but also that there is great potential for finding new ways of representing time in ways that are more suitable for a digitalised society.

The Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT) can be seen as evolved forms of Gantt charts, but they also represent a societal change from line production to project management [15]. They can be represented as networks rather than linear structures. Lean boards enable structuring daily work, together with physical meetings around the board. The physical representations do however lack the possibility of following up, as they are usually written on whiteboards that are erased regularly. In a digital format, lean boards could utilise version control so that older versions can be stored and accessed at a later time.

2.1.4 Visualising Tree Structures

There are many ways of visualising data in tree structures. Here we present four of these techniques, as seen in figure 2.1.

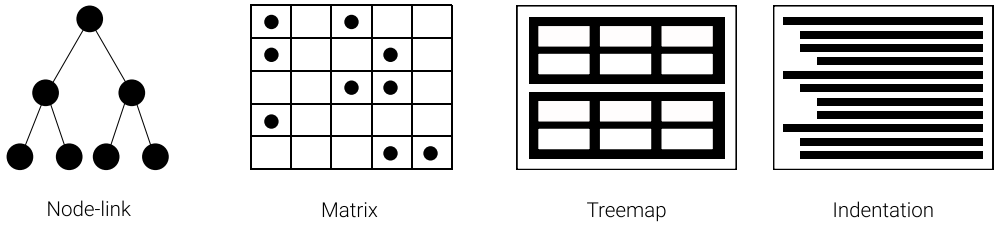

Figure 2.1: Four ways of displaying tree structures.

Ward divides the techniques for displaying trees into two categories: *space-filling* and *non-space-filling* [16, p.320].
Node-link diagrams is a common method to show hierarchies within trees and other graphs. Node-links are non-space-filling, and can sometimes lead to a lot of unused space within the representation [16, p.321][17, pp.210].
Matrix diagrams are stable, predictable and can display data with high density. They do however come with a weakness: Many users need training to be able to interpret networks displayed in matrices [17, p.211].
Treemaps are one of the most common space-filling tree visualizations. This technique uses containment to show the hierarchies of the tree. The highest level node encapsulates all nodes on the next level and they, in turn, contain all the nodes at the next level. Treemaps are mainly used for tree structures with few levels and are especially suitable for tasks that involve understanding attribute values at leaf level [17, p.213-214]. In a treemap, colour can be used to show attributes or relationships. Data features can also be displayed using markings in the different segments [16, p.321].
Another way of visualising hierarchies is by using indentation so that a child node is always skewed one step in relation to its parent [17, p.214].

2.1.5 Transitions and Animations in Visualizations

A known problem while presenting data is when the user changes the view, such as a bar graph to a pie chart, wants to get an overview, or wants more detailed visualizations, where the user loses the orientation and therefore needs to locate the data that they are looking for once again [3]. This problem is especially noticeable while presenting data where it is not the viewer that actuates the transition [3]. To support the user in finding the data after a filter has been applied or when the view has been changed, the visualization can transition in steps, utilising animations to show where different components are moving to [18][3]. Munzner also underlines that animated transitions in visualizations can aid users when travelling from one state to another, as it makes it easier to find the position of an item in the new context.

This is best used when the number of items that changes is small, or when the objects that change behave similarly, as the animations might be too overwhelming to follow otherwise [17, p.248].
Heer and Robertson's study on animations in visualizations shows that staged animations are preferred to direct animations, and both types are preferred to static transitions when it comes to error-rate, user satisfaction, enjoyment, learnability and comprehension of the transitions [3].
Animated transitions in visualizations do not only help the user locate the data. Previous studies also suggest that the transitions can facilitate learning, decision making and increase engagement [3]. However, Heer and Robertson point out that animations may increase the complexity of the visualizations and may be misleading if they violate the data semantics. Therefore, adding animations requires careful considerations and studies of the data and the usage [3]. Heer and Robertson list some advantages of animations, as well as how they can be misused. The list of advantages and misuses are compiled in table 2.1.

Table 2.1: Compilation of use cases and misuse of animations, based on Heer and Robertson's study [3].

	Advantage	Disadvantage
Attention	Motions are good at attracting attention and can easily be perceived in the peripheral vision	Grabbing attention can be perceived as distracting
Orientation	Animations show where an object is moving or what object is being transformed, making it easier for the user to understand what has changed	Transformation into unrelated objects can be misleading and establish a false relation
Relation	Animations can showcase cause-and-effect relationships, as well as intentions	Risk of showcasing a causality that does not exist
Engagement	Animations can achieve increased engagement, motivation and enjoyment	Can be used to highlight the wrong things and therefore be misleading

Furthermore, the timing of the animations needs to be carefully considered, since too long animations will slow down the workflow and too fast ones can be more confusing than helping. Heer and Robertson suggest around one second for each animation, although they suggest that each animation should be well tested and evaluated to accurately set the timing [3]. Heer and Robertson state that *"The upshot is that animation is a double-edged sword, designers must take both the benefits and pitfalls under consideration"* [3]. Table 2.2 is a compilation of different animations with their respective use cases and transitions.

Table 2.2: Compilation of different animation methods with their respective use cases, based on Heer and Robertson's study [3].

Type of Transition	Example of Animations	Use Case
Movement	Panning, zooming	Movement within a visualization, such as a big graph or map
Scaling	Axis rescaling, log transformation, graphical fisheye distortions	Access more details in a visualization
Filtering	Fade-in, Fade-out, zooming, panning	Selection of what data should be visible in the visualization
Visual Change	Transformation of colour, size, shape and placement	Changing visualization technique, such as from a pie chart to bar graph

2.1.6 Interaction in Visualisations and Situational Awareness

When data sets get large enough, interaction becomes crucial if the user is to get any use of the data [17, p.9].
Endsley et al. also note that the data needs to be presented in a way that lets the human mind absorb it properly to enable the forming of situation awareness [19].
One important part of interactive visualizations is letting users select elements within the visualization [17, p.249]. Several design choices need to be made in relation to the selections, such as: which objects should be possible to select, and what should happen when the user selects one of them.

2.1.7 Examples of Information Visualization Platforms

Notable information visualization tools with great success in their field of today include; Gapminder[1] (figure 2.2), Tibco Spotfire[2] (figure 2.3), IBM Cognos Analytics [3] (figure 2.4), Google Analytics [4] (figure 2.5) and Tableau[5] (figure 2.6).
Gapminder is a Swedish foundation that, according to themselves, *"identifies systematic misconceptions about important global trends and proportions and uses reliable data to develop easy to understand teaching materials to rid people of their misconceptions"*. They strive to fight misconceptions and present facts in a comprehensive way [20].
Tibco Spotfire is a data analytics tool used to visualise a large variety of data,

[1]https://www.gapminder.org/
[2]https://www.tibco.com/products/tibco-spotfire
[3]https://www.ibm.com/products/cognos-analytics
[4]analytics.google.com
[5]https://www.tableau.com/why-tableau/what-is-tableau

including big data and real-time data. Spotfire aims to facilitate the analysis of data by including artificial intelligence (AI) and machine learning [21].
IBM Cognos Analytics is a business intelligence platform that can be used by individuals, teams and large enterprises to make visualizations to show the current standing of the business and probable future outcomes [22].
Google Analytics is a tool that visualises data of website statistics, such as the number of users and page views [23].
Tableau is an analytical tool with a wide selection of visualizations for the data. The tool is used by a large number of companies and organisations. The tool has integrated artificial intelligence and machine learning to facilitate the analysis of data. [24].

Figure 2.2: Screenshot of Gapminder.

2.2 Stratsys' Platform

Stratsys provides a type of strategic planning software that they call a plan, do, review (PDR) platform. The software allows for management and governance throughout the organisation [5]. Stratsys customers include Swedish municipalities, such as *Göteborgs Stad* and *Stockholms Stad*, as well as Swedish regional authorities, such as *Region Stockholm* and *Västra Götalandsregionen* [25]. The customer base also includes large companies, such as *Stena* and *Vattenfall* [26], as well as schools, hospitals and government agencies [5].
The data model in Stratsys has a main building block called *scorecard (Swedish name: Styrmodell)*. The scorecard can represent overarching goals for the organisation.
Within the scorecard, there are *columns* that differ depending on the client and their structure.

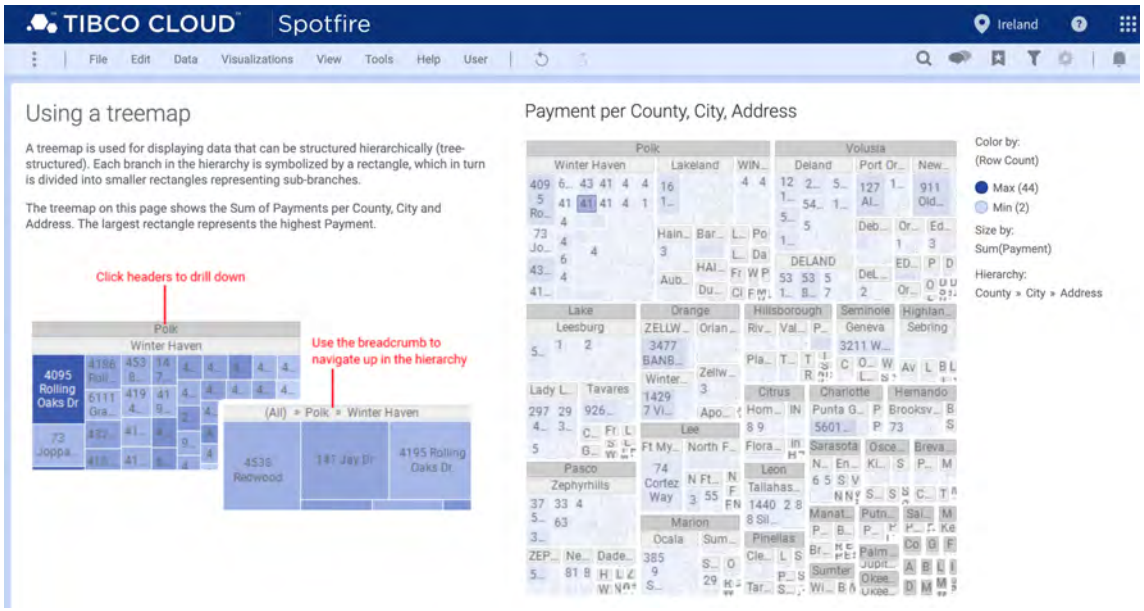

Figure 2.3: Screenshot of Tibco Spotfire.

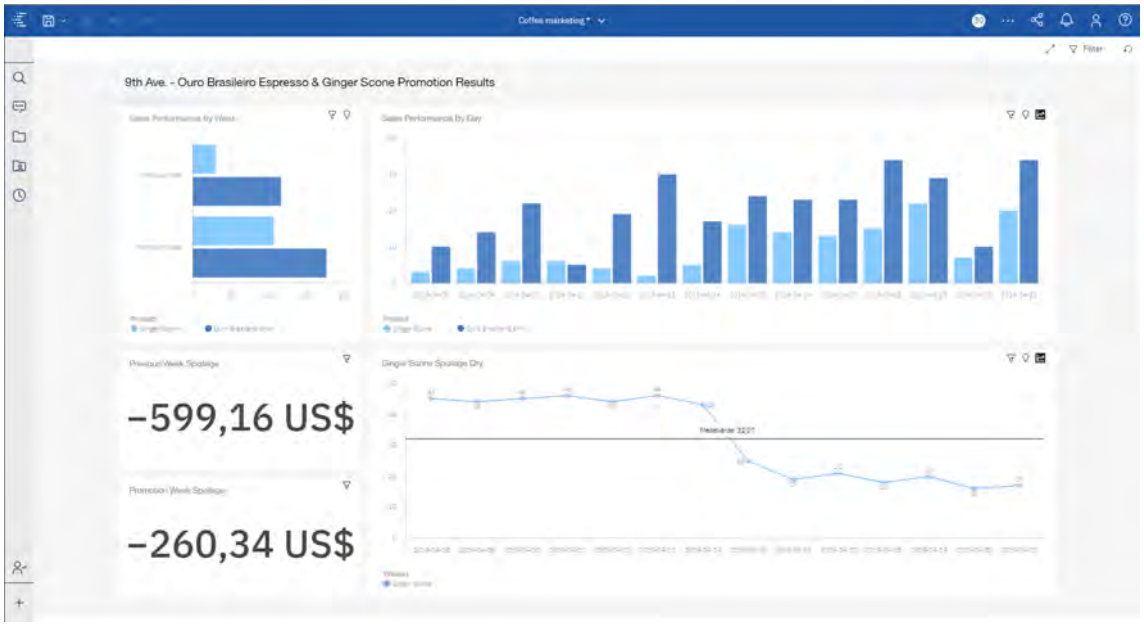

Figure 2.4: Screenshot of IBM Cognos Analytics.

Each column in turn contains *nodes*. The nodes can have types such as *goal*, *measurement*, and *activity*. Measurement is sometimes referred to as *Key Performance Indicator (KPI) (Swedish name: mått)*. Every column can only contain nodes of one type. The node types can contain different data, each type of node can also contain comments from the users. The node types are presented in table 2.3.

Changes within the scorecard can only be done by users with special access, such as administrators. The allowed type of node in a column can only be changed while no nodes are present in the column. A scorecard can only be deleted if it is empty and nothing is dependant on it.

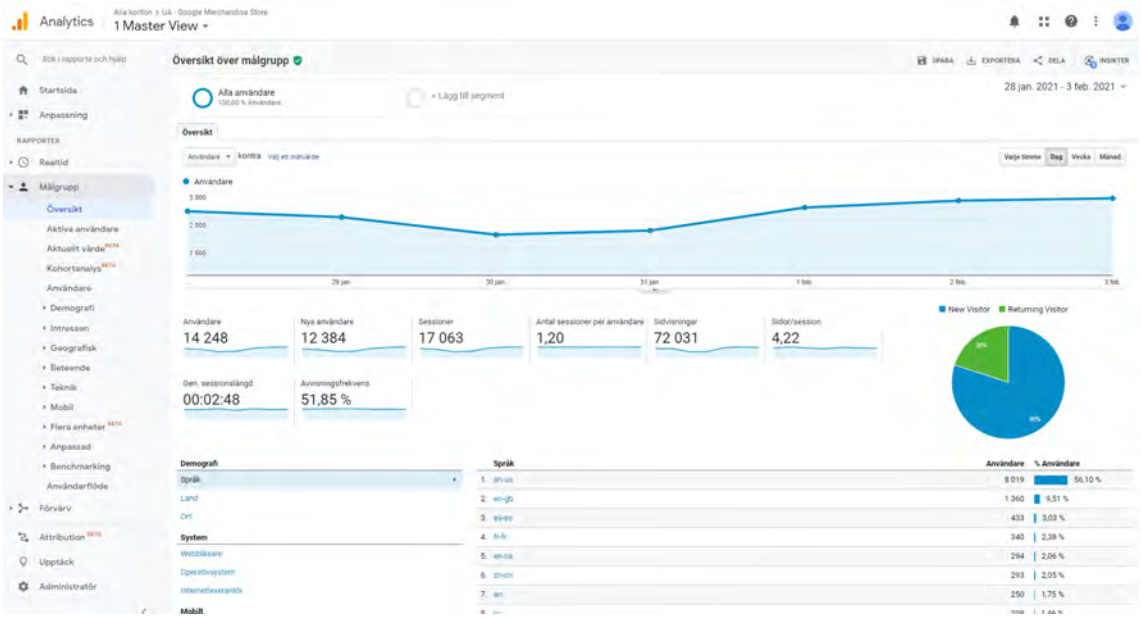

Figure 2.5: Screenshot of Google Analytics.

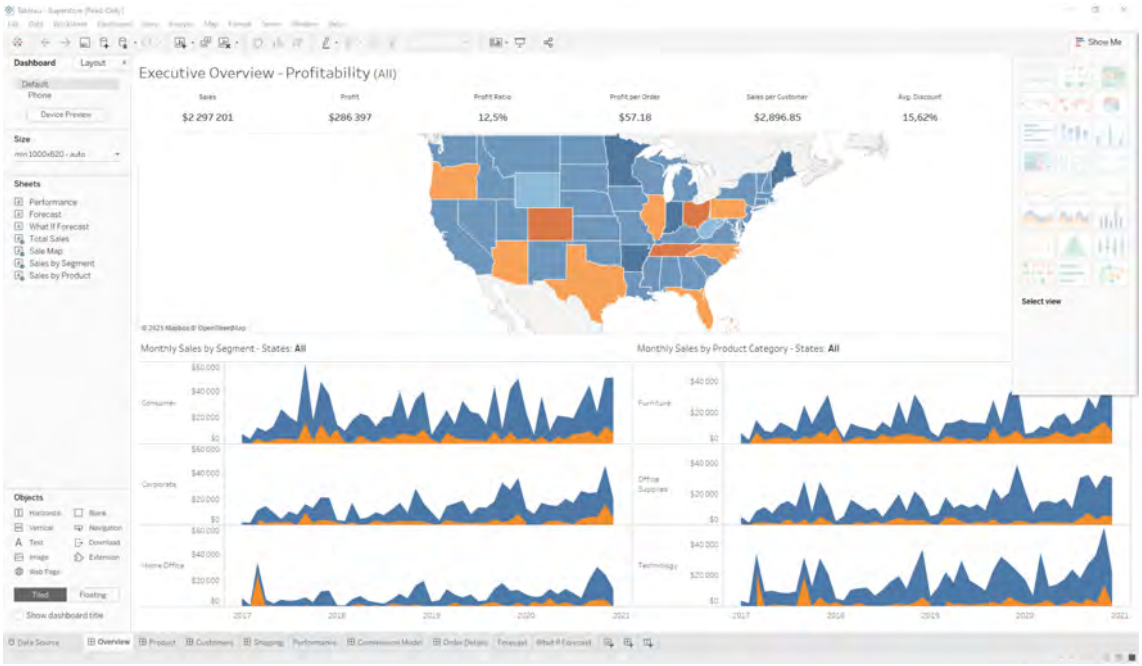

Figure 2.6: Screenshot of Tableau.

Stratsys has two auto-generated scorecards called *gross lists (Swedish name: Brut-tolistor)* that exist for technical reasons and can not be deleted. They contain every KPI node respectively every activity node within the database. The gross lists can be used to add a KPI or activity node to a scorecard. It is possible to make the gross lists visible within a scorecard [27, 28].
Stratsys' data model consists of both quantitative and qualitative data. The most common way to visualise this data during the planning phase is the view called *the connecting thread (Swedish name: röda tråden)*, as seen in figure 2.7. During the

Table 2.3: Categorisation of node types and the possible content.

Node Type	Data Format
Goal node	Only text
Measurement node	Text and numerical data
Activity node	Text, start date, and end date

analysis phase, the view *table (Swedish name: tabell trädstruktur)* is more popular, as seen in figure 2.8. Both of the views can visualise the same data to the user. However, the layouts of the views make them suitable for different situations and tasks.

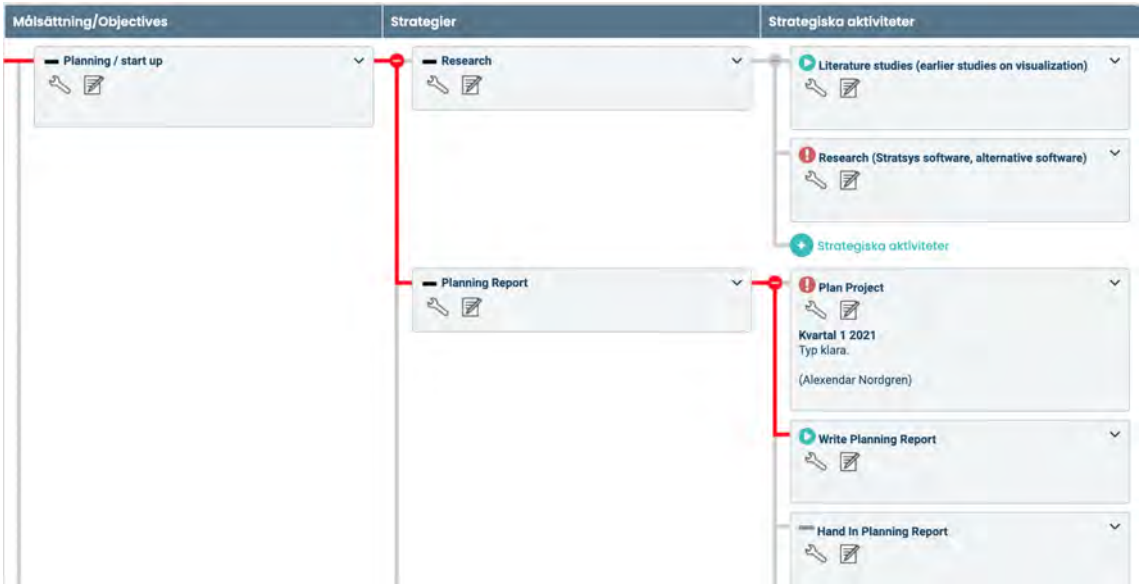

Figure 2.7: The view *the connecting thread* in Stratsys.

According to our mentor Carin Andersson-Sarning, UX designer at Stratsys, the company's users sometimes struggle in finding the data that they are looking for, which in turn causes the users to not fully make use of the data available. As described in chapter 1, one of the main goals of this project is to find ways to facilitate the users in finding data within the platform, as well as promoting overview and understanding of the data.

2.3 Strategic Planning and Visualization Techniques

Utilising visualizations in strategic planning, such as within a *plan, do, review* platform, has been proven useful. Eppler and Platts suggest that the strategic planning process can be divided into four phases: analysis, development, planning and implementation. They argue that the visualizations have different purpose and benefits in each of these phases. [4]

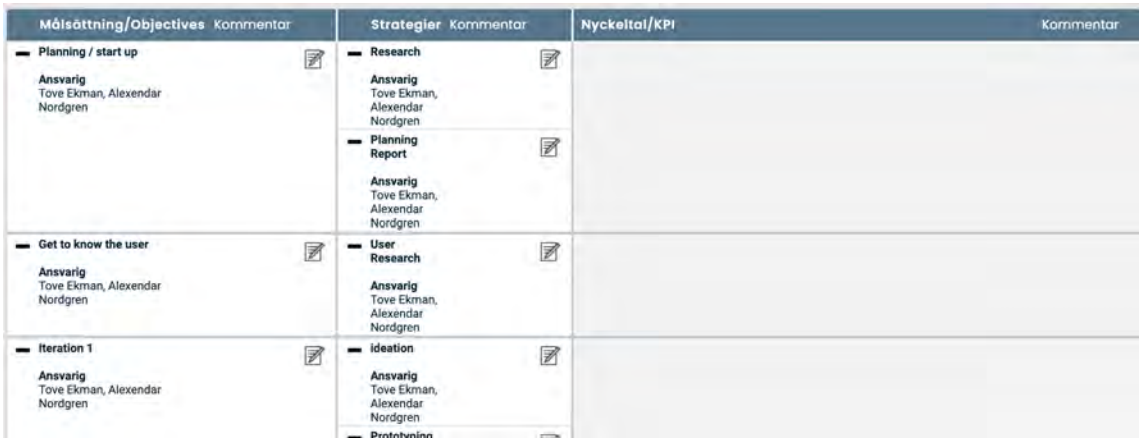

Figure 2.8: The view *table* in Stratsys.

2.3.1 Analysis Phase

The analysis phase focuses on accessing and structuring data and information. The visualizations' purpose in this phase is to relieve the user's cognitive load. Furthermore, in the analysis phase, the most common technique for qualitative data is one that allows for structuring, such as two by two matrices and SWOT matrices. For quantitative data, standard techniques include bar charts, line charts, pie charts and more [4].

2.3.2 Development Phase

The development phase is concerned with generating options for action. Visualizing different options together with their respective goals, activities and resources allows for easier assessing and selection. Eppler and Platts suggest that a visualization may provide the user with new perspectives as well as allowing for comparison between different options.
Furthermore, the visualization can facilitate the discussion and prioritisation among the options. In this phase, it is important to allow for interactivity, such as adding notes or symbols to the visualization, as well as to allow for cooperation in the visualization. In this phase, the visualization should support the user in divergent thinking to generate many options, such as visual brain-writing, knowledge mapping, mind mapping and concept mapping. Furthermore, the visualizations need to support the user in convergent thinking and decision making. This can be done through techniques such as decision trees and morphological boxes [4].

2.3.3 Planning Phase

In the planning phase, the purpose is to define specific objectives and plans to achieve these needs to be formulated. Here, the user works with timelines, allocating resources, responsibilities and deliverables, the main focus is the sequence of goals and actions. Therefore, the visualizations used needs to visualise the sequence and interdependencies of each task. The purpose of the visualization is to reduce the cognitive load and to facilitate communication as well as provide new insights to

the user. In this phase, common techniques for visualization include: timelines, roadmapping, Critical Path Method (CPM), and Project Evaluation and Review Technique (PERT) diagrams [4].

2.3.4 Implementation Phase

In this phase, the visualizations consist of actions, relationships and results. The visualizations can relieve the cognitive load, as well as motivate the user. Furthermore, by visualising the progress, a manager can easily get a grasp on parts that are not progressing as planned and provide a sense of common purpose while at the same time ensuring that everyone involved knows what their tasks are [4].

3

Theory

This section will provide an outline of known visualization techniques as well as known and tested visualization design principles.

In this chapter, we will present a few basic principles about human cognition and perception, which has implications for how a good visualization is designed. We will also state some visualization techniques, that may become useful for strategic planning platforms. We will also go through some general visualization design principles, to have a foundation of theoretical knowledge to use as a basis for our work. Lastly, we present principles on animations and transitions in visualization, which is something that could be of interest when developing new ways of visualising the data in a strategic planning platform.

3.1 Visualization Techniques

There are a vast number of techniques that can be used for visualization, but the number of solutions that are good for a certain means is limited. Therefore, the designers must know about a great number of existing techniques so that they do not miss too many of the choices that could be suitable for the task at hand. [17, p.13]

In any visualization, the designers need to consider the major fields that need to have an appropriate balance: Minimising the navigation by showing a lot of information at once, versus overwhelming the user with visual clutter [17, p.16].

Munzner sets up some categories for different data types, data sets and use cases. These categories can be used for the classification of visualizations, which are useful for deciding what type of visualization technique is suitable at a certain time. [17, pp.16]

In Munzner's view, the different *Data Types* are *Items, Attributes, Links, positions* and *Grids*. The *Dataset Types* are *Tables*, including *Multidimensional Tables Networks*, including *Trees*, *Fields* and *Geometry*. The *Dataset Availability* can be either *Static* or *Dynamic*.

The *Attribute Types* are *Categorical* or *Ordered*, and the *Ordered* can be either *Ordinal* or *Quantitative*. The attributes' *Ordering Direction* can be *Sequential*, *Diverging* or *Cyclic* [17].

Table 3.1: Compilation of Eppler and Platts' four genres of visualizations [4], accompanied by examples and explanations.

Visualization Method	**Example of Techniques**	**When and Why**
Structuring Methods	Bar-charts, line charts, pie charts, 2 by 2 matrices, Boston Consulting Group Matrix, SWOT matrix, Porter's five forces diagram, S-curve diagram.	Reduce cognitive load while organising and synthesising information.
Elaboration Methods	Knowledge mapping, concept mapping, mind mapping, decision trees, morphological boxes.	Elaborate on information and finding patterns as well as to support understanding and developing options.
Sequencing Methods	Timelines, roadmapping, critical Path Method (CPM), Project Evaluation and Review Technique (PERT) diagrams, Gantt.	Showcase a sequence of goals and tasks, as well as dependencies between these. Facilitates communication and can lead to new insights on possibilities and obstructions.
Interaction Methods	Visual metaphors.	Facilitates in motivation, communication. Visualising progress and highlighting problematic areas. Providing an overview and a sense of common purpose.

3.2 Different Genres of Visualizations

Eppler and Platts suggest that visualization within a strategic planning platform serves different purposes and can therefore be divided into distinct genres [4]. Table 3.1 is a compilation of Eppler and Platts' four genres, with the example of visualization techniques from the same source.

3.3 Cognition

According to Ware, the data visualization process has four stages:

- Collection and storage of data.
- Preprocessing stage, where the data is transformed into something more comprehensible.
- Making a visual representation of the data, usually on the user's computer.
- Perception of the data. [8, p.4]

The perception of the data is what takes place in the user's mind. As a human

brain has a limited amount of *bandwidth*, it is crucial to present the data to the user in a manner that reduces the cognitive load for the user. The term bandwidth is a parable to a network and represents how much data can be interpreted in a set time. As noted by Eppler and Platts, one of the aspects to consider for visualization in a strategic planning platform is information overload [4]. Visual search is one of the components in cognitive load, and the cognitive cost of visual search can be reduced by making the visualization as compact as possible [8, p.141].

Visual processing can be divided into channels that do not interfere in the perception. These channels are: *orientation and size* versus *colour* versus *movement and static* [8, p.145].

Another way to reduce the cognitive load is stated in Nielsen's sixth heuristic *recognition rather than recall*. The heuristic is concerned with making available options visible and labelling or using intuitive icons. In short, the user should not have to remember where to find the right functionality, but rather be guided by the interface to find them [29].

3.4 Colour and Perception

Ware notes that seeing colour has been crucial for human survival, for instance for distinguishing red berries among green leaves [8, p.95]. According to Ware, colours can have mixed interpretation, such as turquoise being interpreted as either a blue or green shade. The colours red, green, yellow and blue are the most recognised cross-culturally [8, p.109]. This implies that these colours are especially useful while coding data.

However, Ware argues that the use of colours for coding information may be excluding for users with colour deficiency, who make up around 10% of the male population and around 1% of the female population. The most common colour deficiencies are protanopia and deuteranopia, which both render problems with distinguishing between colours that vary over the red-green spectra. Most people can however distinguish colour on the yellow-blue spectra. [8, pp.98,124]

When colours have similar lightness or luminance, it is hard for the human eye to make out details [8, p.111]. Colours can have different levels of saturation, where low-saturation colours are harder to distinguish between [8, p.134].

3.5 Visualization Design Principles

Visualizations have been around for a long time and a lot of different visualizations have been developed. Here we will list some well-tested design principles that have been presented in literature such as: Plaisants study on visualization evaluation: *The challenge of information visualization evaluation* [30], Wares book on information visualization: *Information Visualization Perception for Design* [8], and Eppler and Platts study on visualizations in strategic planning: *Visual strategising: the systematic use of visualization in the strategic-planning process* [4].

3.5.1 General

The principles listed here apply to visualization in general, primarily how to make a visualization that reduces the cognitive load of the user.

- Complex visualizations with a lot of data can reduce the cognitive load by allowing the user to *filter, zoom-in/zoom-out, group* and *hide* data and information [4].
- Complexity can be reduced through collapsible elements and labelling [4].
- *"Overview first, details on demand"* [8, p.345].
- Specific visualizations are good for specific data and specific tasks, the user should therefore be able to choose among visualizations or the visualization should be adapted to the information. [4].
- To reduce the cost of visual search, the visualization should be as compact as possible while still allowing for clarity [8, p.141].

3.5.2 Contrast

- Important data should be more visually distinct than other data [8].
- Highlighting can be done by adjusting the luminance of unimportant objects, or by adjusting the contrast to the background of important objects [8, pp.78-79].
- Use low-luminance contrast between an object and the background to highlight grey-level gradiations [8, pp. 89-90].
- Different colour, contrast, shape, movement and borders can be used to highlight an object [8, p.154].
- To effectively distinct two objects apart, use both different colours and shape [8, p.159].

3.5.3 Colour

- Do not use grey scale to visualise more than four numerical values [8, p.75].
- Higher saturated colours should be used in small areas, such as symbols and lines [8, p.108].
- Lower saturated colours should be used in large areas [8, p.108].
- Define shapes with borders when the object and background are equiluminous [8, p.113].
- Relative (perceived) colour is more important that absolute colour [8, p.115].
- Consider the luminance and contrast between object colour and background colour [8, p.123].
- Backgrounds should be low-saturation and high-value (such as pastel) and high-saturation for objects and symbols [8, p.125].

3.5.4 Accessibility

- Text-based alternatives may be needed for users with visual impairment [30].
- Alternative colour palettes or tools that enable customisation of colours can be useful for people with colour deficiency [30].

3.6 Animations and Transitions in Visualization

Heer and Robertson suggest a list of considerations to keep in mind while designing animations for visualizations in their paper: *Animated transitions in statistical data graphics* [3]. A compilation of this list follows below.

- Avoid misinterpretation of the data by carefully considering the relation between the data marks and the axis during the transition.
- Consistency in the animations can increase the learnability and comprehension. For example, applying a filter should always be accompanied by the same type of animation, such as fade-in/fade-out.
- A data point that represents specific data should not be reused to represent different data during the transformation.
- Animations should be unambiguous and distinct from other transformations with a different meaning.
- Items can be grouped by undergoing the same type of animation.
- Minimise occlusion by avoiding elements overlapping each other since this can make the user lose focus.
- Using acceleration in the animation emphasises the start and end state of the data points.
- Simple and direct animation reduces cognitive load.
- Complex transitions can be simplified by dividing the animation into smaller steps and sub-transitions.
- Too long transition times can increase task times, too short can be confusing. Testing is needed to achieve the appropriate animation times.
- Animations are only appropriate when the start point and endpoint share a data dimension.
- Avoid many simultaneous animations to reduce cognitive load. [3]

4
Methodology

This chapter will discuss methods that are relevant to the project. How these methods were planned to be incorporated in the project can be found in chapter 5. How the methods were carried out can be found in chapter 6.

4.1 The Design Process

A design process generally consists of understanding the users, defining the problem to solve, developing ideas, prototyping, and evaluating the concepts. *The Double Diamond* is a model of the design process where these steps are referred to as: *discover, define, develop* and *deliver* [1]. The process is iterative and while there is a main path for the process, the designers can move between the four stages wherever needed and relevant for the project. The name double diamond is based on the visual representation of how the scope and focus widens and narrows during the stages of the project, illustrated in figure 4.1. The Double Diamond relies on four principles, taken from Design Council's website and listed below.

- "**Put people first.** Start with an understanding of the people using a service, their needs, strengths and aspirations."
- "**Communicate visually and inclusively.** Help people gain a shared understanding of the problem and ideas."
- "**Collaborate and co-create.** Work together and get inspired by what others are doing."
- "**Iterate, iterate, iterate.** Do this to spot errors early, avoid risk and build confidence in your ideas."

4.2 User Research

User research is concerned with getting to know the user and the context of use of an artefact. The process is focused on generating data of the users, analysing the data, and translating the data into something more comprehensive.

4.2.1 Interviews

According to Wadsworth, a semi-structured *interview* can provide more useful insights than a fully structured interview with only predefined questions. However, the openness of the interview may result in qualitative data which is harder and more time consuming to analyse than a more structured interview. [31, p.190]

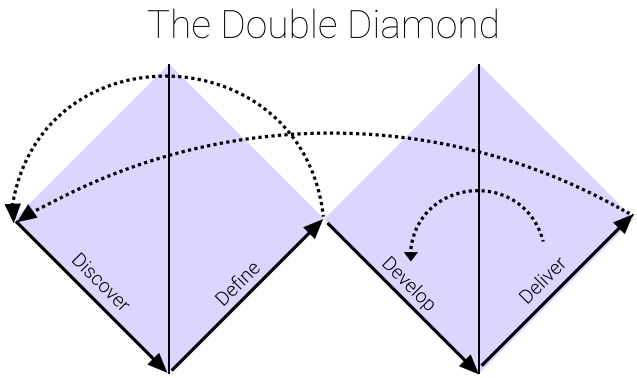

Figure 4.1: Illustration of the double diamond design process. Based on Design Council's illustration [1]. The full arrows represent the regular path through the process. The dotted arrows represent possible paths to take where needed.

While conducting interviews, it is important to be aware of biases, both from the interviewers and the participants. Wadsworth states that there is no such thing as neutral, but being aware of the biases can help both while collecting data and while analysing data. [31, p.67]
Furthermore, while phrasing questions, the interviewers need to be careful not to ask leading questions and all predefined questions have to be well thought through so that the participants can understand them, and that the answers can provide relevant information. It is also important that the interviewers themselves understand their questions well enough so that they can rephrase them to fit the participant if needed. To make sure that the questions are relevant and appropriate, Wadsworth suggests conducting a pilot study to try out and validate the questions. She also states that a pilot study that goes well results in more rather than fewer changes. Having well tested and standardised questions makes it easier to get the information that you are looking for and it also makes the analysis process easier and quicker. [31, p.69]
Wadsworth stresses how important it is to be a good listener during an interview. This can be done by giving the participant cues that you are listening and by not appearing judgemental. Furthermore, Wadsworth explains the importance of letting the participant *"take time"* with their answers or designing the interview so that it is possible to go back to earlier questions in case the participant wants to change their answer. This can be done by going over the questions again at the end of the interview. [31, p.71]
During the interviews, notes need to be taken even if the interview is recorded, as going through recordings is a time-consuming task. However, recordings can aid in clarifying if any notes are unclear. Wadsworth suggests that directly quoting and using the participant's exact terminology can provide more information rather than trying to summarise or memorise the essence of a reply. Notes should be made of as

much as possible of what the participant is saying. This means that the interviewers risk ending up with a lot of generated data, which may make the analysis process more tedious. After every interview, it is important to read through the notes to make sure that nothing is left out and that the notes make sense. Doing this read-through immediately after is recommended to make sure that nothing is forgotten. [31, pp.72-75]
Wadsworth also cautions about the heavy work intensity of conducting interviews. If you have interviews of about an hour each, she suggests conducting at most three or four interviews in a day. [31, p.75]

4.2.2 Questionnaires

While designing a *questionnaire*, a large effort has to be put into phrasing the questions as thoroughly as possible. Since the participants can not ask the researcher to clarify, it is important to make sure that the language used can be understood by the participants. Furthermore, it is crucial to ask the correct questions to make sure that the participants' responses are relevant to the study. It is also beneficial to allow the participants to add extra information to closed questions so that the participant does not feel that their responses can be misinterpreted. Due to the lack of communication in a questionnaire, it is critical that the phrasing and the content of the questions are validated. This means that the questions should be easy to understand, can not be misinterpreted, and are relevant. [31, pp.81-82]
Furthermore, Wadsworth notes that when sending out a questionnaire, it is impossible to know under what circumstances the participant will fill it out. For instance, a participant might be under the influence of stress, distraction, or fatigue. These circumstances might influence the responses that the participants are providing. Another pitfall of questionnaires using closed questions is that the study might provide information that does not help, such as providing information that a problem exists, but not providing any information of what the problem is. [31, pp.81-82]
Known drawbacks of using questionnaires are that the users' responses may be biased by their knowledge, lack of knowledge and norms. Some advantages of using a questionnaire include: they can easily access a large number of users, they can be made completely anonymous which in turn can provide more truthful responses, and they are easy to analyse. [32, Ch.8]
According to Wadsworth, to construct a good questionnaire you need to:

- Reduce the cognitive load of the participants by limiting the amount and complexity of the questions.
- Construct questions that can not be misinterpreted.
- Have done enough research to know what are relevant questions.
- Make sure that the participants will be able to understand the questions.
- Allow the participants to be anonymous.
- Inform the participants of the use of their responses and why their responses are valuable.
- Make sure that the users know what they are consenting to.
- Phrase questions in a way that makes the participants think deeper and reflect.
- Make the users feel safe with their responses. [31, pp.80-90]

4.2.3 Observations

Observations can be conducted to get a deeper and more detailed understanding of how users interact with a product. According to Wadsworth, an observation can also support the researcher in understanding the context of use and in understanding why a user interacts in a certain way. [31, p.99]

Wadsworth points out the influence an observer can impose on people and distinguishes between active and passive observing. As an active observer, the researcher can ask questions to the participant, such as *why do you do this task in this way?* As a passive observer, the researcher tries to distance themselves from the participant to minimise their influence on the observed. However, Wadsworth points out that the observer can not merely observe, but is always a part of the social situation. Awareness about this matter is critical when analysing the generated data. [31, p.99]

4.2.4 Extracting the Data

After the data has been gathered, it needs to be analysed and transformed into a comprehensive format. Methods suitable for this analysis and transformation will follow below.

Thematic Content Analysis

Thematic content analysis is a method that is well suited for analysing qualitative data. Vaismoradi et al. describe the method as being concerned with establishing themes based on the data generated [2]. Firstly, the data is coded, which means that the essence of a reply is summarised into something easier for the researcher to comprehend. The codes are an abstraction of the data. During the coding stage, the interview transcripts are read carefully and data is reduced to focus on the parts relevant for the research. Furthermore, the codes used to summarise the data can be divided into categories, which in turn facilitate the researcher in managing the data. According to Vaismoradi et al., the main focus when coding the raw data is to reduce it to more manageable sections. The second stage in the analysis is to construct the themes, which is done by *comparing, labelling, classifying, translating* and *defining* the codes. This process is done by grouping the codes that are similar or related. The size of the groups reflects how frequent the topic has been mentioned in the data. Each group is then labelled with a word or a sentence describing its content, this is where the themes start to emerge. Lastly, Vaismoradi et al. state that the themes have to be verified, this is done by *immersion and distancing, relating themes to established knowledge*, and *stabilising*. In this stage, Vaismoradi et al. point out the importance of the researchers to distance themselves from the data, this is done so that the researchers can take a more critical stance to the data and enable revealing of new patterns and insights that may not have emerged earlier in the process, I.e get a new perspective of the data. [2]

Personas

Personas are generally based on the data gathered during the user research and they can facilitate in understanding the users as well as facilitating the communication within the design team. The personas are based on patterns and themes in the data collected, they are not to be a replica of an existing user but rather a personification of the patterns within the user group. Furthermore, the personas can function as a reminder of the intended user and developed prototypes and scenarios can be evaluated using the personas as a reference. [33, pp.132-133]

Wants/Needs Analysis

To more easily prioritise what to focus on, the *Wants/Needs, (W/N), Analysis* can tangibly present user requirements. The Wants/Needs Analysis will be referred to as W/N Analysis in the text. The analysis results in a diagram where functions and features are laid out to showcase what the users think is most important while they do their tasks, as well as what additional features the users want. The diagram can be divided into four quadrants, where the top right quadrant consists of features to *pursue*, and the bottom left quadrant consist of features to *avoid*. [32, Ch.9]
Courage and Baxter suggest that the W/N Analysis can be used to set up basic user requirements and is well suited to be conducted at the beginning of a project. The method can also be used in the middle of a product life cycle to determine if, and what changes are needed. [32, Ch.9]
According to Courage and Baxter, people can not always distinguish between what they *really* want and what they *really* need. In addition, people asked may not always consider all variables when asked what they want and what they need. This means that questions asked to gather data for the analysis needs to be well defined and the users need to have some experience of the topic. [32, Ch.9]
Courage and Baxter state that if the user is asked to list features they want and need, it is likely that obvious core functionality may be underrepresented in the W/N, due to the user assuming these features to always exist. Courage and Baxter suggest using domain knowledge to find these features. Furthermore, they state that the W/N can not be considered as a full requirements research, but rather a start point. [32, Ch.9]
The W/N Analysis may support the design team in deciding what features to include and what to omit. Which in turn allow the designers to focus on what is most important for the user, rather than spending time on implementing features that no one asked for. Courage and Baxter suggest creating a top list of the features with the highest combined score of wants and needs, to lead the priorities during the design process. Furthermore, to increase focus on what the users find important, features with low scores, already implemented or impractical to implement can be eliminated from the list. [32, Ch.9]

User Journey Mapping

User Journey Mapping is a method that can visualise the steps and actions performed by the user when they are doing a specific task. The user journey map

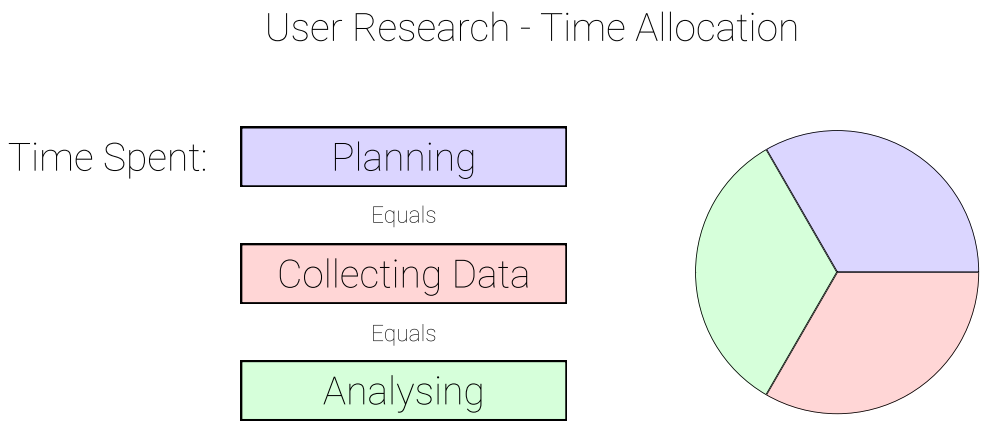

Figure 4.2: Illustration of planned time allocation during user research.

consists of a sequence of interactions that describes how the user interacts with and navigates through the product, it also describes how the user gets familiarised with the product and how the product affects their lives. The user journey map can be connected to a specific persona and function as an extension of the persona to provide an understanding of how the product is used in real life. [33, pp.196-197]

Golden Path

The Golden Path method is used to visualise the optimal way to navigate and interact with a product. The golden path can be based on the user journey map, but rather than showing the sequence of steps and interactions a user is doing, it showcases how it should be done instead to facilitate a more efficient usage. [34]

The Love Letter and the Breakup Letter

The Love Letter and the Breakup Letter is a method where a user is asked to imagine writing either a love letter or a breakup letter to a product as if it were a person. The method encourages the user to be emotional in the writing and can therefore be used to showcase how a product makes the user feel, rather than only focusing on the usability. [33, pp.114-115]

4.2.5 Considerations

Wadsworth lists some pitfalls that are important to avoid during user research [31]. The most common pitfalls while doing research are, according to Wadsworth, not planning it well enough and not giving it enough time.
To allocate enough time for each phase of the research, Wadsworth suggests that the planning of the research, the collection of the data, and the analysing, summarising and planning for how to use the data will all take approximately the same time, illustrated in figure 4.2.

Furthermore, Wadsworth stresses the importance of being aware of biases, both from the observer and the observed and suggests that being aware of the potential bias can help in avoiding misinterpreting the data. [31]

4.3 Design Methods

Design methods can be divided into methods for *ideating, prototyping* and *evaluating*. This section will go through different methods that fit into the different categories. The methods will be briefly explained and a list of methods mentioned is presented in table 4.1.

Table 4.1: Design methods for each part of the design process.

Ideating	**Prototyping**	**Evaluating**
How Might We	*Determine What to Prototype*	*Heuristic Evaluation*
Brainstorming	*Paper prototypes*	*UX Benchmarking*
Crazy 8's	*Paper-in-Device Mockup Prototype*	*Cognitive Walkthrough*
Get Visual	*Wireframing*	*SWOT analysis*
Gut-check	*Rapid Prototyping*	*Think Aloud*
Challenge Assumptions	*Storyboarding*	
Worst Possible Idea	*Wizard of Oz*	
Bundle Ideas		
Decision Matrix		

4.3.1 Ideation Methods

Ideation methods can focus on generating a large number of ideas, which we call *quantitative ideation methods*. This include methods such as: *brainstorming* and *worst possible idea*. Ideation methods can also focus on generating a smaller number of ideas that are more concrete and thought through, we consider these methods to be *qualitative ideation methods*. This includes methods that are closer to prototyping, such as *solution sketching*. Quantitative ideation is not only about coming up with plausible or even wanted solutions, but rather generating as many solutions as possible. Faste et al. suggest that it is easier to create a plausible concept from a wild idea than from a basic idea [35]. The Interaction Design Foundation suggests that encouraging wild ideas and discouraging judgment may lead to a sense of safe space for the designers. They also state that *"quantity breeds quality"*, to encourage quantitative ideation and wild ideas [36].
Hartson and Pyla suggest separating between *idea creation* and *critiquing*. They suggest that idea creation is all about creativity, innovation and new thinking. By allowing designers to ideate freely, more innovative concepts can be developed. Critiquing is about considering the constraints and feasibility of the design. Furthermore, they suggest that mixing the two modes of thinking can inhibit innovation,

especially if criticism occurs during the idea generation. However, critiquing is an essential skill for designers when it comes to deciding which idea to pursue and to review ideas. [6, Ch.7.6]
This section will present methods that can be used for ideation.

How Might We

How might we is a method that can aid in breaking down a problem and therefore work as a tool to facilitate further ideation. The method is concerned with rephrasing problems into concrete questions. One problem can often be broken down into several questions, which might aid in ideation. The phrasing of the questions should allow for a variety of solutions, which means that questions that are phrased too strictly need to be rephrased. *How Might We* is preferably followed by a *brainstorming* session, where answers to the questions and solutions to the problem are generated. [37]

Brainstorming

Brainstorming is an ideation method that mainly focuses on generating a large number of ideas. Sharp et al. stress the importance of creating a safe space around the brainstorming session, which means that no ideas should be criticised or debated, and even silly and wild ideas should be encouraged. Furthermore, the brainstorming needs to be focused on the problem to be solved, which means that the team has to have a clear picture of what they are trying to do. Sharp et al. also suggest that including users and people from a variety of disciplines may be beneficial in brainstorming. Furthermore, Sharp et al. stress that all ideas should be recorded and visual representations should be encouraged. [38, p.385]

Crazy 8's

Crazy 8's is an ideation method where the designers are tasked with creating eight separate sketches or ideas during a predefined amount of time, usually eight minutes. This ideation method focuses on wild idea generation and the focus is on generating a wide variety of solutions to the problem. By setting a time limit, the design team is forced to not invest emotionally in their ideas and move along with new ideas to be able to achieve more quantity rather than quality. The method can be applied individually, as well as a workshop exercise. [39, p.50]

Solution Sketch

The *Solution Sketch* is an ideation method that focuses on making abstract ideas more concrete. The sketches created during the method should reflect different states of the concepts being ideated upon. The solution sketch is a more concrete and detailed version of a regular sketch. [40]

Get Visual

Get visual is a general design approach, rather than a stand-alone design method. The focus of this approach is to encourage the designers to sketch their ideas, or otherwise give their ideas a visual representation instead of only using words to describe them. The idea is that visual representations are more tangible than words and may aid in communication. [41]

Gut-Check

To facilitate in selecting an idea to move forward with, *Gut-check* is a method that focuses on finding the essence of each idea and thereby making comparisons easier. Each idea should be compared to the constraints of the design task as well as other constraints. This is also a chance for the designers to conduct further ideation on the concepts to adapt them to the constraints and thereby create doable ideas. This method is concerned with letting go of unfeasible ideas and reducing the number of ideas to a manageable collection. [42]

Challenge Assumptions

Challenge assumptions is a method that encourages the designers to think in a new way. The focus is to question the status quo and thereby enable new ways of thinking. Dam and Siang at Interaction Design Foundation take as an example the assumption that cars need a human driver and challenge that assumption by asking if that is necessary. The method can be used if ideation gets stuck or to questions what features are crucial for the design and what is merely aspects that we take for granted because we have become accustomed to them. [43]
This method encourages asking *stupid questions*, taking nothing for granted and challenging all assumptions. Assumptions to be challenged include: whether something is impossible, what people need and think, and why something works and others do not. The aim is to gain a new broadened perspective. [43]

Worst Possible Idea

Worst Possible Idea is an ideation method that is closely related to the *Challenge Assumptions* method. The method focuses on coming up with the wildest and craziest idea to solve a problem. The aim of doing this is to relax the design team, create a safe space, and challenge assumptions. By encouraging the designers to come up with the worst ideas, no one can be judged for having a bad idea. The same mentality is beneficial in a brainstorming session, where the *Worst Possible Idea* may function as a warm-up exercise. The ideation method may also provide new insights and promote a new way of thinking and problem solving. [44]

Bundle Ideas

Bundle Ideas is a method for selecting which ideas from the ideation to pursue. The idea is to combine the best parts from several of the ideas from the ideation to more complex concepts. The process starts with grouping similar ideas and discussing

their advantages. Then by identifying themes and patterns, the groups can be expanded and translated to more full-on solutions. [45]

Decision Matrix

Decision Matrix is a method for selecting which idea to pursue. The ideas and concept can be evaluated on two criteria and then visually laid out in a matrix. The method is usually done to compare implementation cost to user value, where the y-axis would be the implementation cost and the x-axis would represent the user value. Visualising like this allow for removing ideas with a high implementation cost and low user value. The criteria on the axes can be changed to other criteria that are relevant for the project. [46]

4.3.2 Prototyping Methods

After ideating solutions and approaches, the idea needs to become more tangible and refined. The process of turning an idea into a tangible concept is called prototyping. Hartson and Pyla suggest that prototyping is the ideal chance to catch flaws in the design concept. Furthermore, they suggest starting to prototype as soon as possible with quick and easy prototypes to find out what to pursue and what needs further work. Hartson and Pyla state that prototyping is a way to save both time and money while developing a product. Their argument for prototyping the design is that *"The sooner you fail and understand why, the sooner you can succeed"*. [6, Ch.11]

Prototypes can aim to convey the features or functionality of a design. Prototyping that focuses on the features is called horizontal prototyping. Prototyping that focuses on functionality is called vertical prototyping. The two distinct prototyping approaches can be combined to form a T-prototype, which incorporates select features and functionality of a concept. [6, Ch.11]

The fidelity of a prototype can also range from low fidelity, such as quick sketches on paper, to high fidelity, such as programmed interfaces. Lower fidelity prototypes are relatively easy and cheap to implement, but lose out on realism. The high fidelity prototypes are usually quite realistic, but time-consuming and expensive to implement. Low fidelity prototypes are preferably used early in the design process and the fidelity increases as the project progresses. [6, Ch.11.5]

Determine What to Prototype

Determine What to Prototype is an activity for choosing which ideas are worth pursuing in the prototyping stage. Before performing this method it is recommended to have a *User Journey Map*, which is described in section 4.2.4. The design concepts can be mapped to the user journey map, to see which of them are used in different parts of the journey. This will help you to decide which concepts are in most need of prototyping. [47]

Paper Prototyping

When prototyping, it is essential to not spend time and resources on an idea that will turn out to be unfeasible. A method that focuses on creating inexpensive and quick prototypes is *Paper prototyping*. This method is concerned with creating prototypes out of paper. The prototype can be simple sketches but also prototypes with moving parts. The focus while paper prototyping is to enable visual and/or tangible representations of an idea, which can be evaluated to verify whether the idea is worth pursuing or not. Hartson and Pyla argue that digital low fidelity prototypes can not replace paper prototypes, since pen and paper allow the designer to focus on the design rather than the tool. [6, Ch.11.6.4]

Paper-in-Device Mockup Prototype

The *Paper-in-Device Mockup Prototype* is an extension of the paper prototype. This method is commonly used for mobile applications. The approach is to create *Paper prototypes* of the interface, scan the images and put them on the mobile. The method allows the users to feel the interface in the form factor that it is designed for. [6, Ch.11.4.4]

Wireframing

When it comes to prototyping the layout of an interface, *Wireframing* is a suitable method. The wireframes can range in fidelity from low to high, which means that a low-fidelity prototype can be developed to evaluate a concept and based on that, higher fidelity wireframes can be developed. The wireframes mainly consist of outlines and shapes to illustrate the layout and positions of items on a screen. The lowest fidelity wireframes consist mainly of rectangles with labels to depict the overall layout and position. Higher fidelity wireframes may incorporate look and feel as well as interactions and navigation. However, wireframes most commonly take the shape of a mid-fidelity prototype, with the look and feel where needed, but not as elaborate as the finished design might have. [6, Ch.9.5]

Hartson and Pyla argue that wireframes can facilitate in communicating design alternatives within the design team, as well as to stakeholders. The wireframes can also be used to showcase a scenario and the flow of interactions. Furthermore, a wireframe can be used as a design specification for implementation. [6, Ch.9.5.2]

Hartson and Pyla suggest considering modularity while wireframing and to avoid hardcoded concepts and details, this is to enable quick and easy changes to the wireframes during the process. Furthermore, they suggest using available template and widget libraries to speed up the wireframing process and to add consistency to the wireframes. Furthermore, Hartson and Pyla state that wireframes that look more like sketches, rather than a finished design, may be beneficial while user testing. This is due to the more sketch-like look is more inviting for suggestions and constructive criticism due to it appearing as a work in progress, rather than as a finished design. [6, Ch.9.5.4]

Rapid Prototyping

Rapid Prototyping is an iterative method where the fidelity gradually increases in each iteration. The strength of this method is that it allows for the early detection of problematic areas in the prototype. The method is built up by several parts, where the first is *Determine What to Prototype*, which is described in section 4.3.2. This first part is followed by phases where you build simple prototypes, test them and then integrate the feedback and iterate back upon the prototypes. Repeating this process will enhance the quality of the prototypes, while simultaneously making design decisions. [48]

Storyboarding

A *storyboard* focuses on the narrative of the usage of a product. The storyboard consists of a series of frames that illustrates the use of a product, the illustration can consist of scenarios, actors, screens, dialogue and interactions. In storyboards, it is common to illustrate the product as a *black box*, meaning that the aesthetics of the product is left out, and the focus should rather be on the context of use and what problems the product can solve [6, Ch.8.4]. Hartson and Pyla suggest that storyboards can be used to showcase the user experience and the emotions that the designers want to evoke. [6, Ch.8.4]

Wizard of Oz

Wizard of Oz is a prototyping method that is well suited when the user responses and interactions are unpredictable. The method consists of a user interacting with a system, while someone from the design team controls the output. The user is not aware that the output is generated by another human. The *Wizard of Oz* method is commonly used early in the design process before more comprehensive prototypes are developed. The method can also be used where a more extensive prototype would be expensive to implement, such as with AI. [6, Ch.11.4.3]

4.3.3 Evaluation Methods

Evaluating the prototypes can be done in several different ways, some methods include users and others do not. Evaluation methods that do not include users are referred to as *Expert Evaluation* with methods such as *Heuristic Evaluation* and *Cognitive Walkthrough*. Furthermore, evaluation methods can be divided into *analytical* and *empirical methods*. Empirical methods are concerned with real users and their performance. Analytical methods are concerned with the attributes of the design, such as design principles. [6, Ch.12]

Heuristic Evaluation

Heuristic Evaluation is an easy and cheap expert evaluation method that designers can use to find usability problems in their design. The method does not require any users to participate. However, it does not replace regular usability testing with real

users. In this method, the designers themselves can go through their design and assess how well the design is doing based on a list of criteria. [33, pp.98-99]
The list of heuristics can be standardised, such as Nielsen's 10 usability heuristics, or an adapted list of heuristics can be used. Nielsen notes that it may be beneficial to limit the number of criteria used during the evaluation. [49]
The number of evaluators involved in the process is often a matter of how many you can get, depending on the budget of time and money. At the beginning of the development process, only one or two evaluators should be enough to find most of the problems [50]. Nielsen suggests that between three to five evaluators are enough and notes that extra evaluators above five usually do not find considerably more errors and therefore the extra evaluators should focus on other types of evaluation instead [49]. According to Nielsen, it is probably a good idea that the evaluators work independently of one another and then compare their results for each heuristic. Furthermore, Nielsen states that the individual scores for each criterion may be more valuable than calculating an average for all [49].

UX Benchmarking

The *UX Benchmarking* method consists of *standardised* tests, metrics, and criteria and function as a way of comparing design alternatives. The criteria are standardised in the sense that the same criteria are used while comparing. However, the criteria are not standardised such that the same criteria are used for all designs, but rather can be chosen depending on the design and the target goal for the design [6, Ch.10.6]. The UX benchmarks are measured by observing a user while they interact with the design. Hartson and Pyla argue that the criteria should reflect the target users and their way of interaction. Furthermore, the criteria should be based on what weaknesses the design could suffer from to facilitate in discovering and amending these. Hartson and Pyla suggest that a minority of available interactions in a design account for a majority of actual usage. Therefore, since the criteria can not cover everything, the criteria should focus on the most common usages [6, Ch.10.6]. *UX Benchmarking* focuses on the users' experience, common metrics include: success/fail rate, time to conduct a task, cognitive load, amount of navigation, and errors made by the user [6, Ch.10.7].

Cognitive Walkthrough

Cognitive Walkthrough is an expert evaluation method that focuses on what steps needs to be taken, how many, and in what order, to achieve a predefined task. The method can be used to establish how easy a design is to use and to calculate the sequence of steps it takes to achieve the task [33, pp.32-33]. The method consists of:

1. Identify the persona to evaluate.
2. Defining tasks to be completed within the system.
3. Assign the traits of the persona to the design team member who does the walkthrough.
4. The assigned team member tries to achieve the task while explaining how they are thinking. [33, pp.32-33]

During the evaluation, the evaluator should not get any guidance from the design team, but rather be encouraged to explain why they got stuck and to explain how they think they can get on the right path. Furthermore, during the process, the observing team members should assess what goes smoothly and easily and what does not [51].

SWOT Analysis

SWOT analysis is a quadrant mapping technique where a rectangle is divided into four distinct quadrants. The quadrants represents *Strengths, Weakness, Opportunities* and *Threats*. The Strengths and Weakness quadrants are concerned with attributes of internal origin, whereas Opportunities and Threats deal with attributes of external origin. The SWOT analysis consists of writing down features of the analysis object and adding them to the appropriate quadrants. A strength of the SWOT Analysis is that it allows for a more visual interpretation of data. [52, p.192]

Think Aloud

Think Aloud is a qualitative evaluation method, usually conducted in a controlled setting, where a user is encouraged to perform a task and tell the researchers what they are thinking while doing so [38, pp.277-278].
The think aloud method allows the researchers or designers to get direct insights into the users' cognitive process while they are solving a problem or conducting a task. Jaspers et al. suggest that it is beneficial to conduct the think aloud method early in the design process so that the prototypes created can be adapted to the users' mental model and thought process. [53]

5
Planning

The design process started with research about Stratsys software as well as alternative software to get an understanding of how this kind of strategic planning platform works. Also, literature studies were conducted to see if there are any new findings in the field of visualization that could be relevant for Stratsys' platform.
As a general approach, we aimed to used triangulation [33, p.188], to not rely on one method, but combine several methods to make up for the weaknesses in each of them.
The design process was planned to be iterative and inspired by the double diamond process as described in chapter 4. An image of the adapted process can be seen in figure 5.1. The project was structured with a user research phase, followed by three iterations. We aimed towards having at least one prototype to evaluate in each iteration.

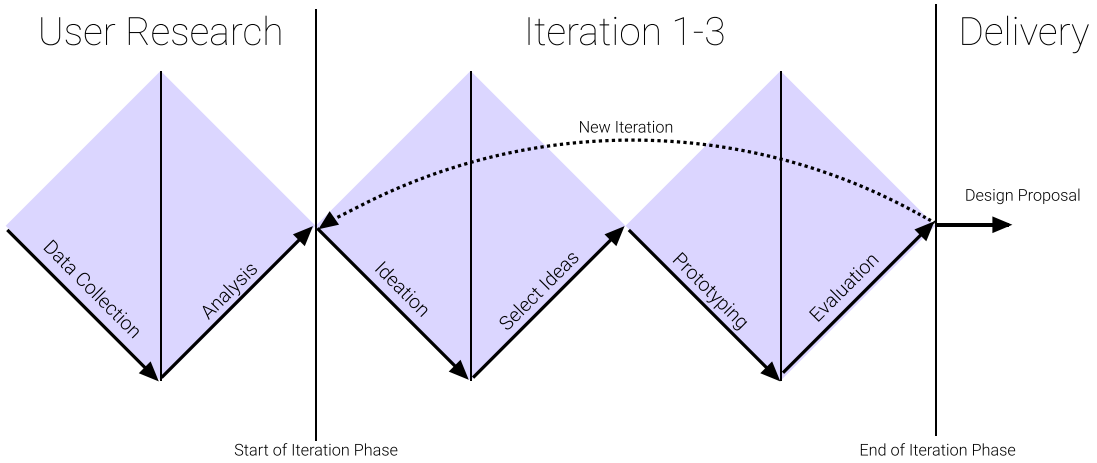

Figure 5.1: Visualization of the planned design process.

5.1 User Research

This project had a large focus on the users with the user research as a central part that would be the foundation of the entire project. Figure 5.2 illustrates the methods that were intended to be used in this stage. The user research includes methods such as interviews, questionnaires, observation, personas, wants/needs analysis, user

journey mapping, the golden path and love letter/breakup letter. The methods are explained in chapter 4.

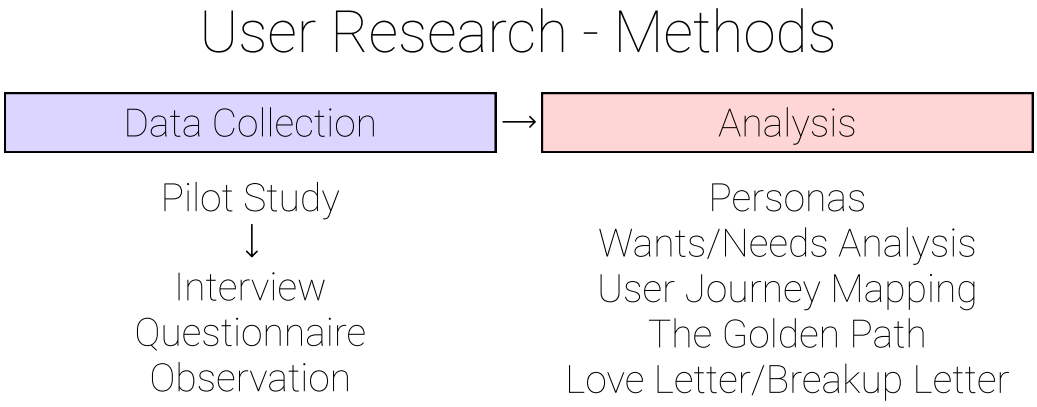

Figure 5.2: Illustration of methods to be used during the user research.

5.1.1 Interviews

The interviews were planned to be conducted as individual interviews through the online meeting tool Microsoft Teams[1]. The users participating was intended to be current users of Stratsys and they should be asked for consent in advance of the interview. The participants should also be asked for consent to record the interview. Recordings should be stored locally on the design team's computers and not be shared outside of the design team. As discussed in section 4.2.1, the interviews should be semi-structured with open-ended questions with predefined questions that could be followed up by appropriate and relevant questions to get a deeper understanding.
Furthermore, as mentioned in section 4.2.1, the work intensity might become overwhelming if too many interviews are held in a row or in a day, therefore we aimed to keep the interviews not too close in time to each other.

5.1.2 Questionnaire

The questionnaire was planned to be sent out to current users of Stratsys to learn more about what they think works well and what needs improving in the visualizations. The questionnaire should be based on themes that emerge during the interviews. As discussed in section 4.2.2, it should consist of both closed questions, such as semantic differentials, and open questions where the users have the possibility of expanding on their usage of Stratsys. Additionally, some questions should be included to aid in the wants/needs analysis. This analysis should provide a clearer

[1] `https://www.microsoft.com/en-us/microsoft-teams/group-chat-software`

image of which additional features the users require in the system, and also provide information of what the core functionality is and needs to be. The data from the questionnaire should be mostly quantitative.

The questionnaire should start by asking the user to give consent to participate, as well as informing the user of the use of their responses. Since a questionnaire does not require any face to face contact with the users, we found this method ideal to conduct during the pandemic, as mentioned in section 1.6.

5.1.3 Observations

Conducting observations of the users in the field would be have been preferred and could have provided valuable information about the use cases and everyday usage. This means going to the participants' environment, such as their workplace, to see how they do their everyday tasks, as noted in section 4.2.3. However, due to the restrictions mentioned in section 1.6, this was not a feasible choice. Instead, the decision fell on conducting an adapted observation technique during the interviews. This technique should provide knowledge of which tasks are conducted and which problems might arise while using the software. However, since we are not observing the user doing an actual work-related task, they would rather be explaining what they usually do, this technique may miss out on problems that may arise in the regular work. Another anticipated problem was that the results might be biased by the participant's memory and by the participant presenting their work rather than conducting their regular workflow. Being aware of the biases that may occur can assist while interpreting the data, as stated in section 4.2.3.

As a part of the online interviews, we planned to ask the participants to share their screen and show us how they are working within the software. Observations allow us to see how the user interacts with the software in a more reliable way rather than having the user explain how they are working. The observations were scheduled to be conducted through screen sharing in Microsoft Teams.

5.1.4 Considerations

As noted in section 4.2.5, the user studies had to be planned carefully to make sure that we are gathering the data that we are looking for. Furthermore, we had to allocate enough time for the user studies to make gathering a reliable amount of data feasible.

Since we planned to include open-ended questions in both our questionnaires and interviews, they should provide us with more detailed data. On the other hand, it carried a risk of providing data that would be more time consuming to analyse. This means that our planned process should include enough time for us to analyse the data and summarise it comprehensively. Furthermore, we should make sure that we use the data that we have gathered and that we based our design decisions on the data.

5.1.5 Expected Results from the User Research

Based on the data gathered from the user research and the analysis results, we should be able to compile a list of criteria that could guide the heuristic evaluations and benchmarking in later phases of the project.

5.2 Iteration 1

This iteration was planned to mainly focus on producing as many ideas as possible. Therefore, the methods chosen here focus on quantitative ideation, as well as quick and low-fidelity prototyping, see figure 5.3.

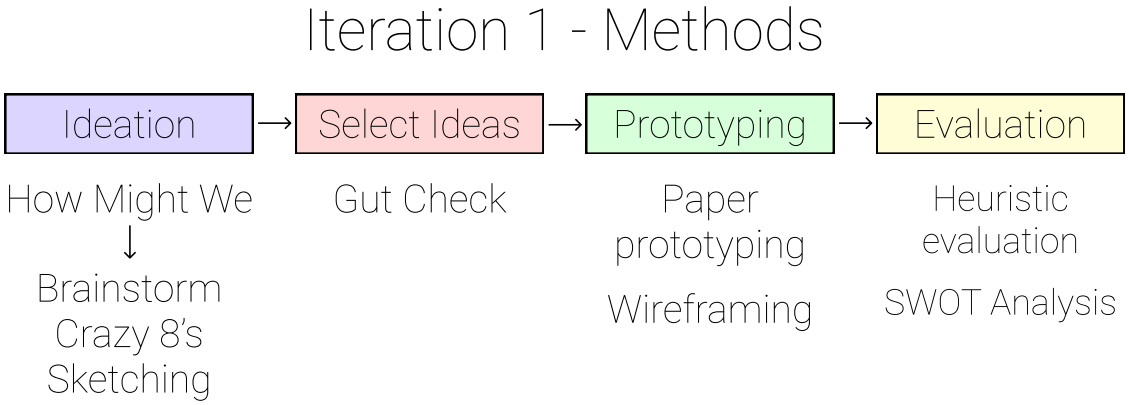

Figure 5.3: Illustration of planned methods in Iteration 1.

First out, we planned to conduct How Might We to aid in breaking down and defining the problem statement to facilitate future ideation methods. This would be followed by regular brainstorming, combined with the methods crazy 8's and sketching. These methods were chosen to facilitate in producing a large number of ideas. If needed, some of the methods could be used in parallel.
At the end of the ideation phase, we intended to conduct the method gut-check, to facilitate the process of narrowing down and picking out the best of the ideas that we have generated.
Based on the ideation, the generated ideas that were considered valuable should be prototyped. The aim was to prototype most of the ideas, therefore the prototypes should be quick and in low fidelity. The focus here was to concretise the ideas so that they could be evaluated. Prototyping methods intended to be used here include: Paper prototyping and low-fidelity wireframing. These methods were chosen since they produce prototypes quickly and therefore allow for producing a large number of prototypes.
The prototypes were intended to be evaluated using methods that comply with our limitations. The evaluation at this stage aimed to highlight the strengths and weaknesses of the generated ideas, to aid in moving forward in the next iteration.

Furthermore, the evaluations should facilitate the comparison between the ideas we generate and the platforms used for benchmarking. Evaluation methods in this stage include heuristic evaluation and SWOT analysis. After the evaluation, we should have more information to base the choice of which ideas to pursue in the next iteration.

5.3 Iteration 2

This iteration should focus on improving the concepts, ideas and designs developed in the previous iteration. Methods used in this iteration are illustrated in figure 5.4. The ideation phase should focus on more qualitative ideas based on the ideas generated in iteration 1. A qualitative ideation method that fits into this iteration is bundle ideas, which was described in section 4.3.1.
To facilitate in selecting ideas to prototype, the method decision matrix could showcase the different ideas' strengths and weaknesses based on predefined criteria.

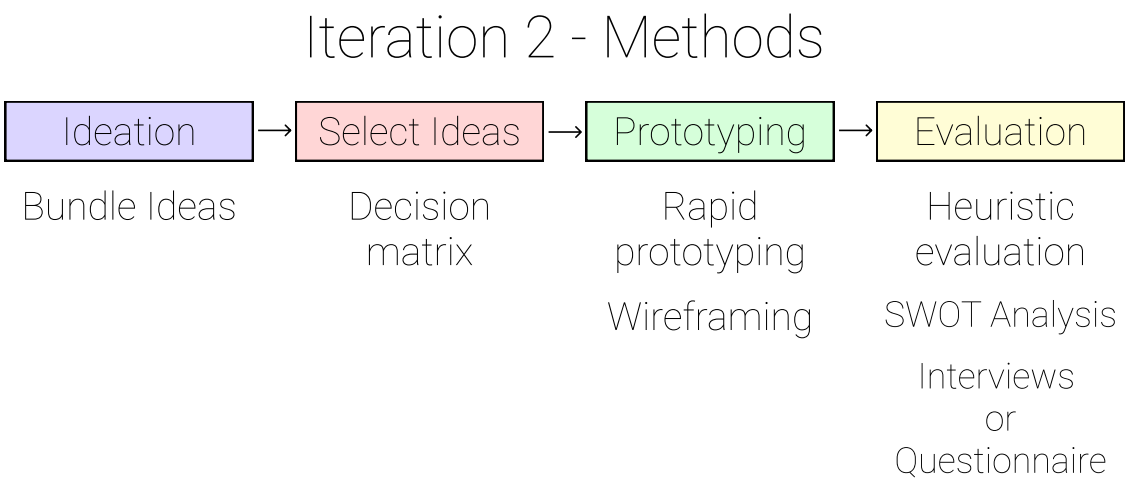

Figure 5.4: Illustration of planned methods in Iteration 2.

To prototype the selected idea, we planned to conduct the rapid prototyping method, which is built up of four parts, starting with determining what to prototype, as described in section 4.3.2. However, which ideas would be prototyped should already be determined from the decision matrix. Rapid prototyping is an iterative method where the fidelity gradually increases in each iteration. The strength of this method is that it allows for the early detection of problematic areas in the prototype. The rapid prototyping was planned to be done through wireframing.
This iteration aimed to improve on selected ideas from the previous iteration and the same evaluation methods as in Iteration 1 would be beneficial for comparison. However, the end-users should also be included at this stage. This was planned to be done through interviews or questionnaires, where we show users the prototypes to get their feedback on how they view the different solutions and whether they

understand what we are trying to visualise or not. Based on this feedback, we were hoping to know which of the ideas should be pursued in Iteration 3.

5.4 Iteration 3

At this stage, we should have one or possibly two visualization alternatives that have been successful in the previous iterations. This iteration was intended to focus on implementing a high fidelity prototype of these design alternatives, as well as improving them based on earlier evaluations. Methods included in the planning of this iteration are illustrated in figure 5.5. The design alternatives developed in this iteration should be evaluated extensively to confirm that they provide true value to the stakeholders. The ideation phase in this iteration should be limited to solving the problems that are brought up from Iteration 2. The choice of ideation methods was planned to be based on the type of problems that need to be solved. Hence, the methods for ideation and selecting ideas to pursue could not be planned.

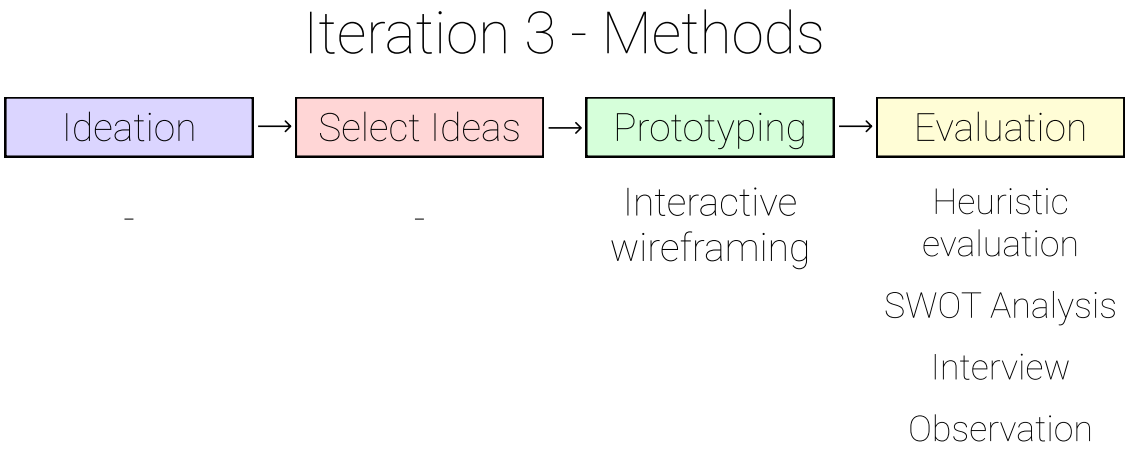

Figure 5.5: Illustration of planned methods in Iteration 3.

The prototype in this iteration should consist of interactive high fidelity wireframes with look and feel. This means that the prototype generated here should include aesthetics, such as colour schemes and fonts. Based on this higher fidelity prototype, we should be able to evaluate how the design affects the users emotionally, as well as the usability of the concept. The focus in this prototype should be on the user experience and usability. Therefore, the evaluation methods needed to include the users to a larger extent than previous iterations. The evaluation stage in this iteration should be based on methods such as observations and interviews. Furthermore, we should evaluate the prototype using the Heuristic Evaluation and SWOT Analysis to be able to compare it to previously developed prototypes.

5.5 Additional Methods

To facilitate in evaluation and allowing for comparison to existing design solutions, other visualization platforms should be benchmarked based on the same criteria (see section 4.3.3 on page 35) that were used during the heuristic evaluations.

Some methods that might be useful for this project can not be planned into the schedule but may be useful in cases when the process feels stuck. Such methods include: Challenge assumptions for ideation and storyboarding for prototyping, these methods are described in chapter 4. Additional methods not mentioned within this chapter might be used where we see fit during the project.

5.6 Ethical Concerns

During the project, we intended to conduct user studies and tests involving users, which could pose some ethical aspects that need to be cared for. Always when including users in the process, we need to consider the users' privacy and always be clear that the users are not obliged to participate. This means that the users need to give their consent before we can use their data. Furthermore, all participants will be kept anonymous and none of the data gathered should be possible to be linked to any individual. If we involve recordings, such as sound, images or videos, the participants need to consent to this in addition to the consent to participate. The participants would be informed on what types of data we were gathering and how this data was to be used.

We must consider accessibility throughout the entire design process and look into literature on the field. When it comes to information visualization, we need to be inclusive of people who have a colour deficiency and consider issues such as cognitive workload [8].

One important consideration is how the design guidelines might affect the users and the society around them.

- Will the design contribute to increased or decreased stress?
- Will it make people feel more controlled?
- Will some people be unable to use the software due to functionality variations, leading to increased discrimination in society?

These questions and more that arise during the project should be considered throughout the design process.

5.7 Time Plan

The time plan is presented in the Gantt schedule below, figure 5.6 and 5.7. The schedule was preliminary and open for change during the project. However, it was intended to function as a guide for the work.

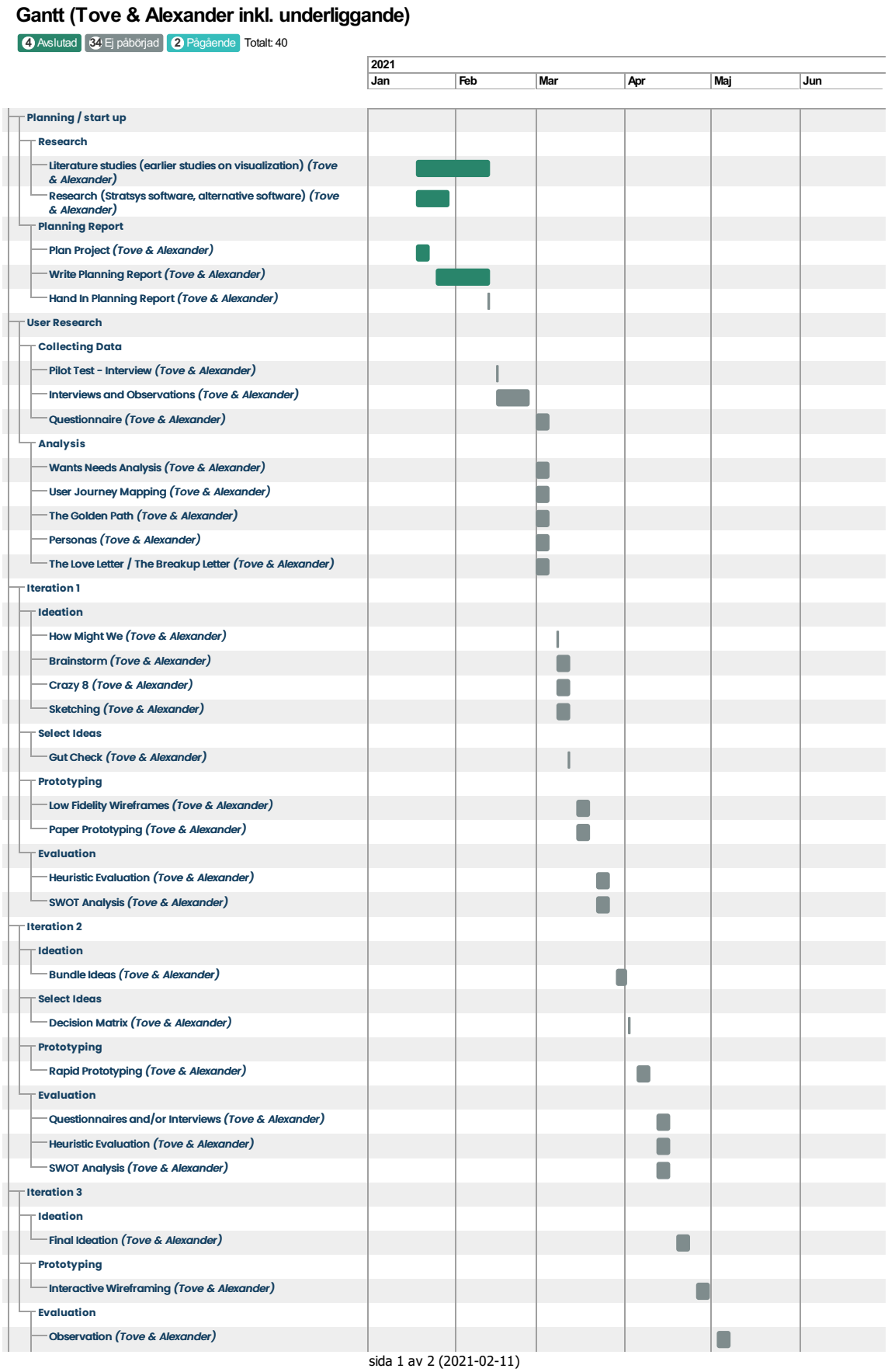

Figure 5.6: Rough schedule for the project. Continued in figure 5.7.

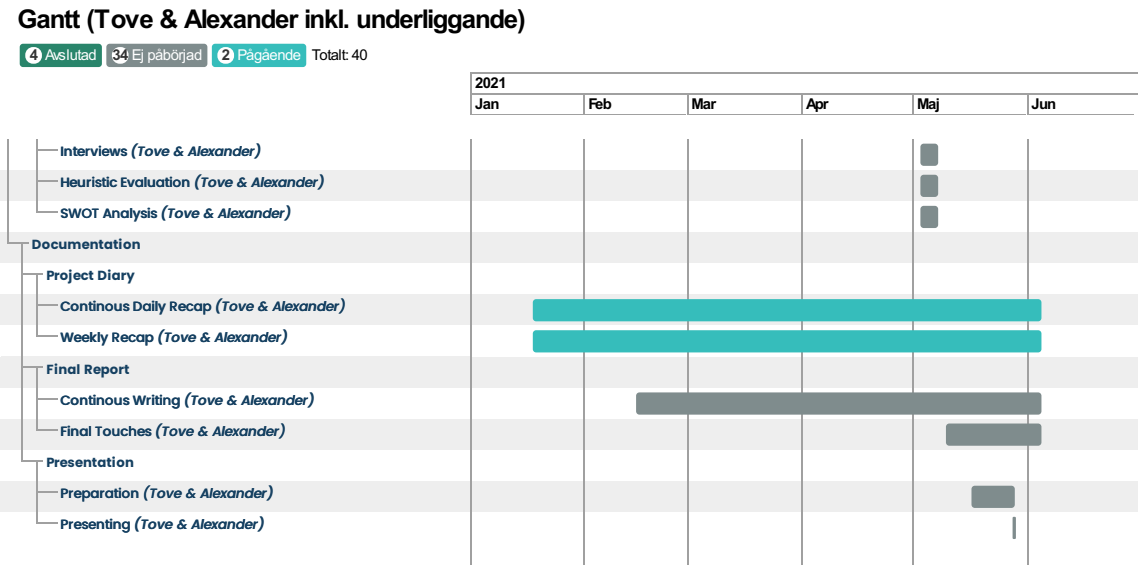

Figure 5.7: Continuation of the schedule in figure 5.6.

6
Execution and Process

The process of this project was iterative and started with a user research phase, followed by three iterations. The user research aimed to provide us with insights into the users' requirements and what they are commonly doing while working in Stratsys' platform. Iteration 1 focused on generating a large variety of visualization concepts. Iteration 2 attempted to narrow the selection of visualization concepts through user evaluation. Iteration 3 focused on generating more refined prototypes of the concepts considered to bring the most value to the users. The insights gathered through the user evaluation was used as the basis for the results of this project. This chapter will discuss the process of the project. The methods mentioned in this chapter are explained in chapter 4.

6.1 Participant Privacy Concerns

Since this project included participants and observations, a large concern had to be put into preserving the privacy of the participants, as well as the privacy of their employer. Throughout the project, these concerns were considered.

6.1.1 Privacy Concerns During Communication

In the cases where we contacted several users with the same proposal via email, we either sent the users one email each or used the blind carbon copy, bcc, function, so that the participants' addresses would not be revealed to others. The regular carbon copy, cc, function would reveal the recipients' email addresses, which was not desirable as this contact information could be used to identify the participants.

6.1.2 Privacy Concerns in Interviews and Observations

The interviews were carried out digitally through Microsoft Teams, as described in chapter 5. The documentation of the interviews was made and stored in Google Sheets. All of the data was anonymised, any names of persons and companies have been removed from the data to protect the participants. Where the participant has given consent, the interview was recorded and stored locally on the interviewer's computer. However, due to the implementation of the software used to record, the recording was automatically uploaded to a password protected cloud storage service. The recording was then downloaded to be stored locally and the copy in the cloud storage service was deleted.

6.1.3 Privacy Concerns in Questionnaires

Before the participants could respond to the questionnaire, they had to confirm that they had read and agreed to the terms of data storage and usage that we had set up. The users were informed that we would not store any personal data, such as name, address or employer. The participants were also informed that the raw data will be deleted once the project is finished. Since the questionnaire included some questions where the participants could write text freely, we asked them to not include any personal information in these fields. The participants were informed that if this would occur, we would manually edit their reply and remove all personal information that could be linked to a person. Each participant in the questionnaire received an anonymous link to the questionnaire, which meant that it was impossible to know which of the invited users had filled it out.

6.2 User Research

The first part of the process was concerned with getting to know the users. This was done through an extensive user research phase consisting of interviews, observations, questionnaires and analysis.
The users consulted during the research were Stratsys users who had been in contact with UX designer Carin Andersson-Sarning, our mentor at Stratsys. These users were people that Andersson-Sarning had been in contact with before concerning evaluations of Stratsys' platform, and who were interested in providing their ideas to further develop Stratsys' platform.

6.2.1 Interviews - User Research

In the first and second week of the user research phase, five semi-structured online interviews with Stratsys users were held. Each interview took approximately one hour to conduct and we limited the number of interviews in one day to a maximum of two to reduce the work intensity, as discussed in section 4.2.1. Limiting the number of consecutive interviews allowed us to go through the interview transcript and transfer the replies to a Google Sheets document that facilitated the analysis. Furthermore, each interview was discussed between the interviewers to conclude that the transcripts were comprehensible.
To prepare for the interviews, a set of questions was formulated, using a compilation of questions provided by Stratsys as a basis, and adapted to suit our research. The interview questions can be found in appendix A. The questions consisted of questions related to the participant's work life and which tasks the participant usually carry out at work, as well as questions related to how the participant uses Stratsys in their work and what they think about the system, what works well and what does not.
As a visual aid for us and the participants during the interviews, presentation slides were used. The presentation started with information about the interview, information on how the data gathered was to be used, followed by one slide for each of the interview questions.
At the end of each interview, the participant was shown images of the available

views in Stratsys, accompanied with questions such as: *have you used this view?* and *what do you find this view useful for?*

Pilot Interview - User Research

Before the interviews were conducted, a pilot interview was carried out. The pilot interviewee was a consultant working for Stratsys, whom we asked to reply to the questions as if he were a regular user. At the end of the pilot interview, we asked the participant how it felt and if anything was unclear in the questions. Insights from the pilot include:

- Having more than one question on the same slide may make the user reply to each question at the same time, which makes asking follow-up questions and taking notes difficult.
- Technical issues may occur and having a backup plan to circumvent these is necessary.
- Formalities, such as usage of private information and responses may be easier to remember to include if they are written in the presentation slides.
- Using presentation slides on the same computer as the conference call is on may obscure the video from the participant so that the interviewer can no longer see the participant during the interview.

The pilot interview resulted in changes to the presentation slides to solve the mentioned issues. Another result was more preparation for technical difficulties and note-taking, as well as minor changes in the phrasing of the questions.

Observations in Interviews - User Research

The adapted observation technique described in section 5.1.3 was conducted as a part of the user interviews. The participants were asked to share their screen to show us which views they are normally using in Stratsys. The participants were also asked to show and describe how they normally use the software in their daily work. During the screen sharing, the participants were encouraged to present their work freely. However, the participants were guided where needed to provide information especially relevant to the project. Questions asked during the observations include: *how often do you perform this task?* and *what works well and what does not work well when you are performing this task?*
The adapted observations gave some basic insights into the regular tasks that the users perform in Stratsys, and what type of information is important for them. It also revealed which views are commonly used for different tasks and some of the problems with the views. The observation resulted in a presentation of the users' work, rather than an observation of how they do their work.

Interview Analysis - User Research

The interview transcripts were documented and stored in a Google Sheets document, where any identifying information about the interviewees was removed. This allowed for storing all of the interviews in the same place, which was an aid during the analysis. Based on the transcripts, we could locate themes in the replies from the

participants and summarise the answers. Further analysis was done by conducting some of the methods described in section 4.2.4, such as thematic content analysis, and creating personas.
The first analysis was concerned with thematic content analysis and establishing themes that could be found in the data. The rigorous process of thematic content analysis was developed with large research projects in mind, and using all of the steps in the thematic content analysis on this comparatively small project with only five interviews would have been too time-consuming for the scope of this project. Therefore, a simplified and adapted version of the method was used instead. Each reply was coded based on recurring words, unique words and statements that we found interesting and/or relevant.
The codes were an abstraction of the replies and the level of abstraction was done from a full sentence down to a maximum of three words. The process of coding and abstraction can be seen in figure 6.1. The codes were transferred to virtual sticky notes to facilitate grouping and visualising the formation of groups. Due to the limitations described in section 1.6, we used digital sticky notes, called Jam Board, in Google Drive to give us the possibility to collaborate remotely.
When all codes had been transferred, the grouping process began. We decided to create two levels of groups, such as *work done in Stratsys* with subgroups such as *documentation* and *planning*. Each group received a label that describes the content of the group. The label is not equivalent to a theme, however, with the smaller amount of data gathered in this study and within the context of this project, the labels are enough to showcase similarities and key findings within the data. Therefore, we did only verify our labels and considered them as thematic findings.

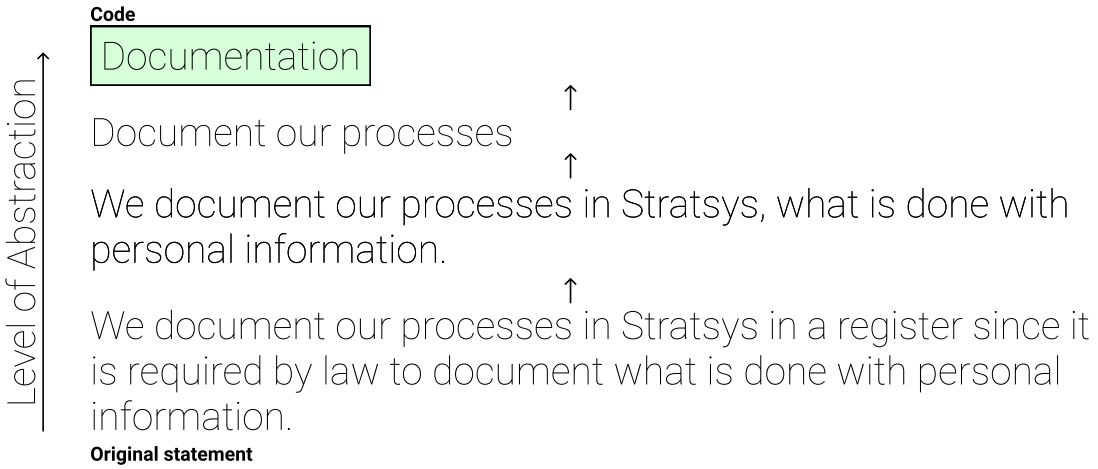

Figure 6.1: Illustration of the coding process, inspired by Vaismoradi et al. [2].

Interview Results - User Research

The thematic content analysis of the interview transcripts resulted in four lists of abstract codes and themes. The four lists are presented in table 6.1. The first list

Table 6.1: List of findings from the thematic content analysis of the interviews.

Use Cases	Tasks	Positive	Negative
Governance	Building models	Improves communication	Lacking filtering
Administration	Adapting models	Provides overview	Cumbersome navigation
Documentation	Analysing	Improves understanding	Non-customisable
Risk management	Filtrating	Provides context	Lacking structure
Follow-up	Adjusting		Lacking overview
Planning	Compiling		Unclear connections in data
Accounting			Outdated interface

is concerned with the *use cases* of Stratsys, the second list is concerned with the *tasks* that the users perform in Stratsys, the third list is concerned with what the users find *positive*, and the fourth list is concerned with what they find *negative* in Stratsys. The first and second list provides information of what the interviewees use Stratsys for, as well as which tasks they typically perform while working inside Stratsys. The third and fourth list compile themes and codes that appeared when the interviewees were asked to describe what they think works well and what does not work well. The four lists are compilations of the most frequently occurring themes and codes from the thematic content analysis.
From the interviews and observations, we could see that it is not uncommon that a user's interactions with the platform cycles from intense usage for a couple of weeks, followed by barely using it at all for months and then intense usage again. This suggests that the users need to familiarise themselves with the platform and structure of the information each time they are using it.
The data generated from the interviews and the results from the thematic content analysis would later be used while constructing the questionnaire, see section 6.2.2, as well as the basis for the personas, described in section 6.2.4.

6.2.2 Questionnaire - User Research

Based on the data gathered and analysed from the interviews, a questionnaire was constructed. The questionnaire was designed to provide more quantitative data than the interviews. The questions in the questionnaire were constructed to be able to verify the findings from the interviews. Furthermore, open-ended questions were used to provide new insights from the users.
The questionnaire consisted of questions for a wants/needs analysis, the method is described in section 4.2.4, where the participants were asked to rate a feature based on how important it is for their daily work and how much more enjoyable they believe that this feature would make their work. The functionality evaluated in the

questionnaire can be found in table 6.2.

Table 6.2: List of functions and features used during the questionnaire.

#	**Functionality Evaluated in the User Research Questionnaire**
Q1	Being able to see how the information moves to a new location when I change to a new page in Stratsys
Q2	Reducing the amount of scrolling/navigation to see all information
Q3	Being able to access a page with detailed information from an overview page
Q4	Being able to expand more details inside an overview of the information
Q5	Being able to see the connections between different information objects
Q6	Being able to overview the structure of the information
Q7	Being able to overview all information at the same time on the screen
Q8	Being able to have fewer objects on the screen to make room for more details within objects
Q9	Being able to hide details to make room for more objects on the screen
Q10	Being able to sort the information dynamically
Q11	Being able to have personal filters that are applied every time I open the page
Q12	Being able to adjust how the pages look on my screen (Colours, fonts, etc)
Q13	Being able to adjust how the information is displayed on my screen (position, structure, etc)

The rating was done on a bipolar semantic differential scale with seven points. The choice of an uneven number of points on the scale was made to provide a neutral point for the respondents. A seven-point scale is also the type of scale that is most frequently used in research according to Rosenberg et al. [54]. A drawback with the seven-point scale is that providing a neutral point can skew the data when the participant is indecisive about what to answer. However, using an even-point scale can also skew the data since the measurement may not reflect neutral users [54]. At the end of the questionnaire, there was a section for more open-ended questions concerning the users' work in Stratsys, where the users could explain in greater detail which problems they face during their daily work.
An invitation to take part in the questionnaire was sent out to 11 Stratsys users, as this was the number of users that our mentor Carin Andersson-Sarning could find for us. Two reminders were sent out after the initial invitation, and the questionnaire was closed 10 days after the first invitation was sent out. The number of answers collected was eight, which gives a reply ratio of 73 per cent.

Questionnaire Analysis

Analysis of the quantitative questionnaire results was carried out through a wants/needs analysis. The method is described in section 4.2.4 on page 27. The mean values of the scores for wants and needs for each functionality were calculated in a Google

Sheets document and an approximate score was visualised in a graph in a Figma document. The graph was divided into four quadrants. The top right quadrant consisted of high scores in both wants and needs, which are functionalities to pursue. The bottom left quadrant consisted of low scores on both wants and needs and these functionalities should be avoided to pursue. Since some functionalities received a similar score, they were combined and visualised as one item in the graph, to facilitate readability and reduce overlapping in the visualization.
The qualitative questions were analysed by compiling key findings.

Questionnaire Results

Quantitative results from the questionnaires were compiled into a wants/needs graph, seen in figure 6.2 on page 54. In the graph, we can see which of the functionalities are most interesting for the users in terms of both wants and needs. Most of the functionalities fell into the pursue-quadrant, which includes the functionalities that scored more than four on both the want axis and the need axis, on a scale from one to seven. Only Q12 fell outside this section, making this topic less relevant to pursue.
The top five features from the W/N Analysis are listed in table 6.3. The list is sorted by question number, not the total score achieved.

Table 6.3: Top five functions and features from the W/N Analysis. Ordered by question number.

#	**Functions Evaluated in Questionnaire (Wants/Needs)**
Q2	Reducing the amount of scrolling/navigation to see all information (W5.25/N5.5)
Q3	Being able to access a page with detailed information from an overview page (W5.13/N5.38)
Q4	Being able to expand more details inside an overview of the information (W5.38/N5.13)
Q6	Being able to overview the structure of the information (W5.88/N5.13)
Q10	Being able to sort the information dynamically (W5.38/N5.25)

The topics in Q3, Q4 and Q6 are concerned with overview, which was one of the initial problem statements of this project. The wants/needs analysis has confirmed that this is one of the most important features that were brought up in the questionnaire.
As for the qualitative questions at the end of the questionnaire, the answers were used to build personas.

6.2.3 Benchmarking

To get an overview of the benefits and problems in existing data visualization software, we decided to conduct benchmarking of the software listed in section 2.1.7, together with the Stratsys platform.

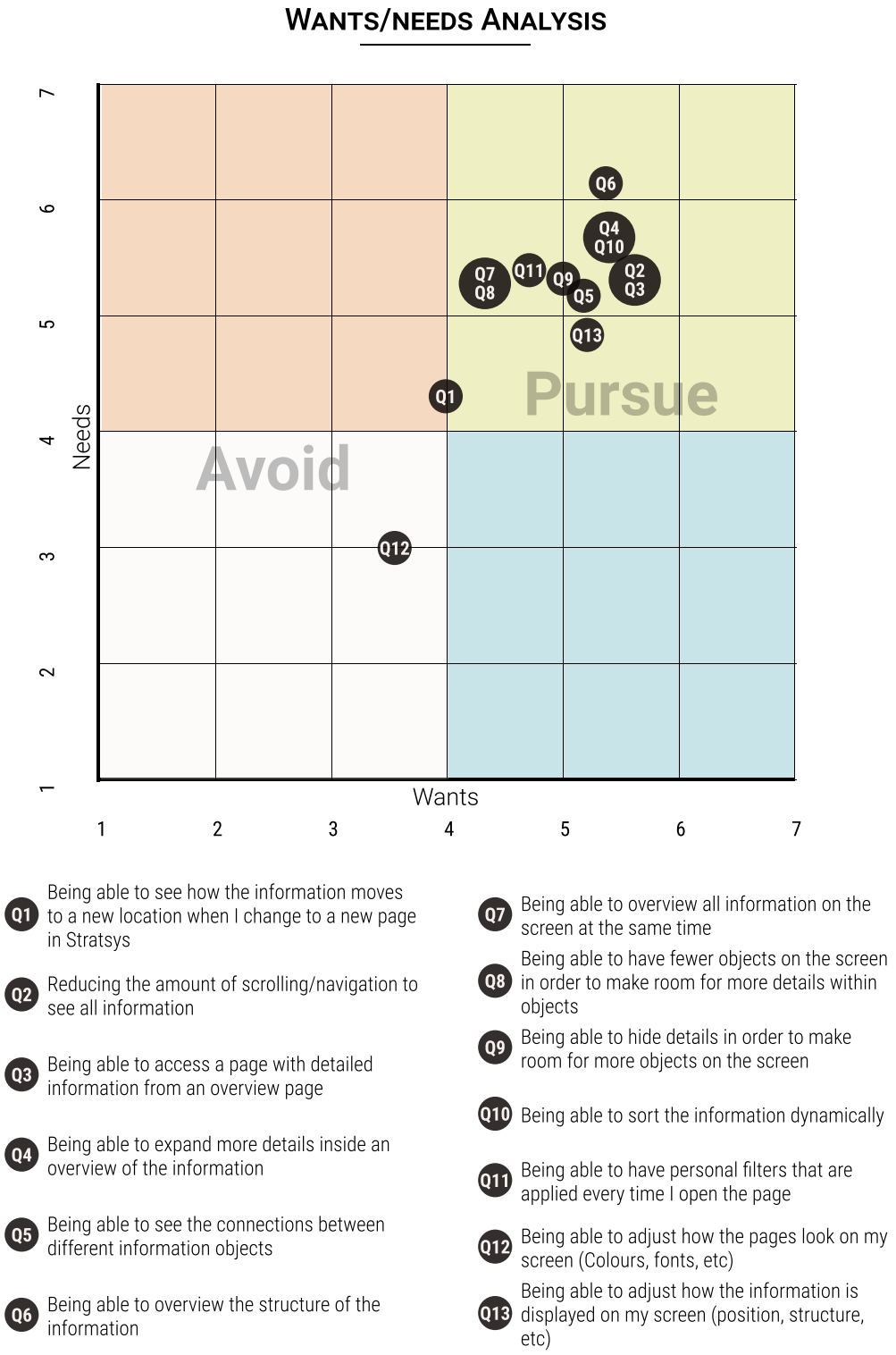

Figure 6.2: Results from the wants/needs analysis.

When conducting a benchmarking process based on heuristic evaluation, it is preferable to keep a short list of heuristics to build the evaluation on, as noted in section 4.3.3. Hence, we conducted a literature review on heuristic evaluation and information visualization, from which we extracted the heuristics and design principles that we found to be most relevant to the research task at hand. The selected heuristics were then processed into a comprehensible list, which can be found in table 6.4. Each criterion was backed by literature, the motivation and sources are presented below.

Table 6.4: List of criteria used during the benchmarking.

#	**Benchmarking Criteria**
B1	Reduces short term memory load
B2	Provides overview first, zoom and filter, then details-on-demand
B3	Supports the feeling of being in control
B4	Utilises space efficiently, reduces blank spaces
B5	Removes the extraneous
B6	Is usable for people with color deficiency
B7	Is consistent
B8	Provides feedback on user action
B9	Speaks the user's language

Criteria B1, *Reduces short term memory load*, is based on Nielsen's sixth heuristic *recognition rather than recall*, which is described in section 3.3.
Criteria B2, *Provides overview first, zoom and filter, then details-on-demand* is Shneiderman's information-seeking mantra. The mantra argues for providing the users with an overview and allowing the users to zoom in on what they find interesting, filtering out what is not relevant for the user and also allowing the user to select an item to get further details [55].
Criteria B3, *Supports the feeling of being in control*, is also based on Shneiderman's work, together with Lazar and Jones. Lazar et al. argue that a sense of internal locus of control will reduce the level of frustration in the user. Therefore, external locus of control should be avoided and the software should *support the feeling of being in control* in the users [56].
Criteria B4 *Utilises space efficiently, reduces blank spaces*, B5 *Removes the extraneous* and B6 *Is usable for people with colour deficiency* are taken from a list of heuristics for information visualization evaluation compiled by Zuk et al. [57]. Their list of heuristics has been compiled to provide heuristics specifically for information visualization, rather than usability in general. Criteria B4 and B5 focus on utilising the available screen space efficiently by removing unnecessary items and blank spaces. Criteria B6 focuses on accessibility for people with colour deficiencies.
Criteria B7 *Is consistent*, B8 *Provides feedback on user action* and B9 *Speaks the user's language* are based on Nielsen's heuristics of *consistency and standards*, *Visibility of system status* and *Match between system and the real world*. The purpose of being consistent is to not confuse the user by reusing icons and wordings for ac-

tions and features that are different from each other [29]. *Feedback on user action* should be provided so that the user can always be aware of what is going on. Furthermore, words, icons and figures should *speak the user's language* and reflect the user's mental model rather than the system's implementation model.

The benchmarking process was carried out individually, as this is the process recommended by literature, as discussed in section 4.3.3. Accounts with mock data were used to access the programs and to get a feeling of how well the different programs lived up to the criteria, listed in table 6.4. To find out how well the programs did on criteria 6, *Is usable for people with colour deficiency*, the tool Coblis[1] was used. Coblis is a tool from the blog Colblindor[2], where you can upload images to see how people with different types of colour deficiencies perceive them. We uploaded screenshots of diagrams in Coblis to see how visible the data is for people with colour deficiencies. The results from these tests would provide a part of the scoring for criteria B6.

Findings and ratings of the criteria were noted in two separate tabs in a Google Sheets document. In the document, ratings on a score between 1 and 7 were provided together with comments and motivations on the scores received. The results were then discussed and a calculated average was transferred to and visualised in a Figma document.

Benchmarking Results

The results from benchmarking the software are presented in the graphs below. The date of benchmarking is included since there is no version number available for the software and their design and implementation may change over time.

[1] https://www.color-blindness.com/coblis-color-blindness-simulator/
[2] https://www.color-blindness.com/

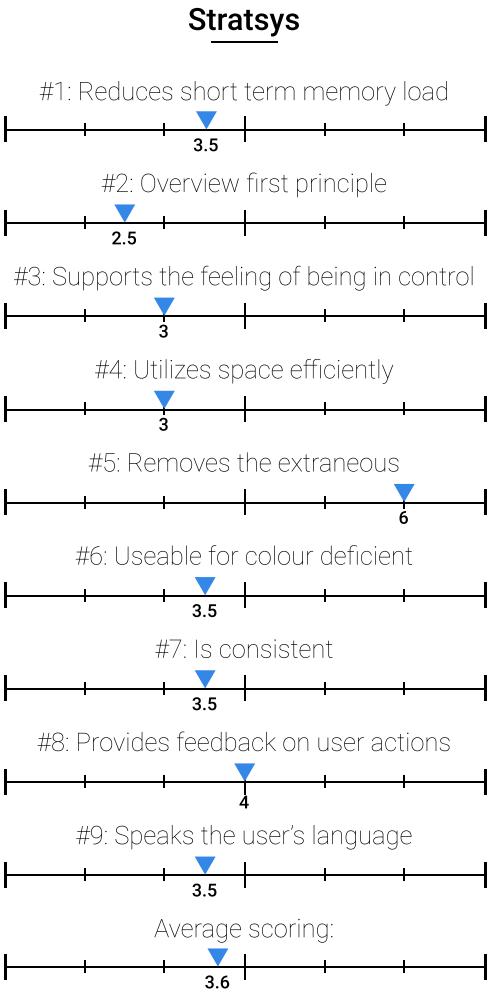

Figure 6.3: Benchmarking of Stratsys. Date of benchmarking: 2021-03-02.

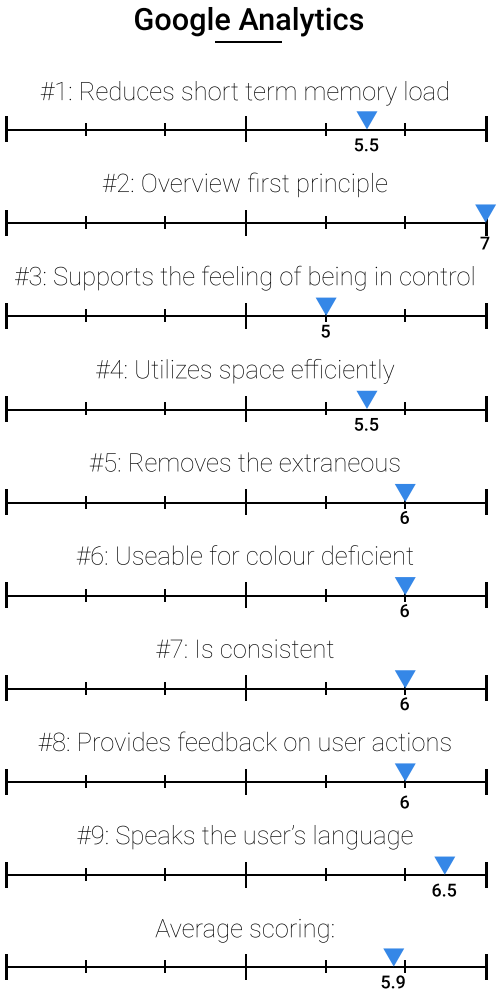

Figure 6.4: Benchmarking of Google Analytics. Date of benchmarking: 2021-03-02.

Stratsys' average score was set to 3.6, mainly due to a lack of overview, but the software received low scores on all of the criteria. The scoring for each criterion can be found in figure 6.3.

The average score for Google Analytics was set to 5.9, which is to be considered a high score since achieving the highest score of 7 is very unlikely to occur. The scoring for Google Analytics can be found in figure 6.4 Google Analytics received high scores throughout the benchmarking. We had nothing to complain about when it comes to the second criterion, B2, of the overview first principle, where the software received the highest score possible. Furthermore, the results show that Google Analytics did not receive low scores on any of the criteria and only minor errors were found throughout the software.

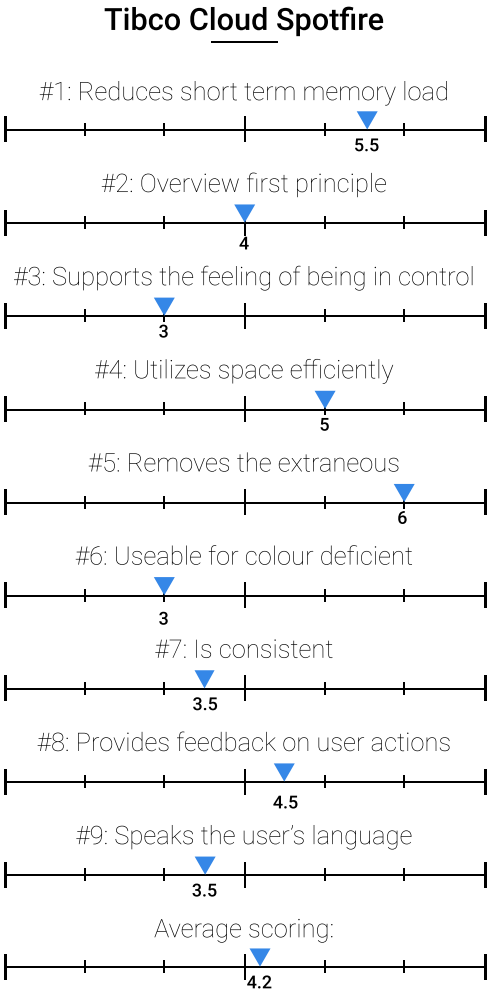

Figure 6.5: Benchmarking of Tibco Cloud Spotfire. Date of benchmarking: 2021-03-03.

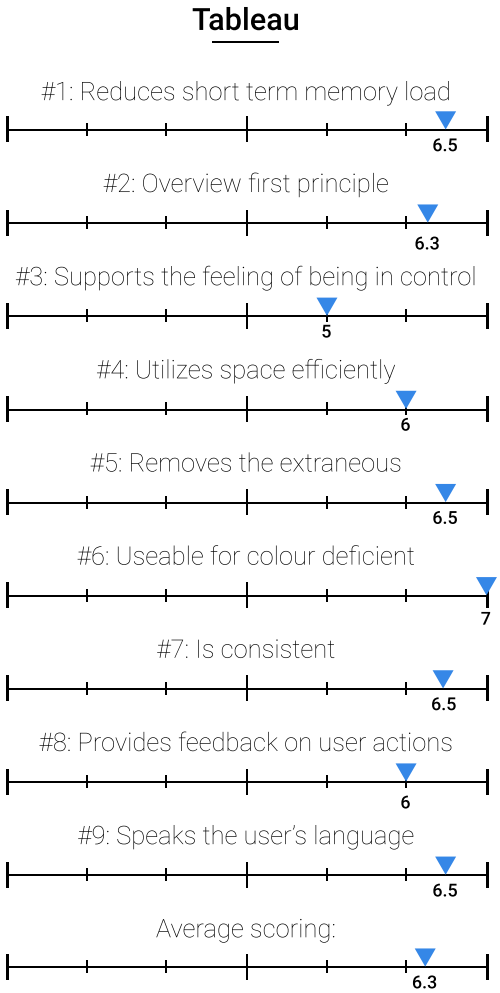

Figure 6.6: Benchmarking of Tableau. Date of benchmarking: 2021-03-03.

The highest score in the benchmarking was achieved by Tableau with an average of 6.3, as seen in figure 6.6. Tableau received high scores on each of the criteria. The designers have genuinely considered colour deficiency in their design and therefore they received a 7, the highest possible scoring, on that criterion. The criteria where Tableau did not do as well is in criteria B3 *supports the feeling of being in control* where the software scored 5, this is likely due to the software being very extensive in the functionality and capabilities offered to the user.

Tibco Cloud Spotfire achieved an average score of 4.2, as seen in figure 6.5. Tibco Cloud Spotfire received varying scores on the criteria. What stands out is the lack of consideration for colour deficiency and problems with supporting the users' feeling of being in control, criteria B3 and B6. These criteria received a scoring of 3, which is to be considered as *not okay*. Overall, the software utilises the screen space efficiently and reduces the cognitive load for the users.

The information visualization tool Gapminder received a score of 4.9.

Gapminder scored above 4 on all of the criteria, which means that no criterion was poorly considered in their design. However, there were some minor flaws in their design, such as inconsistent use of labels for icons. There were some issues concerning the implementation as well, where there were problems of inconsistency and unclarity when making colour settings, trying to zoom and applying personal filters. Furthermore, the colours chosen for the visualization are not always ideal for people with colour deficiency. Gapminder utilises the screen space efficiently in most of their visualizations, where the visualization takes up most of the screen. However, in some cases when filters have been applied, the visualization becomes very spacious with a lot of blank spaces, which seems to be a design decision due to the data fading out rather than being removed.

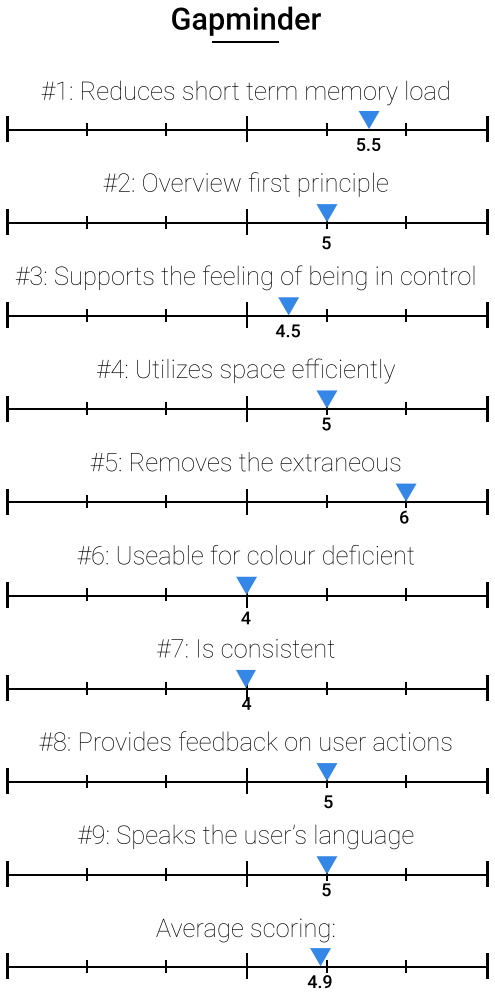

Figure 6.7: Benchmarking of Gapminder. Date of benchmarking: 2021-03-04.

6.2.4 Results - User Research

Based on the user research, key takeaways are that the users can sometimes struggle in getting an overview of the data and information in Stratsys. This is a confirmation of the initial problem statement described in chapter 1. The users sometimes felt that they were scrolling a lot in the available visualization and thereby losing track of how the information is connected and where the information is located.

Personas

Personas were built by using findings from the interviews and the questionnaire. Recurring themes from different work roles were extracted and compiled into three different personas. The number of interviews was limited to five and the questionnaires were answered by five people at the time the personas were created, which made us assess that the number of three different personas was appropriate for this amount of ground information.
The personas were attributed with the following sections: *First name, Occupation, Stratsys usage, Worklife, Personality, Uses Stratsys for*, and *Concerns*.
Our primary persona is called Katarina, as seen in figure 6.8. She works as a controller in the public sector and uses Stratsys daily. She wants to keep everything

organised and her main work task is to follow up on what her colleagues are doing. Katarina is a disciplined person that likes having a lot to do. She is independent and does not like having to depend on other people. However, she is a social person and she always sees the best in everyone. Katarina likes using Stratsys since it gives her an overview of the organisation and allows her to manage the work more efficiently. Katarina's main concern in her daily work is that she has to nag on people to get them to do their work. She also thinks that she spends too much unproductive time by scrolling and searching in Stratsys to find the items and information that she is looking for. She wants to get an even better overview of the information.

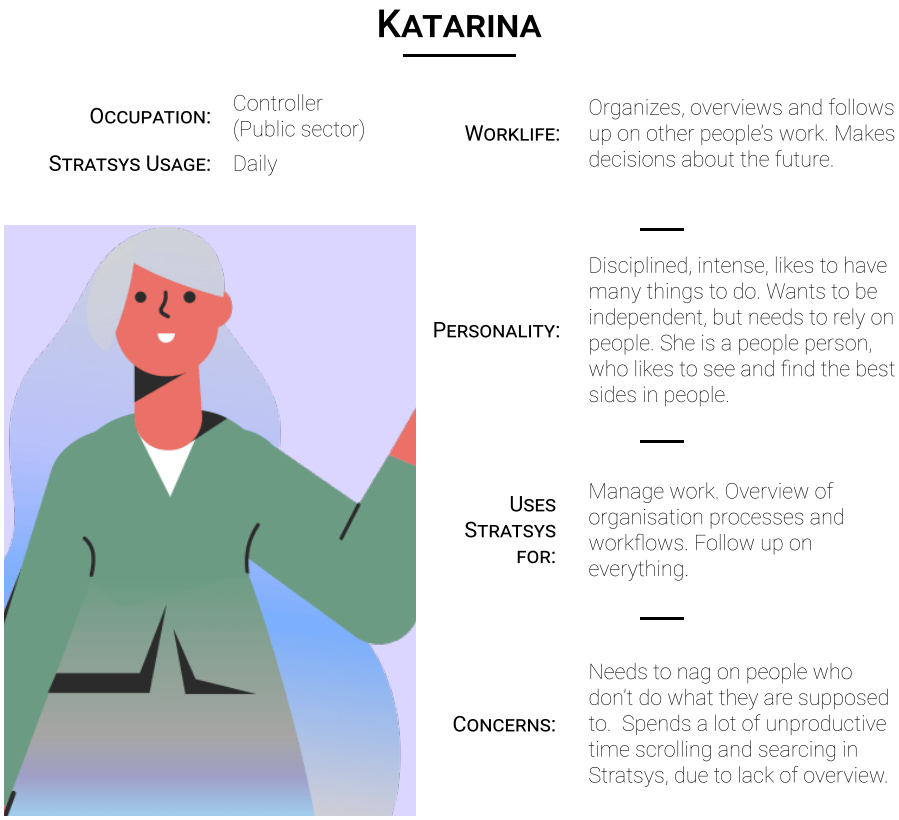

Figure 6.8: The primary persona, Katarina. She is a frequent user.

The persona Margareta, as seen in figure 6.9, works as a manager in the public sector. Her job involves keeping a constant overview of the people within the organisation, without being their boss. She uses Stratsys daily, but not as much as Katarina does. She has some intense periods when she sets up business plans for her organisation. She also uses Stratsys as a basis for annual reports, and to follow up on the development within the organisation. She likes structure, order, discipline and control. One thing Margareta hates is when unexpected events occur, that mess up her schedule and cause stress. She is also annoyed about having to scroll in Stratsys to find the sections she is responsible for.
The persona Kenneth, as seen in figure 6.10, works as a controller in a private company. He works a lot with customers and likes to keep strict boundaries between work and personal life. Kenneth uses Stratsys periodically, and every time he opens

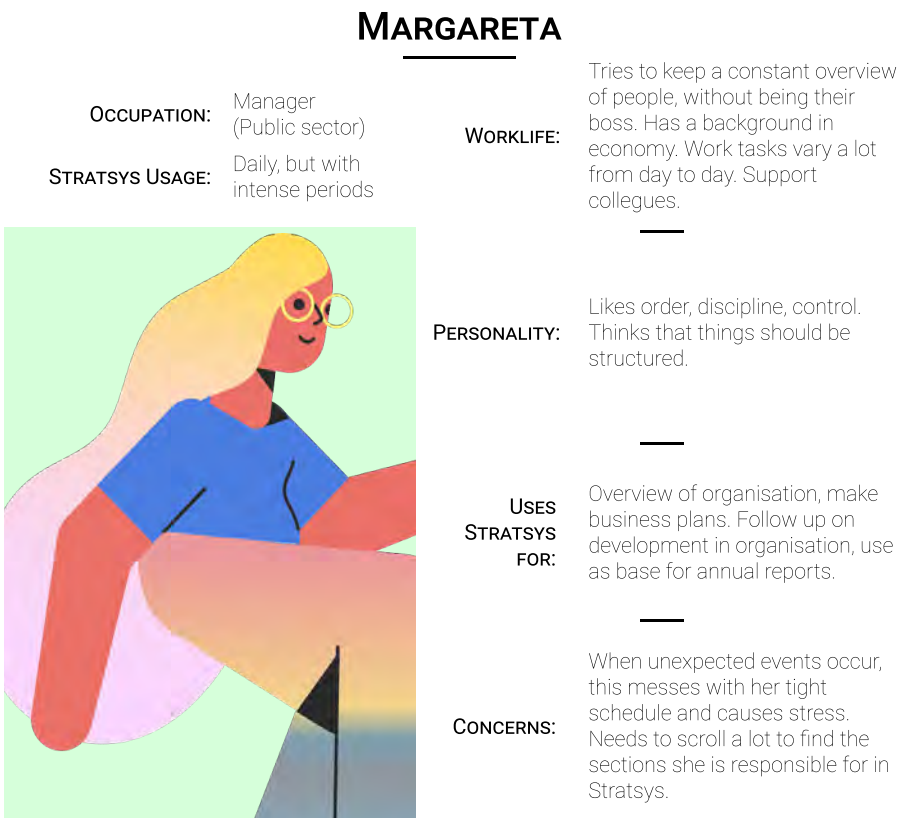

Figure 6.9: Persona Margareta. She uses Stratsys intensively in periods.

the software he struggles with understanding it, as it has been so long since he last used it. He uses Stratsys to build views and create processes, as well as for risk assessment and follow up on the planning. A concern Kenneth has is that he thinks that the views in Stratsys are too rigid and does not allow for the flexibility he wants.
Stratsys has its own set of five personas, which we have been introduced to by our mentor, Carin Andersson-Sarning. Stratsys personas represent five different types of users with different opinions of using Stratsys in their work. This project focuses on two of these personas. The personas created in this project has been verified against the personas assigned from Stratsys.

6.2.5 Discussion - User Research

The two largest parts of the user research phase was the interviews and questionnaire involving real users. Hence, the discussion will focus on these two parts.

Interview Discussion

Using the adapted observation method, as discussed in section 6.2.1, gave us less insight into the users' daily tasks than expected. None of the subjects did an actual task, but merely showed which views they use in their daily routines and talked about what they use them for. In hindsight, we see that an option that could have

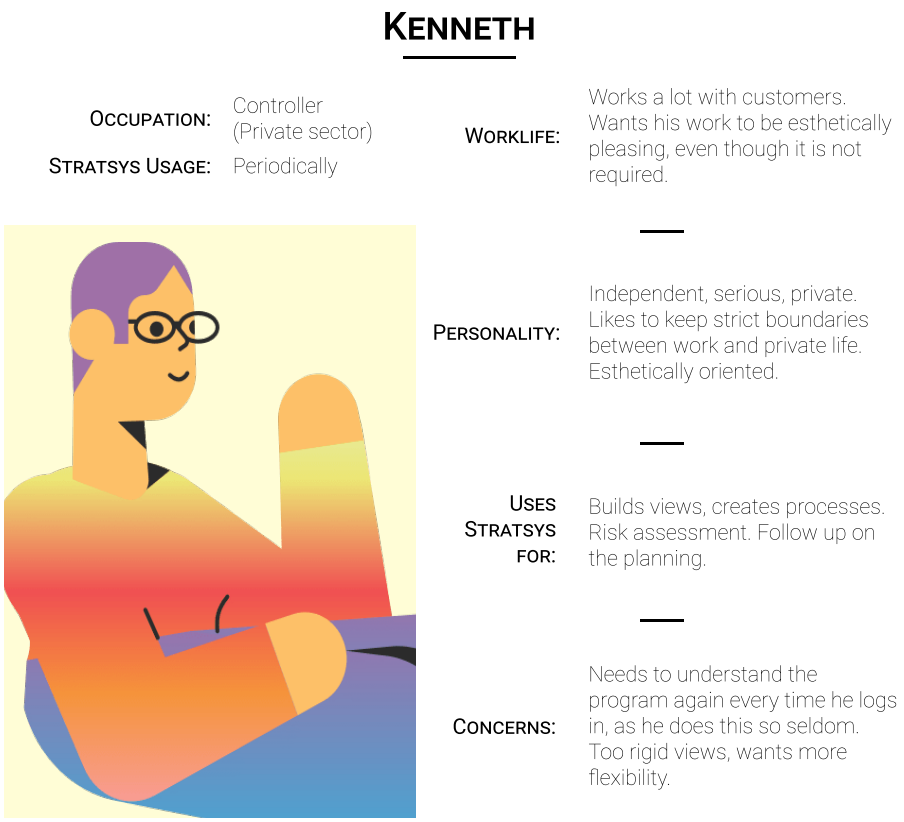

Figure 6.10: Persona Kenneth. He uses Stratsys periodically.

given us deeper insight into the daily tasks is to use the tool Lookback[3] to observe the users online while they were going about their actual daily tasks. This was not done as we believed that the chosen observation method would provide sufficient results, and there were technical issues that made it cumbersome to get started using Lookback, such as licensing.

After the data has been analysed, we could see that the knowledge gathered on the users' usage is abstract. To achieve a more concrete picture of what the users' do when they say that they are, for instance, *documenting*, we scheduled an interview with the support division at Stratsys. The support division knows the customers and their daily tasks. The interview was prepared with questions such as *what do the user do when they say that they are documenting in Stratsys*, the interviewee was asked to share their screen to show and describe to us how the user does.

The additional interview resulted in clarification of the terms used by the users in the previous observations. Furthermore, the interviewee was able to provide additional information and knowledge into what the user is doing in the platform. The thematic content analysis resulted in a list of abstract themes and findings from the data, which facilitates in making the data easier to compare and more comprehensible. However, the resulting data from the thematic content analysis is very abstract which might make the data less precise and lose its context.

[3]https://lookback.io/

Questionnaire Discussion

As the number of participants invited to the questionnaire was limited to 11, and the answering frequency was 72.7 per cent, the conclusions that can be drawn from the questionnaire are limited. However, the intention of the questionnaire was not to give a hard answer, but rather to get a general perception of which of the issues found during the interviews that the users seem to be most interested in. We can not say that these are the only topics of interest to the users, since the choice of issues to discuss has been done to focus on the scope of the project. The results do however reveal which of the functionalities relevant for the project are also of greatest interest to the users. The results also reveal that most of the functionalities that were brought up were of relevance to several users.
As the respondents were anonymous due to privacy concerns, there was no way of knowing which of the invited users had responded. This had the effect that reminders were sent out to users that had already responded to the questionnaire. There is no indication that this practice has affected the results negatively. Furthermore, since the participants were entirely anonymous, there is no way for us to link a response to any individual. This could pose an issue if any of the participants wanted their responses removed from the research. Future questionnaires should include a clear way for the users to have their responses removed from the data.
While analysing the questionnaire results, we could see that most participants did distinguish between wants and needs in their responses. However, some participants did reply the same score for both want and need on most of the questions, where these users did differentiate on wants and needs was on either question Q1 or Q2. The reason for this pattern may be due to the participants not fully understanding what we meant by wants and needs. A reason for Q1 and Q2 to stand out may be due to them being the first questions asked in the questionnaire. Since the questions always appeared in the same order to all users, we can not confirm this to be the reason, but merely speculate. Additional studies would be needed to confirm this to be the reason.
The result does not clearly distinguish between what the users want and what they need. However, it clearly shows what the users find important in some sense. Furthermore, question Q3 and Q4 were asked to see which solution of accessing detail in an overview the users would prefer. The scoring for these two questions was similar and high. The users showed no preference for any of the approaches, rather the results point to the importance of solving the problem.
The questionnaire was structured to facilitate the wants/needs analysis. However, when the data was analysed, we could see that all features closely follow a linear curve, which might be due to the questions being misinterpreted by the participant. The result does not show any clear distinction between what the users want and what the users need. The result is still relevant and valuable since it reflects which functionalities the users think are important.
The questions were thoroughly phrased and piloted on other designers. A large concern went into phrasing the questions in a way that can not be misinterpreted. However, as designers with knowledge of the wants/needs analysis method, we may have been biased in the interpretation of the questions. Piloting on actual users might have given a better insight into how the questions are understood.

Benchmarking Discussion

During the benchmarking process, we noticed that a problem was that the programs were unfamiliar to us, which made it hard to understand things that might be obvious to a more experienced user. It was also hard to find which data to use, and how it should be understood. However, we believe that the benchmarking process gave us some insights into how different information visualization tools work, as well as recurring problems and good solutions for them.
The benchmarking of Stratsys was made on a database with a small amount of data that we have set up, which might not reflect the database and use cases of the average user, which might have affected the outcome.
When benchmarking Tableau, it might have been an issue that neither of us had any previous knowledge of the software and the learning curve is quite steep.
During benchmarking, we could see similarities and differences between the implementation of the different platforms. Some criteria proved to be more valuable than others. On criterion B5, *removes the extraneous*, all of the benchmarked platforms received a score of 6, except for Tableau which received 6.5. This criterion was not very efficient for comparing the chosen platforms. Furthermore, some criteria received very varied scores between the platforms, for instance, criterion 2 *overview first principle* which ranged from 2.5 to 7. Criterion number 6 *Usable for colour deficient* also received varying scores from 3 to 7. Criteria with more variation in scoring might be more beneficial to use while benchmarking for comparison. However, it is not clear what these criteria are before conducting the benchmarking.

6.3 Iteration 1

Iteration 1 started with an extensive ideation phase based on the results from the user research. This iteration focused on generating a large number of ideas and therefore, a lot of the ideas were prototyped without any formal evaluation. Thus, the ideation and prototyping stages were combined, as sketching and wireframing were used for ideation. Continuously during the ideation phase, ideas were evaluated and potentially feasible ideas were prototyped through wireframing. Some ideas were discarded without being sketched out, as they were considered to be infeasible or irrelevant for the project.

6.3.1 Ideation - Iteration 1

The ideation phase was built up by the methods how might we, brainstorming, crazy 8's and sketching. Each method was based on results and conclusions that had been generated in previous work.

How Might We - Iteration 1

When designing the questions for the method how might we (HMW), topics from the questionnaire were used as a basis. All of the topics that had fallen into the pursue section in the wants/needs analysis were regarded and rephrased to fit the

model of how might we, as discussed in section 4.3.1. The questions were phrased to be broad enough to allow for several solutions, but narrow enough to give a starting point for brainstorming. Some of the topics from the questionnaire were divided into several HMW questions, and some were disregarded as they did not give enough room for brainstorming. We also went back to the interview results to see if there were any topics there that could be interesting to brainstorm on, which resulted in five additional questions. The questions can be found in 6.5.

Table 6.5: List of questions posed for the how might we method in Iteration 1.

#	**How Might We Questions**
HMW1	How might we visualise transition when nodes change position?
HMW2	How might we visualise transition when the information is displayed in a different type of view?
HMW3	How might we reduce the amount of scrolling?
HMW4	How might we reduce the amount of navigation?
HMW5	How might we reduce the amount of navigation and scrolling to access all data?
HMW6	How might we access details about nodes from an overview of the data?
HMW7	How might we visualise connections between nodes?
HMW8	How might we give the users a sense of the data structure?
HMW9	How might we give the user a sense of what data is available?
HMW10	How might we visualise the available data restricted to the size of the screen?
HMW11	How might we fit more data objects on the screen?
HMW12	How might we fit more nodes on the screen?
HMW13	How might we reduce the time to understand the structure?
HMW14	How might we make it easier to find data?
HMW15	How might we reduce the feeling of being restricted by screen size?
HMW16	How might we make the visualization less scattered?
HMW17	How might we make the visualization feel less rigid?

Brainstorming - Iteration 1

The brainstorming sessions were done over a period of two days, where the HMW questions were ideated on. The brainstorming was done remotely through Google Jam Boards, where the ideas were written on virtual sticky notes. Similar ideas were grouped to facilitate comparison. The generated ideas were discussed over Zoom.

Sketching - Iteration 1

Some ideas from the brainstorming session were further evolved and concretised through sketching. The sketches were done with pen and paper. As we were working

remotely, images of the sketches were shared through Slack and each sketch was described and discussed within the team via Zoom.

Crazy 8's - Iteration 1

As the initial focus of this iteration was to ensure that all possible ideas were taken care of, we initiated a crazy 8's session as a follow up to the general sketching. This resulted in 15 quick sketches, as seen in figure 6.11.

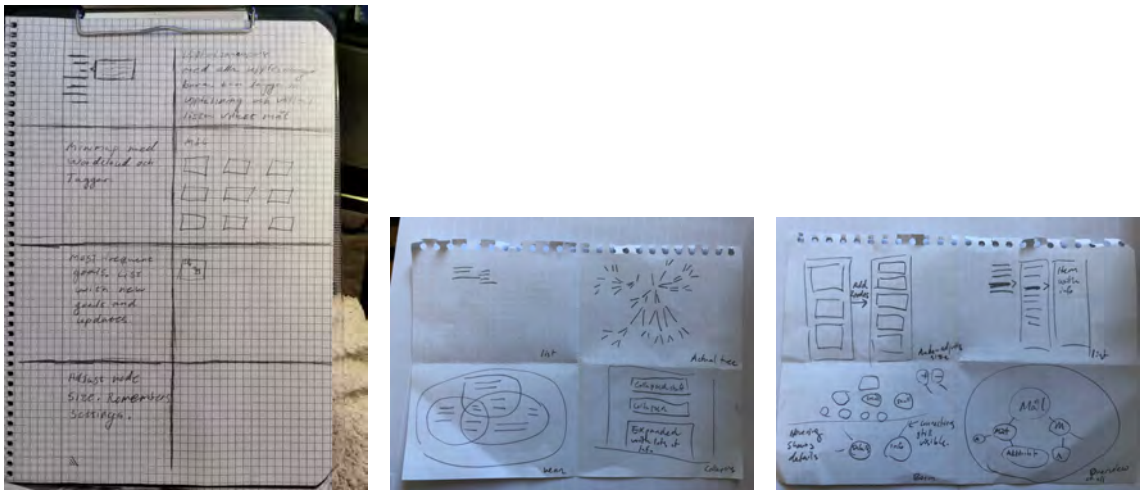

Figure 6.11: Sketches created during the crazy 8's session.

6.3.2 Selecting Ideas to Pursue - Iteration 1

Since this iteration focused on generating a lot of ideas and concepts to develop, no formal idea selection took place. Rather than removing available ideas, we conducted an informal evaluation to decide which ideas were feasible and which were not. Furthermore, the remaining ideas were prioritised based on the knowledge gathered from the user research as well as the anticipated impact the concept will have. Ideas that target the criteria presented in table 6.6 were seen as most important and therefore prioritised the highest to be prototyped.

Table 6.6: List of criteria to select ideas to pursue in Iteration 1

#	Criteria
1	Provide an overview of the data.
2	Less static visualizations.
3	Reduce scrolling and navigation.
4	Utilise the screen more efficiently.
5	Clarify connection between data.

Some of the sketches were decided to not be transferred to digital format, as they were deemed as not interesting or feasible enough. This was part of the process of

narrowing down the number of ideas to take further, but the selection was not done in any formal way.
The selection of ideas to prototype was based on knowledge gathered through the user research, as well as the project description provided by Stratsys. No formal method for idea selection was conducted, but rather an informal selection took place, where most relevant ideas were taken further to the prototyping stage. The ideas that were prototyped largely focused on the structure and overview of the data. Other ideas that were prototyped focused mainly on decreasing the amount of navigation and scrolling from the user to access their data.

6.3.3 Prototyping - Iteration 1

The prototypes in this iteration were done through non-interactive wireframes constructed in Figma and Adobe XD.

Wireframing - Iteration 1

To try out the basic sketches in more detailed forms, we used Figma and Adobe XD. The initial software used was Figma, as this had been used successfully earlier in the project. The wireframing process was iterative and the focus was on constructing a large variety of prototypes to be evaluated.
As Stratsys provided us with their component library in Adobe XD, to make prototyping faster and also facilitate in achieving the look and feel of their platform, the choice was made to start using Adobe XD instead of Figma.
Each of us looked at the sketches and drew up more detailed wireframes of them in Adobe XD, partly using the design library provided by Stratsys.
The wireframes were constructed on top of a screenshot of Stratsys' current interface to further facilitate the look and feel. The screenshot was edited to remove Stratsys' current visualization and to create a blank area for our wireframes. The background image can be seen in figure 6.12.
To further facilitate in making the prototypes feel real, we used data from a mock database in Stratsys that should be similar to real data. In total 19 wireframes were constructed. The majority of the prototypes focused on providing an overview to the users, which resulted in a large extent of changes in the current structure of data in Stratsys. This may impact how the users interact and navigate through the platform. The wireframes constructed largely did not showcase interaction or the navigation within the software, but rather focused on the layout of a more static page, as they were still of rather low fidelity to enable evaluation of a larger number of ideas.
Some additional wireframes were constructed to showcase features of the concept, such as if a field is expanded. Some of the sketches generated more than one wireframe, as they could be developed in several directions and to showcase alternative approaches to the solutions. There were also some wireframes constructed where other concepts were combined into one.
The wireframes can be found in section 6.3.5 and in appendix F.

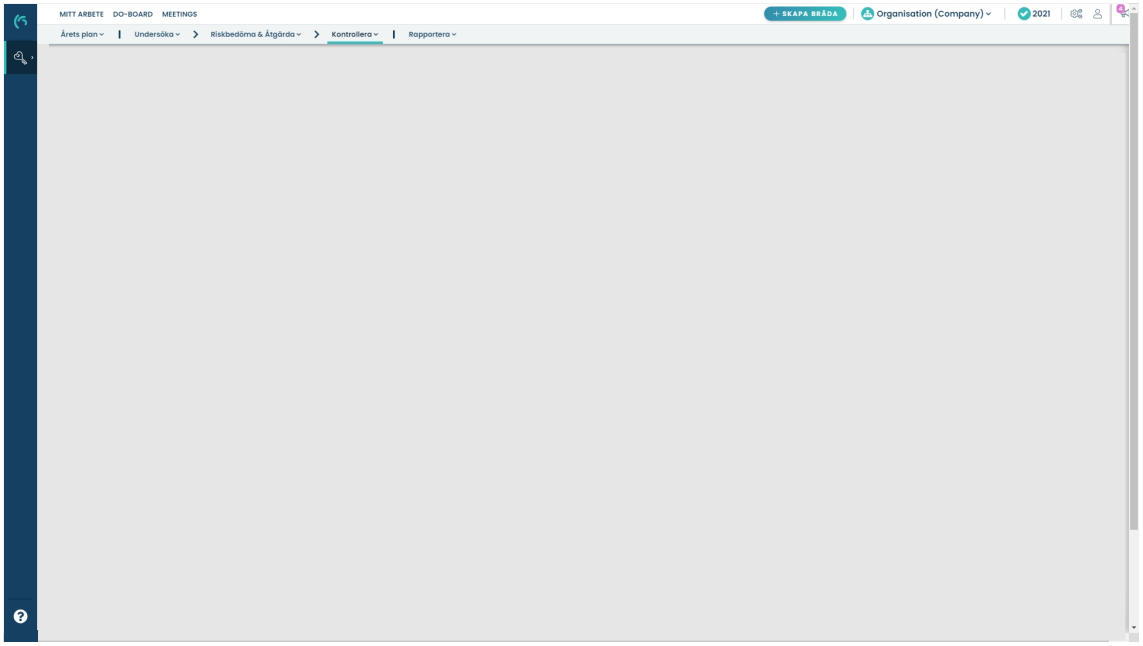

Figure 6.12: The edited screenshot of Stratsys software was used as a background for the constructed prototypes to enhance the look and feel.

6.3.4 Evaluation - Iteration 1

The prototypes constructed in this iteration were evaluated without involving any users. This was done to save time and due to the prototypes being of lower fidelity, making them less suitable for presentation to people outside of the design team. Methods used to evaluate the concepts were to benchmark each prototype and to conduct a SWOT analysis for each concept. The benchmarking in this stage used the same criteria as used in the user research stage, as can be found in section 6.4 on page 55.

Heuristic Evaluation - Iteration 1

The heuristic evaluation was conducted individually for each of the wireframes and documented in a Google Sheets document. The results were used to determine what needs to be further developed and what works well in the current version of the concept. The evaluation revealed that some concepts, such as Zoom and Pan and Mini Map, are very similar and could therefore be combined. Furthermore, the evaluation allowed for comparison of the concepts and thereby facilitated in deciding which concepts to keep for the next iteration.

SWOT Analysis - Iteration 1

In the SWOT analysis, we made a compilation of the different concepts' strengths and weaknesses that were found during the heuristic evaluation. These were put into the four different sections of the SWOT matrices, one for each concept. The Strengths and Weaknesses sections were used as intended in a SWOT analysis, which can be seen in section 4.3.3. However, the Opportunities section was used for ideas

that could be implemented in the concepts to improve them in further iterations, as opposed to external opportunities. The Threats section was used to anticipate how the users could react to the concept.
The result may facilitate future development and it showcased what the different concepts are focusing on.

Selecting Concepts to Pursue - Iteration 1

The evaluation methods focused on highlighting what works and what does not work. The result in itself was not enough to decide which concepts to pursue and which to eliminate. To facilitate in selecting which concepts to pursue, two criteria were constructed. The criteria focus on whether the concept can function as a stand-alone concept and whether there is a similar concept that we deem as working better. The two criteria for selecting ideas to eliminate or to pursue were:

1. Is there another prototype that is similar and works better?
2. Does this concept work on its own as a stand-alone visualization?

The two questions above were answered informally by us. If the answer to the first question is *yes*, then that concept is eliminated. If the answer to the second question is *no*, then that concept was deemed as a complement.

6.3.5 Results - Iteration 1

Iteration 1 resulted in 19 wireframes that were evaluated. After evaluating the wireframes, two were removed and four were seen as complementary visualizations rather than stand-alone concepts.

Prototyping Results - Iteration 1

The prototypes constructed in this iteration have different focuses and target different areas of Stratsys' platform as well as different problems that were brought up during the user research. The areas that the prototypes mainly focused on are presented in table 6.6 on page 66.
The concepts constructed received names to facilitate communication and discussion. Concept names are stylised as Small Caps throughout the report. The concepts constructed in this iteration include: Checklist, Enclosure, Indentation List, List Overview, Goals Overview, Focus View Vertical, Focus View, Horizontal, Focus View Reversed, Tags, Tree Structure, Zoom and Pan, and Mini Map. More figures and descriptions of the concepts can be found in appendix F.

The prototype Checklist was constructed to reduce the amount of scrolling that is required to access all items in a list and thereby provide a better overview. By dividing the list into two columns and hiding detailed information, less vertical space is required. The Checklist - Expanded, as seen in figure 6.13, shows the view with one element expanded to show details.

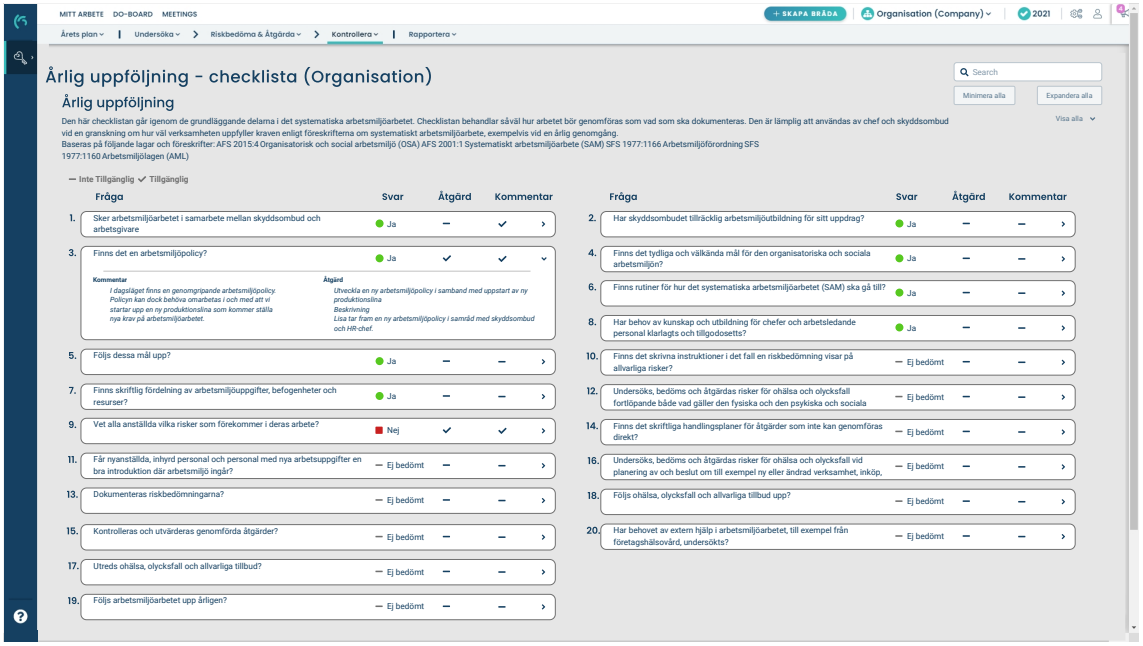

Figure 6.13: The CHECKLIST prototype, here with one element expanded to reveal detailed data.

ENCLOSURE, as seen in figure 6.14, was constructed to provide an overview of the data, and at the same time showcase the hierarchies in a clear way. It is inspired by the treemap visualization, described in section 2.1.4, which uses enclosure to visualise hierarchies. Each parent node encloses all of its child nodes, and this is done recursively.

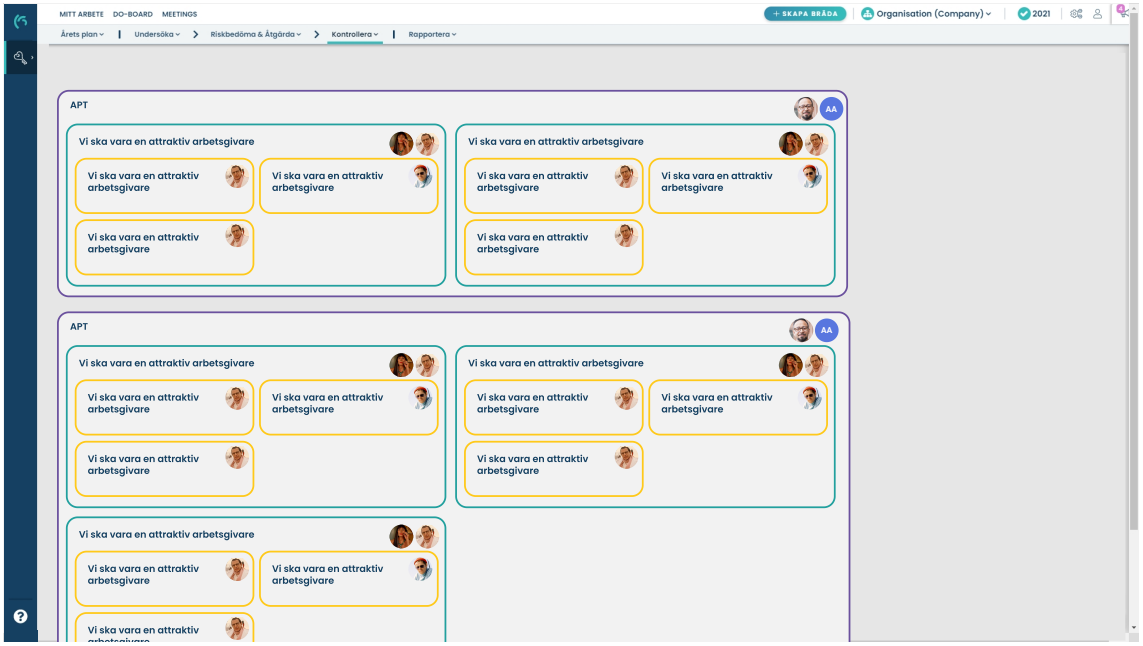

Figure 6.14: ENCLOSURE utilises enclosing elements to show hierarchies.

The INDENTATION LIST, as seen in figure 6.15, is based on a common design element

to show hierarchies within in a list of text. The list consists of only text and can therefore be made more compact than the other concepts prototyped in this iteration. This type of list may not be suitable to be used as a stand-alone visualization, as text format does not provide an easily comprehensible visual aid in understanding the data structure, but it could rather function as a tool for navigation as a complement to another type of visualization.

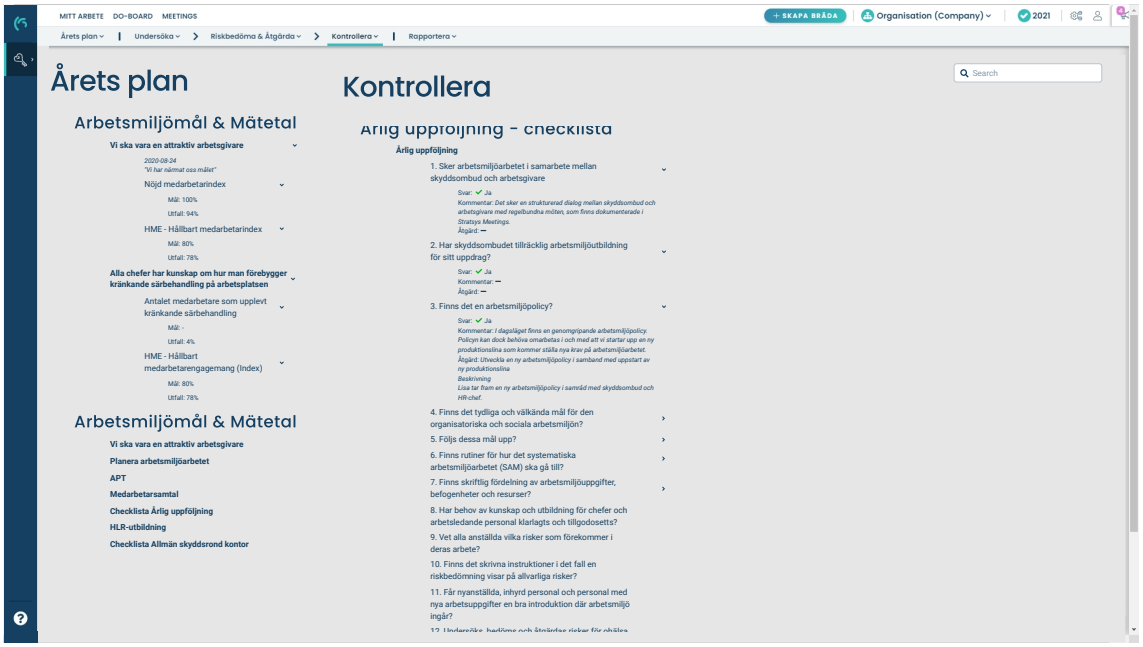

Figure 6.15: Indentation List is a space efficient list that show hierarchies by indentations in a list of text.

List Overview, as seen in figure 6.16, uses juxtapose lists to showcase hierarchies in the data. The user hovers the mouse over an element to reveal child elements next to it. The list is interactive and clicking an element navigates to a different view with more details. The hierarchies in List Overview are commonly displayed in this way in menus.

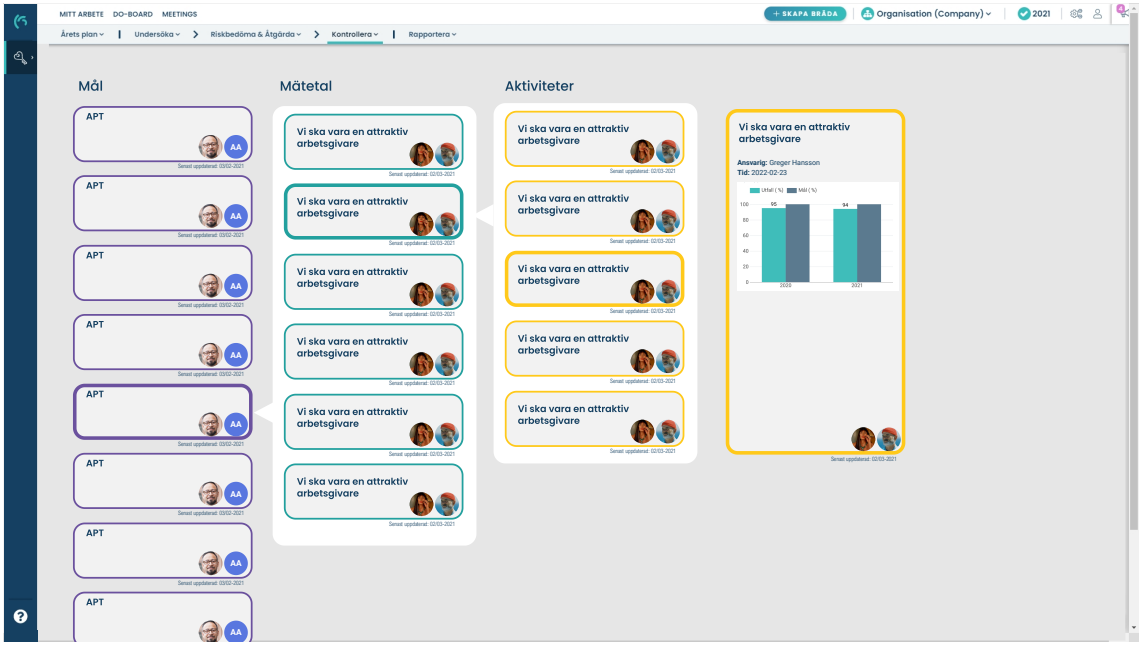

Figure 6.16: List Overview shows hierarchies by expanding subelements next to the parent element.

Goals Overview, as seen in figure 6.17, hides the child elements to make room for more parent elements on the screen. The idea is to reduce scrolling and thereby provide a better overview of the data. Tooltips were not included in the wireframe but could be used to display a node's child elements.

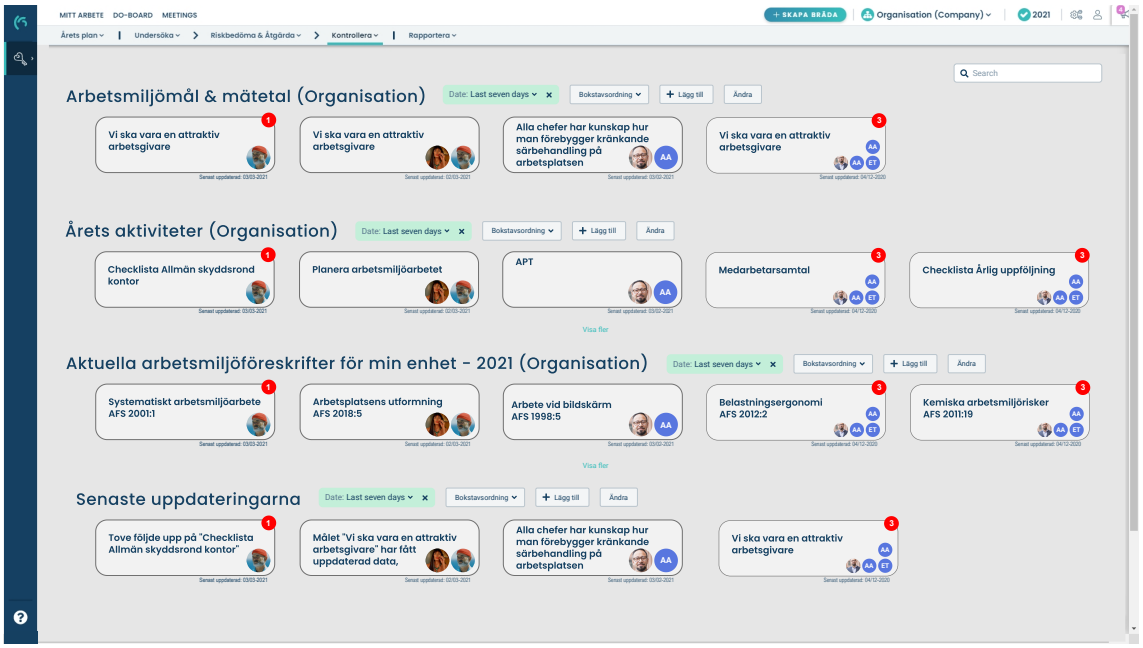

Figure 6.17: Goals Overview provides an overview of all available parent nodes, mainly strategic goals.

Focus View Vertical, as seen in figure 6.18, is a concept that aims to provide

increased focus on the task or goal that the user has selected. The idea is to make it easier for the user to see which actions, options and data is available for the selected goal. Focus View Vertical does not focus on providing an overview for all of the parent elements. The Focus View Vertical allows the user to navigate to other parent elements through the navigation panel located to the left.

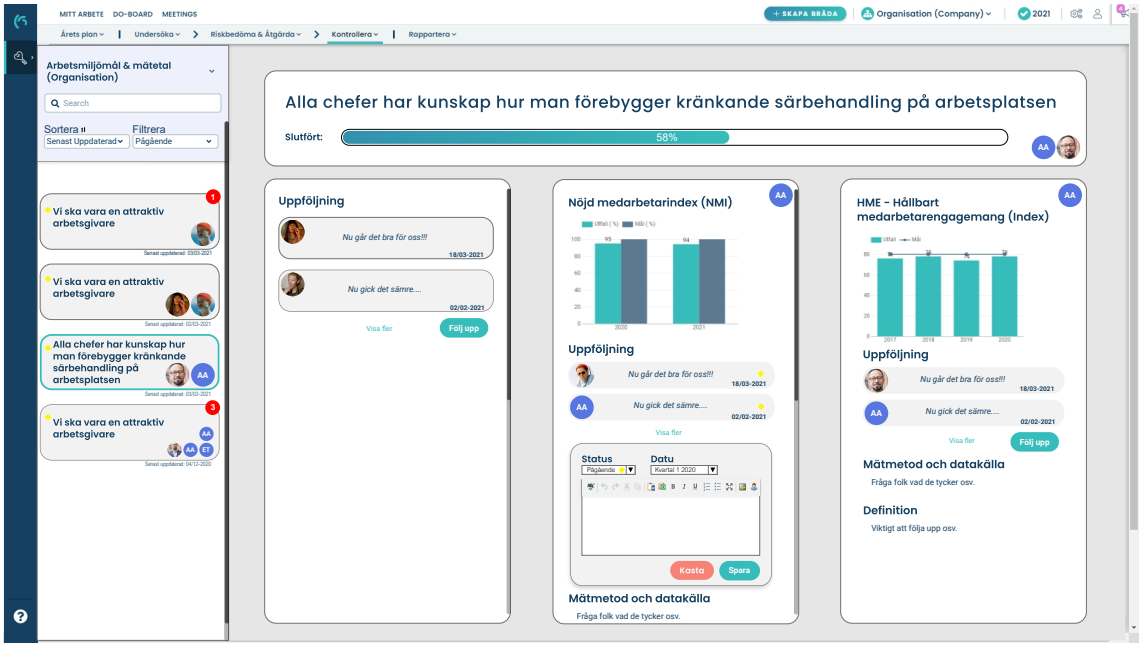

Figure 6.18: Focus View - Vertical aims to provide an overview of the child elements when a parent element have been selected.

Focus View Reversed, as seen in figure 6.19, is a variation of the concept used in Focus View Vertical. In this version, the parent elements and the more detailed child elements have reversed position and focus on the screen. In Focus View Reversed, the larger area of the screen is used to provide an overview of the available parent elements with some additional details. The details panel, located to the right, is used to access more details about an element.

Figure 6.19: Focus View - Reversed i similar to the Focus View - Vertical (figure 6.18), but aims to provide an overview of the parent nodes instead.

Tags, as seen in figure 6.20, is a concept well known to many users. It makes use of so-called tags, that can be attached to objects, to highlight attributes or themes of the object. A tag can also be called a keyword. One of the benefits is that tagging enables making flexible groups that can be used for filtering and searching.

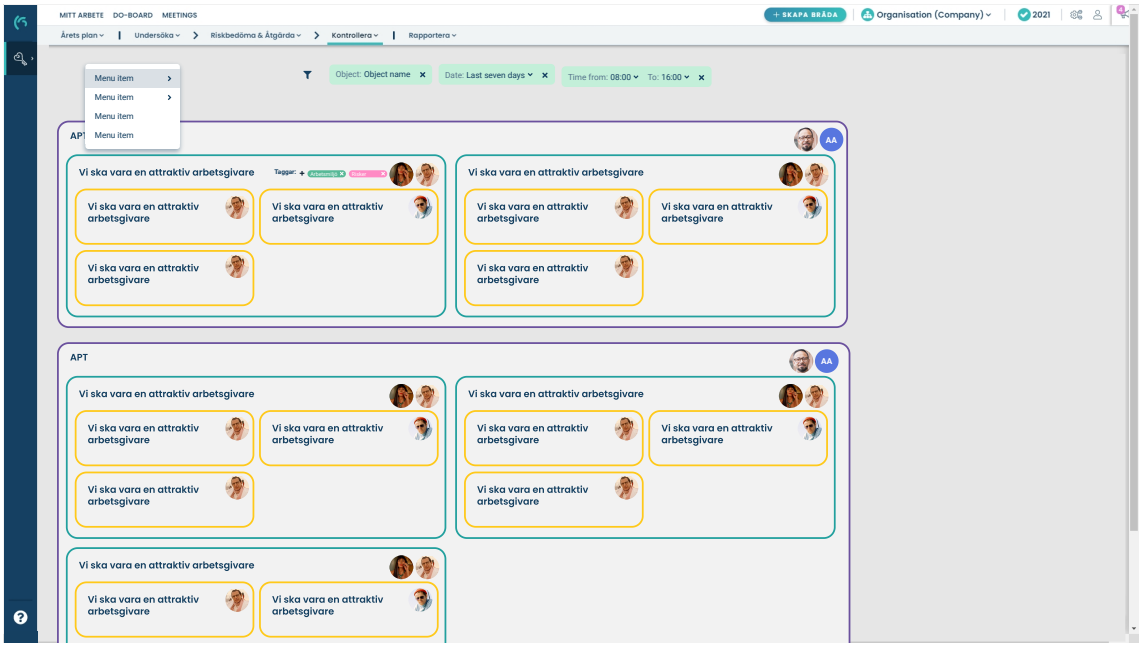

Figure 6.20: Tags is an experimentation of allowing the users to tag their information to facilitate in sorting, filtration, searching and comparison. It is not a stand-alone view, but rather a complement to any other visualization.

Tree Structure, as seen in figure 6.21, is an attempt at reducing the amount of white space in Stratsys' Connecting Thread view. The structure is the same as in Connecting Thread, but it is arranged in a way that is more space-efficient. As the number of nodes is commonly increasing for every step downwards in Stratsys' hierarchies, the highest level node is placed in the centre. For every new level, the nodes are placed on the outside of the level before, which gives an area that is expanding together with the diameter of the content on the previous level.

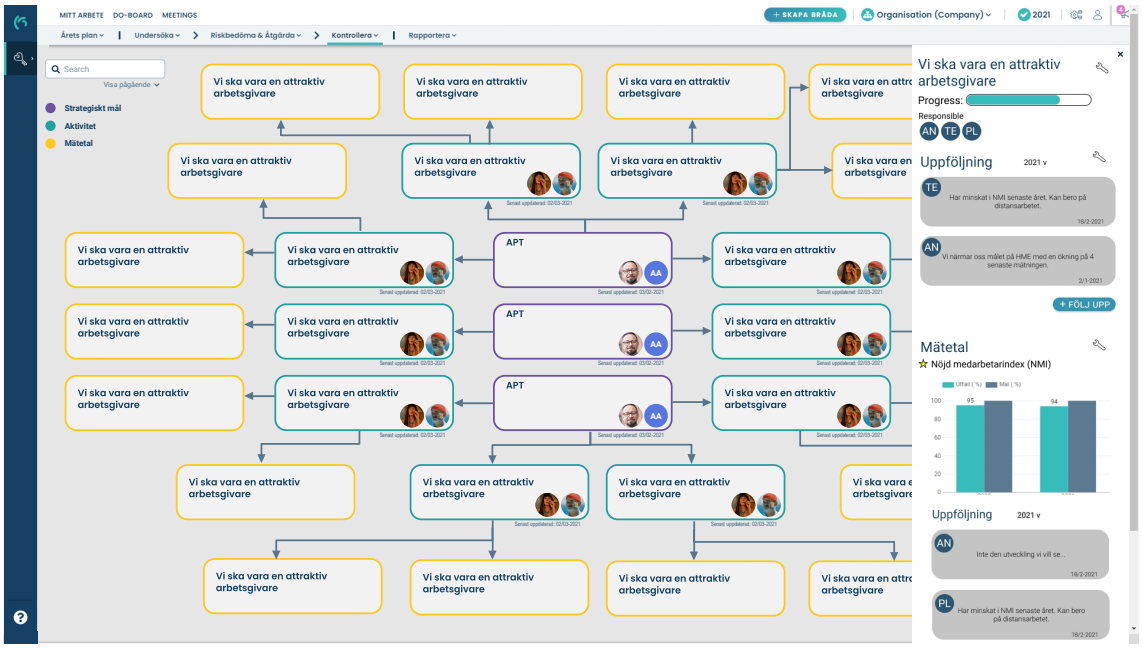

Figure 6.21: Tree Structure - Details is an example of how to access more detailed information from the Tree Structure visualization.

Zoom and Pan, as seen in figure 6.22, is a concept that is not stand-alone, but can be used together with other concepts, for instance Tree Structure or Enclosure. The concept's main benefit is that it enables the user to see the entire structure at once, while also being able to zoom in on chosen objects. The minimap in the top right corner can be used to see where in the structure the visible objects are, the minimap is a component that was initially constructed as a seperate concept.

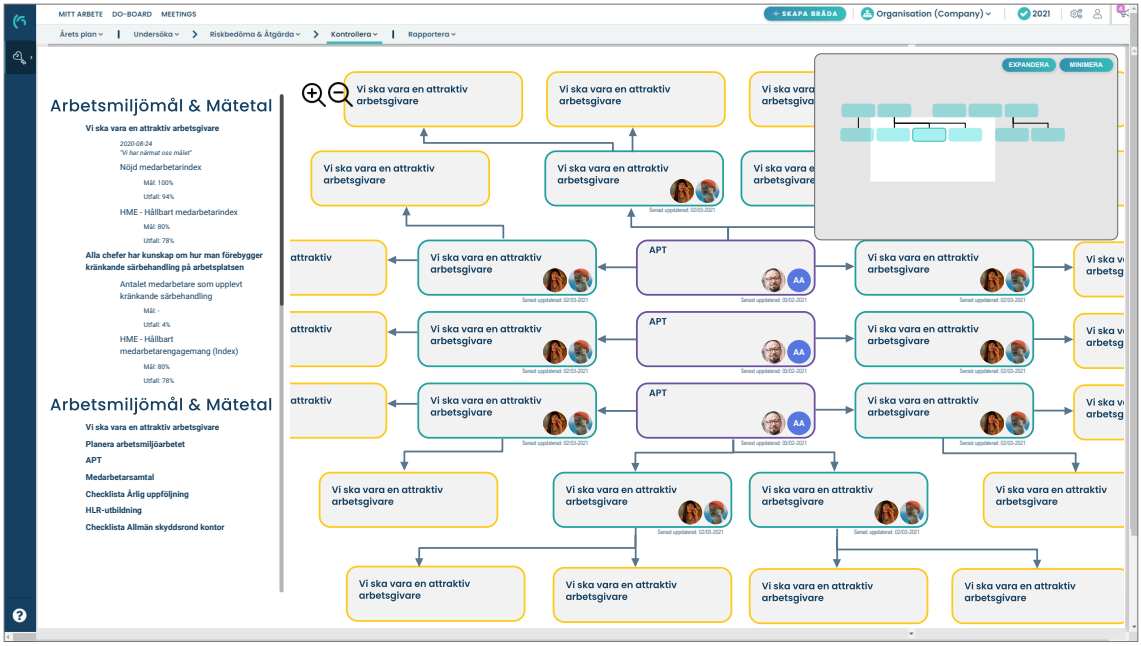

Figure 6.22: Zoom and Pan is an example of how larger amounts of data could be handled by the Tree Structure (figure 6.21) visualization. It incorporates elements from the Indentation List (figure 6.15) and the Mini Map (figure 6.23).

The concept Mini Map, as seen in figure 6.23, is meant to be used in an interface such as in the concept Zoom and Pan where the user can navigate their way through the visualization in multiple directions. The Mini Map uses a design language that is commonly used in games, but also in some visualizations.

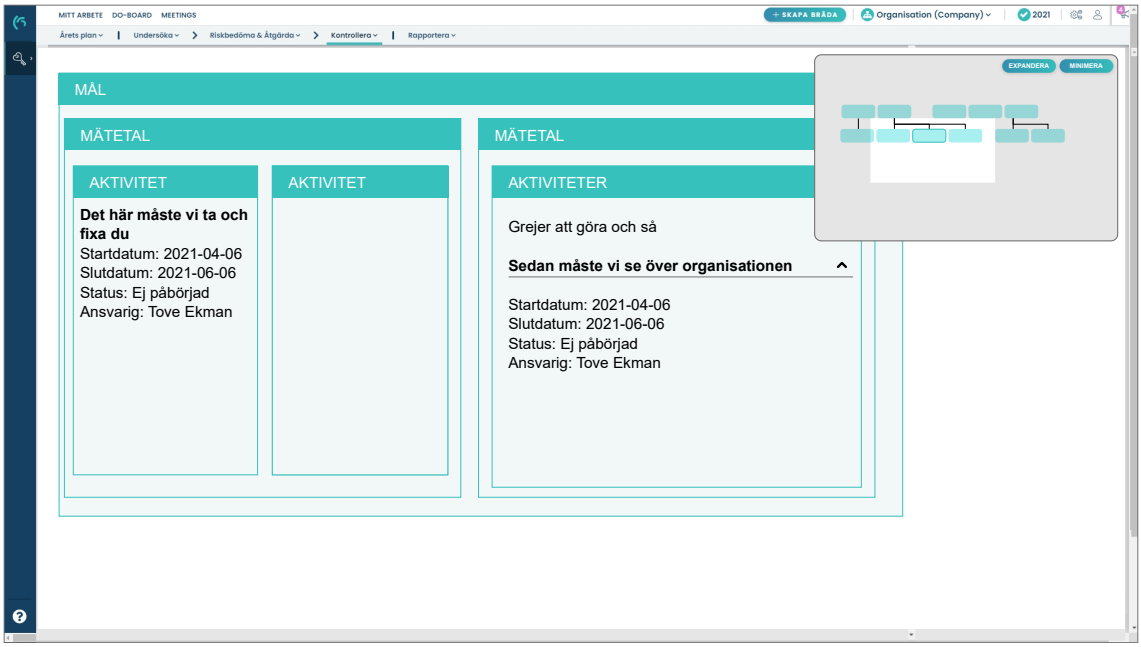

Figure 6.23: Mini Map is similar to Zoom and Pan and allows the user to navigate through the visualization by clicking and dragging in the mini map or the main screen.

Table 6.7: Concept classification based on the evaluation.

Pursue	**Complementary**	**Discard**
Enclosure	Tags	Mini Map
Focus View Vertical	Tree Structure	Focus View Horizontal
Focus View Reversed	List Overview	
Zoom and Pan	Indentation List	
Checklist		
Goals Overview		

Evaluation Results - Iteration 1

Based on the evaluation, two concepts were removed. The first concept that we chose to remove was Focus View Horizontal, due to the vertical version of the same concept utilise the screen space more efficiently. The second concept that was removed was Mini Map, as this concept was similar to the Zoom and Pan concept that we chose to focus on instead.
During the evaluation, we also found that some of the concepts were not suitable as stand-alone implementations, but could be useful as complements to other visualizations. This applies to the concepts Tags, Tree Structure, List Overview and Indentation List.
The result of the elimination process was two eliminated concepts and five complementary concepts. This resulted in five main ideas to pursue in the next iteration.
The results from conducting the evaluations can be found in table 6.7.
The compiled results from the SWOT analysis, as well as the SWOT diagrams, can be found in appendix D.
The evaluation revealed that the concepts Tags, Tree Structure, List Overview and Indentation List have properties that can be useful for the users. However, they do not work as a stand-alone concept and will therefore only be used as a complement to other concepts.
The concepts that showed the greatest opportunities and strengths in the evaluation include Enclosure, Focus View, Focus View Reversed, Zoom and Pan, Checklist and Goals Overview.
Furthermore, the evaluation revealed problems within the concepts, such as: messy visualization, lots of blank spaces, lack of overview and visualization not being space efficient. These problems need to be resolved in upcoming iterations. A summary of the takeaways from the evaluation is presented below.

Iteration 1 Takeaways

Tree Structure

Provide an overview of the information structure in a more space-efficient way than Stratsys current solutions.

The Structure is somewhat messy and the amount of available detailed information is limited.

It is not made clear how the nodes should be distributed and how to implement the distribution.

May be beneficial to be combined with Zoom and Pan for bigger visualizations.

May be beneficial to include a Indentation List as a side panel to facilitate navigation and to provide an additional overview.

Enclosure

Potential to be a space-efficient solution with a clear structure.

The current implementation is not space-efficient when the number of nodes is uneven, as an uneven amount renders blank space in the visualization.

May be beneficial to be combined with Zoom and Pan for bigger visualizations.

May be beneficial to include a Indentation List as a side panel to facilitate navigation and to provide an additional overview.

List Overview

Potential to provide a good overview of the information.

The user can drill down in the visualization to access more information, which may enhance the focus for the user.

The space efficiency is limited due to the large amount of blank space to the right of the lists.

There is no way for the user to compare child nodes since only one parent node's content can be shown at once.

The space efficiency is a deal-breaker. The concept may however have potential in combination with other concepts, such as Goals Overview.

Tags

The concept of Tags is widely known to users and commonly used in applications and on websites.

The concept may provide additional opportunities for filtering and search options.

The tags used needs to be memorised, which may affect the cognitive load negatively.

If the tags are not commonly used, they may just be seen as clutter in the interface.

Tags is not a stand-alone concept but may be used as a complement to other concepts.

Iteration 1 Takeaways

Mini Map & Zoom and Pan

Zoom and Pan and Mini Map were initially considered to be two separate concepts but after evaluation, we could see that they are very similar to each other and should therefore be combined into one concept.

The concept provides the user with a highly interactive interface that is flexible.

The concept can yield an overview of the information when it is zoomed out.

The Zoom and Pan concept has the potential to be combined with Tree Structure or Enclosure.

The Indentation List could be used in a side panel as an additional navigation alternative.

The concept is not a visualization in itself, but rather a navigation concept, and could be used with different visualizations where the users can choose how to represent the data.

Indentation List

May provide a space-efficient representation of the information with clear hierarchies.

Text-based visualization is space-efficient and a lot of information may fit on the screen in this concept.

Using only text as representation for the information does not provide the best user experience.

May be best suited as a complement to other, more visual approaches.

Goals Overview

May provide easy access to common goals.

May enable a lot of filtering options.

There is no way to overview the child nodes, as well as no way to compare these.

The interfaces may be confusing for first time users, due to not following the current structure of information in Stratsys.

Accessing detailed information may be cumbersome since it is not available in the same view.

Focus View

Collects a lot of information and functionality in one place, which may be beneficial.

Provides a focus on the progress of a goal.

Provides an overview of the child nodes within a parent node.

Is inviting for interactions.

Does not provide a good overview of other parent nodes and their content.

It may not be very space-efficient and the concept may not be suitable for smaller screens.

Iteration 1 Takeaways

Focus View Reversed

May provide a good overview of parent nodes and their content.

Each node takes up a large amount of space in the current implementation, which may result in a lot of scrolling to access other nodes.

Checklist

Simple layout that fits a lot of content on the screen.

It does not feel intuitive to have two columns.

The horizontal space could be used for detailed information rather than the second column,

6.3.6 Discussion - Iteration 1

Due to the limitations described in section 1.6, the entire iteration was carried out remotely. Working remotely may have affected the outcome, due to lowered motivation and lack of inspiration. Furthermore, working remotely may result in working in suboptimal conditions, due to the home environment not being optimised for work.

Ideation Discussion - Iteration 1

The ideation phase was initiated by the how might we (HMW) method. This method resulted in a list of features that could function as a to-do list. The How Might We method may have facilitated keeping the ideation more focused.

Based on the HMW questions, a brainstorming session for each question took place. This resulted in several brainstorming sessions being conducted after each other. This may have affected the result, due to the participants getting more and more tired for each session. Limiting the number of questions to be ideated on may facilitate keeping the participants alert and thereby provide a higher quality of the brainstorming.

Based on the brainstorming, we used pen and paper to create sketches of the ideas, which were then translated into wireframes. By keeping the sketching process from digital tools, it may have been easier to focus on generating ideas rather than focusing on details and tools.

When we felt that we got stuck during the prototyping phase, we used the crazy 8's ideation method to generate more ideas and to get into a more creative state of mind. By conducting the crazy 8's method in the middle of prototyping, more concepts were constructed and earlier concepts were refined. Going back to ideation from prototyping may facilitate creative thinking and less detailed focused prototyping.

Prototyping Discussion - Iteration 1

Since we used sketching and wireframing as ideation in this iteration, there was no clear distinction between the ideation and prototyping phases and therefore, no formal idea selection method took place. Instead, the ideation became prototyping when we transferred the sketches done on paper to digital prototypes in Adobe XD. Since this iteration focused on generating a large number of ideas with great variety, there is no indication that the lack of a formalised idea selection affected the outcome negatively.
The prototypes in this iteration were planned to be of low fidelity to facilitate critical thinking and to preserve time to be able to construct as many prototypes as possible. However, the wireframes constructed had higher fidelity than anticipated, mainly due to the usage of Stratsys' design library, which may have resulted in a more time-consuming prototyping phase. Another effect the higher fidelity prototypes posed was that constructive criticism may have focused more on the details than what is appropriate in this stage of the project. The team members had to occasionally remind each other to not focus on the details, but rather on the underlying concept. Due to the wireframes being of higher fidelity and therefore more time consuming to create, fewer prototypes may have been constructed. However, the ideas that we considered to be feasible and relevant for the project were prototyped.
To save time and due to the intention of creating prototypes of lower fidelity, we did not prototype any sequence of interactions and system responses. This resulted in wireframes that more resemble screenshots of the concept, rather than software.
Using data from a mock database in Stratsys facilitated in creating prototypes that will work for that kind of data. By using mock data, we could see what amount of text is commonly used and thereby adapting the size of the containers to that. However, since this was not planned to be the focus of this iteration, but rather something for later iterations, this may have affected the prototypes in a way that was not intended for this iteration.

Evaluation Discussion - Iteration 1

During the heuristic evaluation, we noticed that this method might not be appropriate for prototypes of low fidelity, as many assumptions had to be made about the concepts to evaluate it according to the heuristics. These assumptions in turn render the evaluation results arbitrary. The SWOT analysis felt more appropriate for low fidelity prototypes, as it addresses known strengths and weaknesses, and these can more easily be discussed regardless of the prototypes' fidelity.
The results from the evaluation were not solid enough to determine which prototypes that are worth pursuing and which are not. The results from the evaluation methods chosen may be more valuable to determine what needs to be changed and what works well for further design iterations. While the results can be used to argue for why certain concepts were eliminated and why others were deemed as only work as a complement for other visualizations, the decisions were based on two factors that the formal evaluations did not answer.
In total, ten concepts were kept to be further iterated upon. The number of concepts was considered to be suitable for Iteration 2, where the number of ideas was planned

to be narrowed down further through user testing.

6.4 Iteration 2

Iteration 2 focused on refining and evolving the prototypes created and evaluated in Iteration 1. The information gathered through the evaluation phase in Iteration 1 was incorporated and further refinements were done. The iteration began with presenting the results from the previous iteration to our mentor at Stratsys, UX designer Carin Andersson-Sarning. She suggested adding a prototype of scorecards, which was not done in Iteration 1. According to Andersson-Sarning, scorecards is something that is sought after by Stratsys users. She also said that checklists are already being redesigned by Stratsys, which indicates that checklists may be outside of our scope.

6.4.1 Ideation - Iteration 2

The ideation phase of Iteration 2 focused on refining and further evolving the prototypes developed and evaluated in iteration 1.

How Might We - Iteration 2

The ideation phase started with the How Might We method, where 10 questions concerning the findings from the previous evaluation were formulated. The constructed How Might We questions can be found in table 6.9.

Table 6.9: List of questions posed for the Mow Might We method in Iteration 2.

#	**How Might We Questions**
HMW1	How might we make Enclosure more space efficient?
HMW2	How might we visualise details in Goals Overview?
HMW3	How might we make Focus View - Reversed more space efficient?
HMW4	How might we present a better overview in Focus View - Vertical?
HMW5	How might we visualise more measurements and activities in Focus View - Vertical?
HMW6	How might we make Tree Structure less cluttered?
HMW7	How might we make it easier to locate data in Tree Structure?
HMW8	How might we present details in Tree Structure?
HMW9	How might we change the layout in Zoom and Pan when new nodes are added?
HMW10	How might we make Checklists less static?

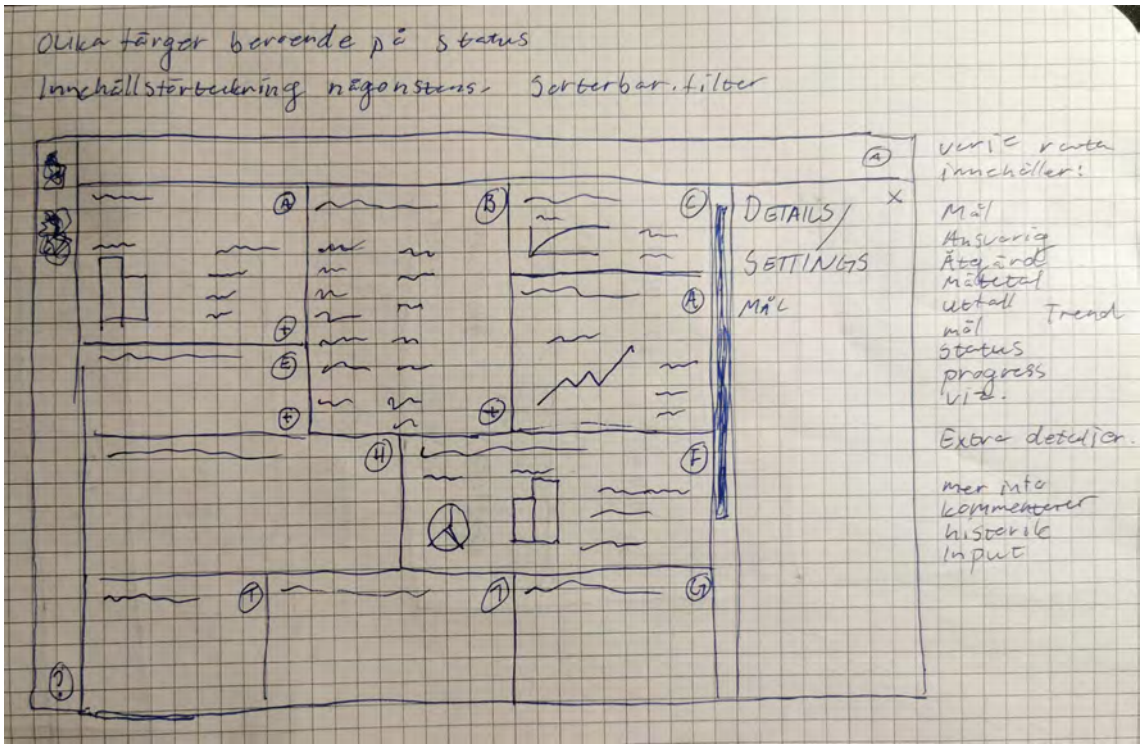

Figure 6.24: Sketch of the concept Scorecards.

Sketching - Iteration 2

The HMW questions were ideated individually through sketching, as opposed to brainstorming since this iteration focused on more qualitative idea generation. The sketching was carried out individually and remotely. The sketching was done with pen and paper and the results were shared and presented to the other team member through Slack and Google Drive. The sketching was based on the How Might We questions, but additional sketches were also created, based on ideas and concept that were outside of the How Might We questions. Figure 6.24 shows an example of how the concept Scorecards looked in the sketching state. Figure 6.25 shows an example how how the concept Enclosure were sketched with different solutions and layouts.

6.4.2 Selecting Ideas to Pursue - Iteration 2

Similar to Iteration 1, no formal method for selection ideas to pursue in the prototyping was conducted. The reason for doing this was that the smooth transition between ideation and prototyping worked well in Iteration 1 and therefore this was done in this iteration as well.

6.4.3 Prototyping - Iteration 2

The prototypes in this iteration were constructed as wireframes in Adobe XD.

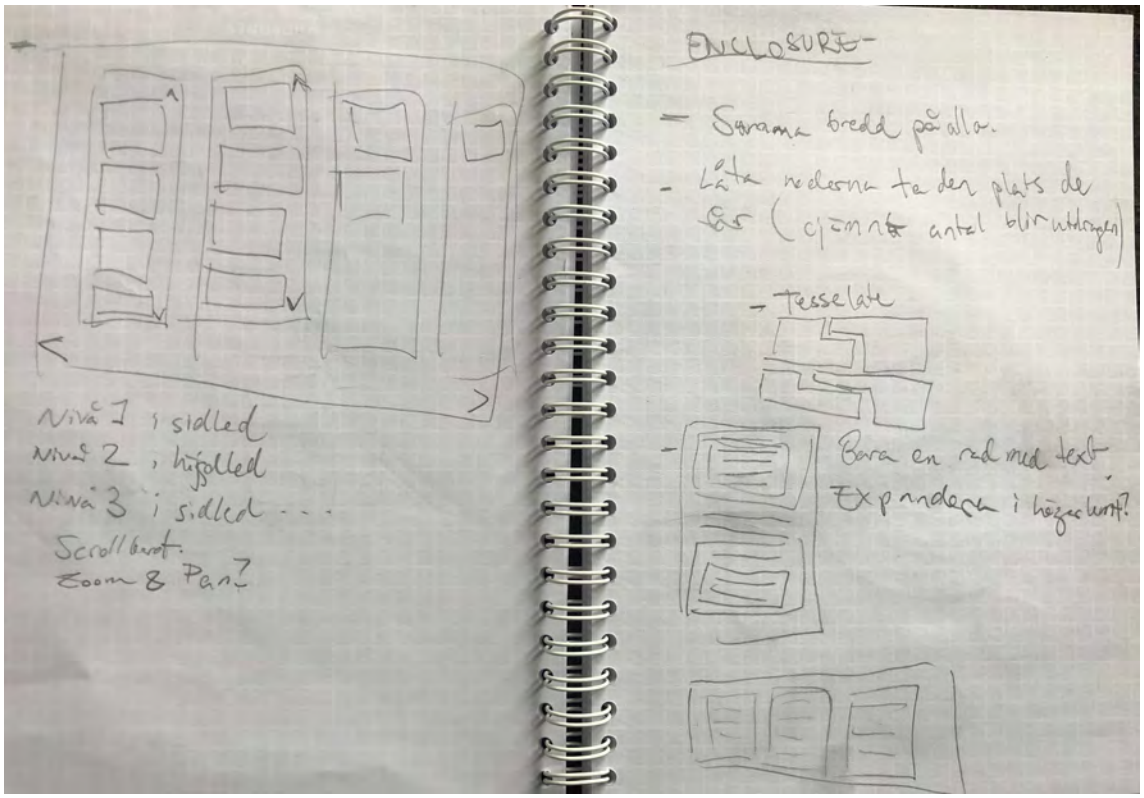

Figure 6.25: Sketch of the different alternatives for the concept Enclosure.

Wireframing - Iteration 2

The wireframes created in this iteration were largely a continuation of the wireframes created in the previous iteration. Components and layout from Iteration 1 were largely reused. Two of the prototypes created incorporated interactions and navigation to showcase what the user can do and also to showcase where the user can find information and where to edit the data. The interactions created were simple and relied on navigating from one view to another. Images and descriptions of the prototypes can be found in appendix G and in section 6.4.5.

6.4.4 Evaluation - Iteration 2

The prototypes developed in this iteration, as well as the concepts Focus View and Zoom and Pan from Iteration 1 were evaluated through interviews and questionnaires with current users of Stratsys. The participants were to a large extent the same as in the user research phase. However, since not all of them were available, new participants were found. In the cases when we sent the same email to several users, we used the bcc function so that the users could not see the other participants' email addresses. The evaluation aimed to select a maximum of three concepts for continued development in Iteration 3.

Interviews - Iteration 2

The interviews were prepared before interviewing the users. We planned to conduct a pilot interview as preparation. However, no pilot interview was conducted, due to time constraints and a low number of available participants. Only two of the five participants from the interviews made during the user research phase accepted to participate in a second interview, and the participant from the previous pilot interview was not able to participate. We asked our mentor at Stratsys, UX designer Carin Andersson-Sarning about finding more participants. She reached out to a few consultants at the company, out of which one accepted. This gave us a total of three persons to interview. We considered that using one of them to conduct a pilot interview would be less beneficial than making three interviews.
In total, three interviews were conducted over Microsoft Teams. The interviewees were informed of the data usage and asked for consent to be recorded. The prototypes were shown to the participant, accompanied by prepared questions. The prepared questions for the interview are shown in table 6.10. Additional questions were asked where appropriate. After the first interview, we noticed that question IQ6 and IQ7 were very similar and the responses were to a large extent the same for the two questions. Therefore, question IQ6 was removed for the next two interviews. The participants were encouraged to view the prototypes as if they were sketches and they were reminded that all feedback is important, both positive and negative. The participants were also encouraged to provide feedback on additional features and changes that could increase the user experience in the concepts. Furthermore, the interview participants were asked to state which of the concepts they thought should be further developed in our next iteration and which of the concepts are least relevant for their work.

Table 6.10: List of interview questions from iteration 2. IQ = Interview Question.

#	**Interview Question**
IQ1	What is your first impression of this concept?
IQ2	Is there anything that you find unclear or vague?
IQ3	What do you think are the strengths of this concept?
IQ4	What do you think are the weaknesses of this concept?
IQ5	Do you think this concept would be beneficial to you and your work?
IQ6	Is there anything that you think is missing from this concept?
IQ7	Do you have any proposed changes or improvements for this concept?

Questionnaire - Iteration 2

The questionnaire was sent out through Google Forms to a total of seven users. The questionnaire consisted of images of the prototypes, followed by six questions for each where the user was asked to describe what strengths and weaknesses they believe that the concept has. The questionnaire questions can be found in table 6.11. For three of the concepts, the users were also asked to pick which alternative

they prefer. The questionnaire was finalised by asking the users to sort the concepts based on which they thought would be most useful in their work.

Table 6.11: List of questionnaire questions from iteration 2. QQ = Questionnaire Question.

#	**Questionnaire Question**
QQ1	How well do you think this concept provides an overview of the information (1-7)
QQ2	How well do you believe this concept would support you in your work? (1-7)
QQ3	What do you think this concepts strengths are?
QQ4	What do you think this concepts weaknesses are?
QQ5	What do you believe this concept could be used for?
QQ6	What, if anything, do you think this concept provide that Stratsys currently do not?
QQ7	Rank the concept based on which you think would be most beneficial for you (1=best, 7=worst)

Analysis - Iteration 2

The data gathered through the interviews and questionnaire was to a large extent qualitative data, which renders a more time-consuming analysis process. The responses for each question in both the questionnaire and the interview were transferred to an adapted SWOT diagram to provide a more collected picture of the results from the two evaluation techniques. The matrices were constructed in the online collaboration tool Miro[4] which is a tool that simulates sticky notes. One matrix was constructed for each of the concepts, which gives a total number of seven matrices that can be found in appendix E. An example of the diagrams can be seen in 6.26. The adapted SWOT diagrams consisted of the sections *Strengths, Weaknesses, Use Cases, and Novelties*. The section names were chosen so that the diagram would reflect the questions asked during the evaluation. The section Use Cases describes how the different concepts could be used, to find if there are differences between the concepts. The section Novelties includes notes of what the particular concept could contribute to Stratsys that does not already exist. This section could then be used to facilitate in prioritising the concepts, due to a lack of novelties may be interpreted as the concept as not being needed. The *Notes/Comments* section was used for suggested improvements or comments that did not fit into any of the four sections. Blank notes represent questionnaire participants that did not leave any reply to the corresponding question.
The quantitative data from the questionnaire was transferred to bar graphs to visualise the differences. The quantitative data from the overview assessment is presented as the red colour in figure 6.27, the data of how valuable the concepts are

[4]https://miro.com/

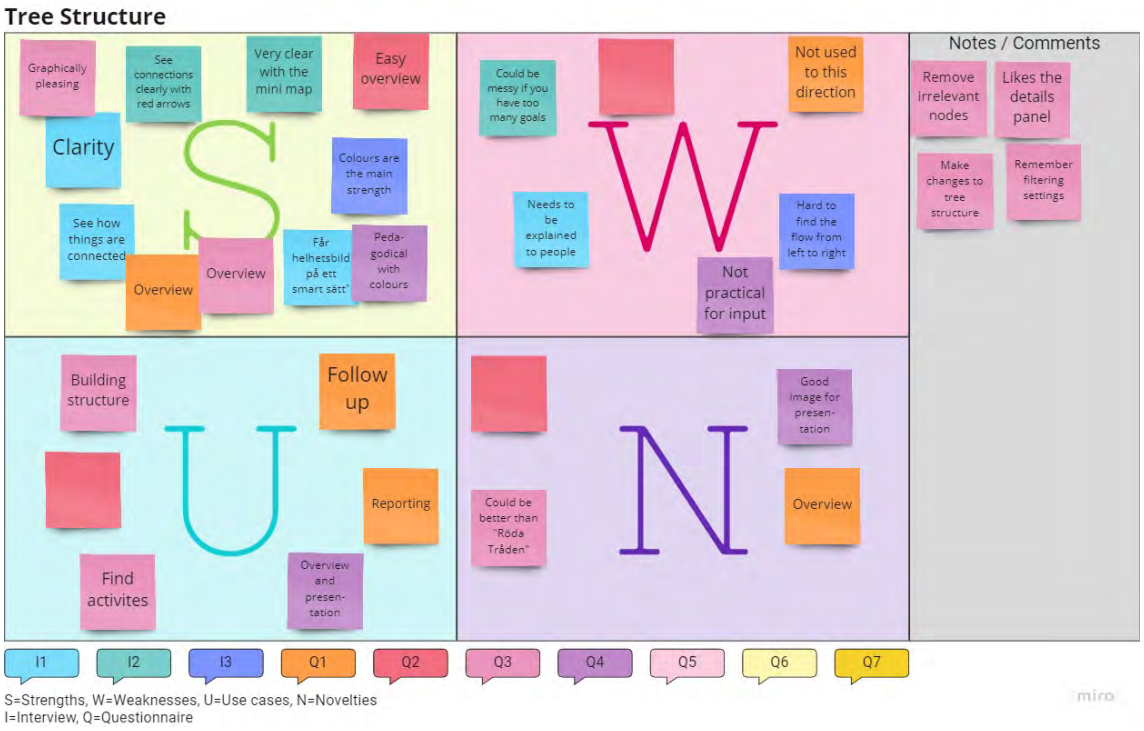

Figure 6.26: 2x2 Decision Matrix for the concept Tree Structure.

for the users' work is represented in blue in the same figure. This data is based on the questions QQ1, how well do you think this concept provides an overview of the information, and QQ2, how well do you believe this concept would support you in your work, that were asked for each of the concepts.
The data from the ranking question at the end of the questionnaire is represented in figure 6.28. This data was not considered to be reliable due to inconsistent responses from users where the least favourable concept in other data is deemed as the best concept based on this data. The reasoning behind excluding this data while selecting concepts to pursue is further described in section 6.4.6

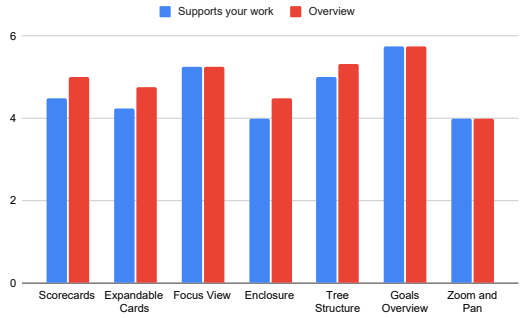

Figure 6.27: Data from the questionnaire. Higher is better.

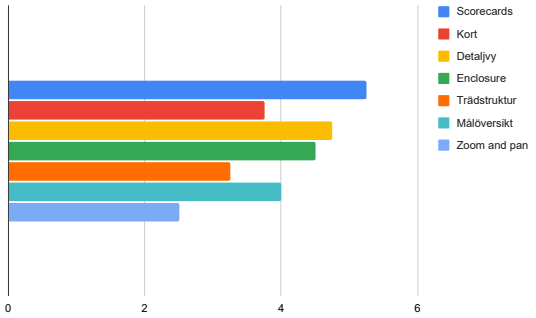

Figure 6.28: Data ranking question from the questionnaire. Lower is better.

The compiled results from the evaluation did not give a clear answer to which concepts should be pursued in Iteration 3. To be able to decide which concepts to

continue working on in Iteration 3, we consulted our contacts at Stratsys to see if they had any preferences.

Interview with Stratsys

To further facilitate in selecting which concepts to pursue, an interview with employees of Stratsys design department was scheduled. The two concepts that were deemed as least valuable for the users were removed from this interview. The five remaining concepts were presented to the participants, and they were asked which of the concepts they believe is the most relevant and valuable for their platform.

6.4.5 Results - Iteration 2

This section will describe the resulting prototypes as well as present the results from the evaluation.

Prototyping Results - Iteration 2

In this section, the concepts that were expanded upon are presented. All of them build on concepts that were present in Iteration 1 6.3.5, but here they may be combined or have changed names since then.

The resulting concepts include Scorecards, Expandable Cards, Tree Structure, Goals Overview, Enclosure. More images and descriptions can be found in appendix G.

Scorecards is a concept that focuses on visualising measurements and trends for the measurements. Scorecards is a continuation of the Focus View - Reversed from Iteration 1. The information is laid out in cards and the background colour of each card visualises the progress of the measurement. The user can decide if the colour coding should be based on the trend, the outcome or something else. The colours used can also be changed by the user to accommodate their needs and preferences. The amount of measurements can be changed by the user as shown in figure 6.29 and figure 6.30. There is also an option to show 16 cards at once. Furthermore, to access more detailed information, as well as a declaration of the contents, a side panel can be accessed to the left, as shown in figure 6.31.

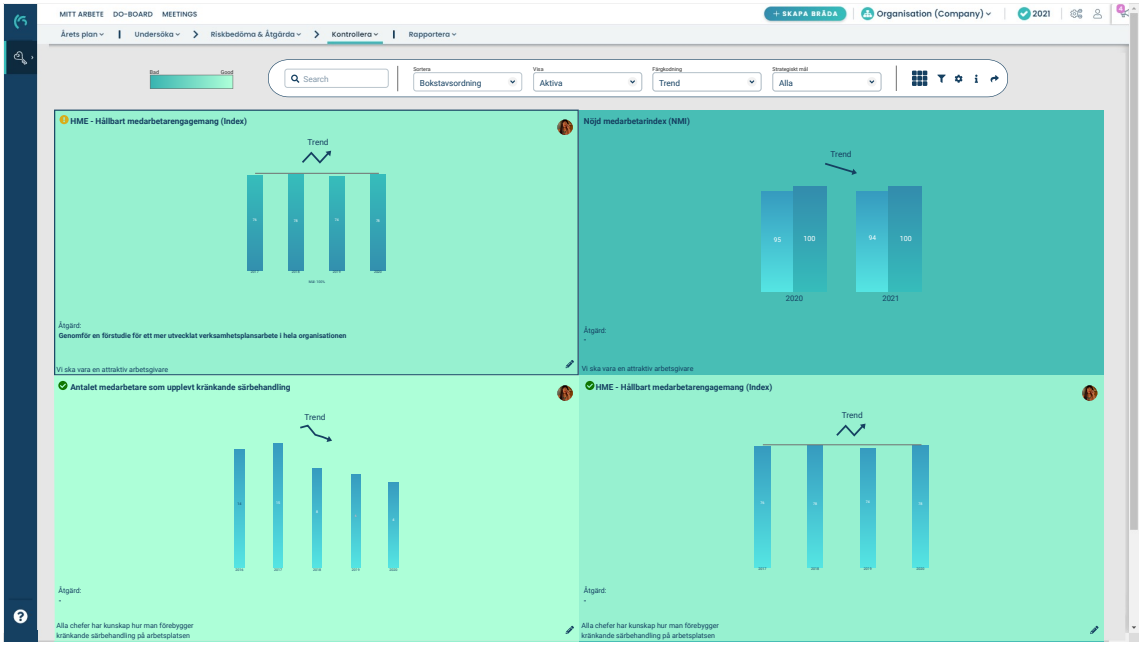

Figure 6.29: Scorecards - 4 showing four nodes at the same time.

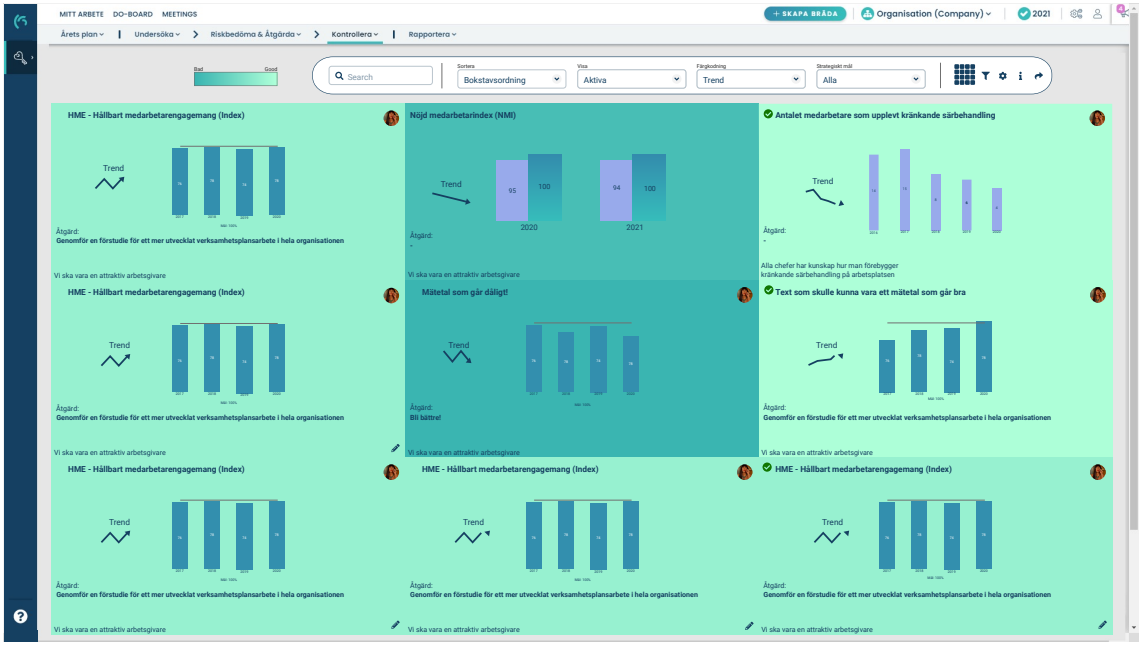

Figure 6.30: Scorecards - 9 showing scorecards with nine nodes.

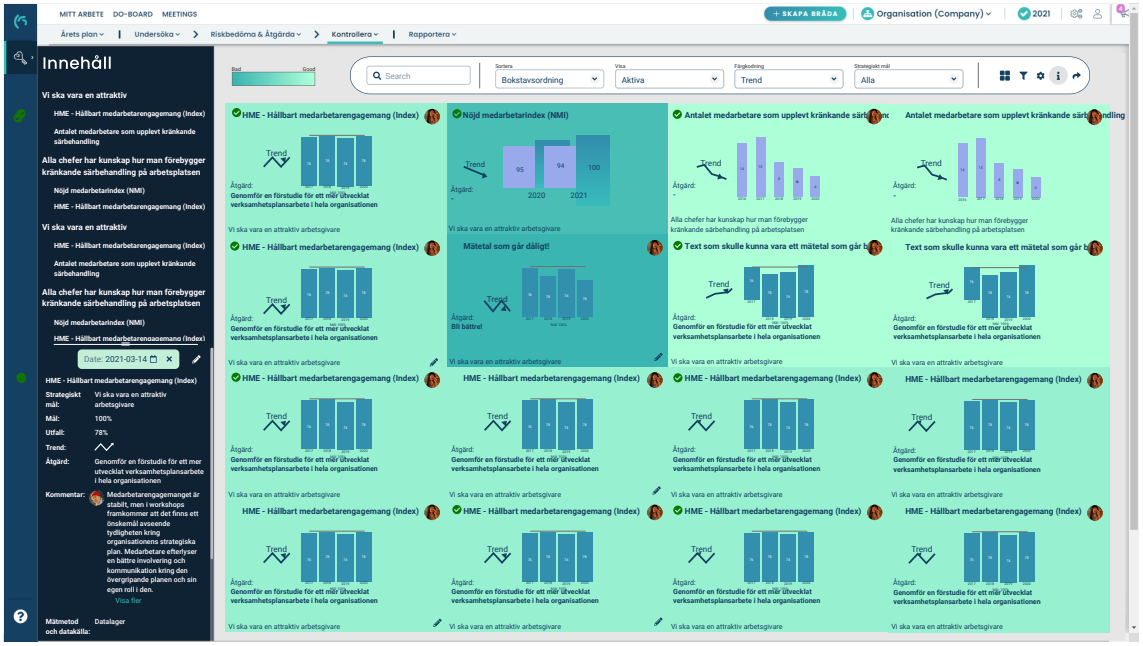

Figure 6.31: Scorecards - 16 with details showing scorecards with 16 nodes and the details view and table of contents on the left side.

Goals Overview is a continuation of the concept developed in Iteration 1. The prototype is described in section 6.3.5 on page 69. The first view of Goals Overview has not changed at all from the previous iteration. The view Goals Overview - Details in figure 6.32 were constructed in this iteration to showcase how to access measurements and activities that are linked to a goal. The information is displayed in an expandable list inside a pop-up window. While elements in the list are minimised, only information such as title, trends, responsible and dates are visible. When an item is expanded more detailed information such as comments, ability to add comment, graphs, goal, outcome and description is available.

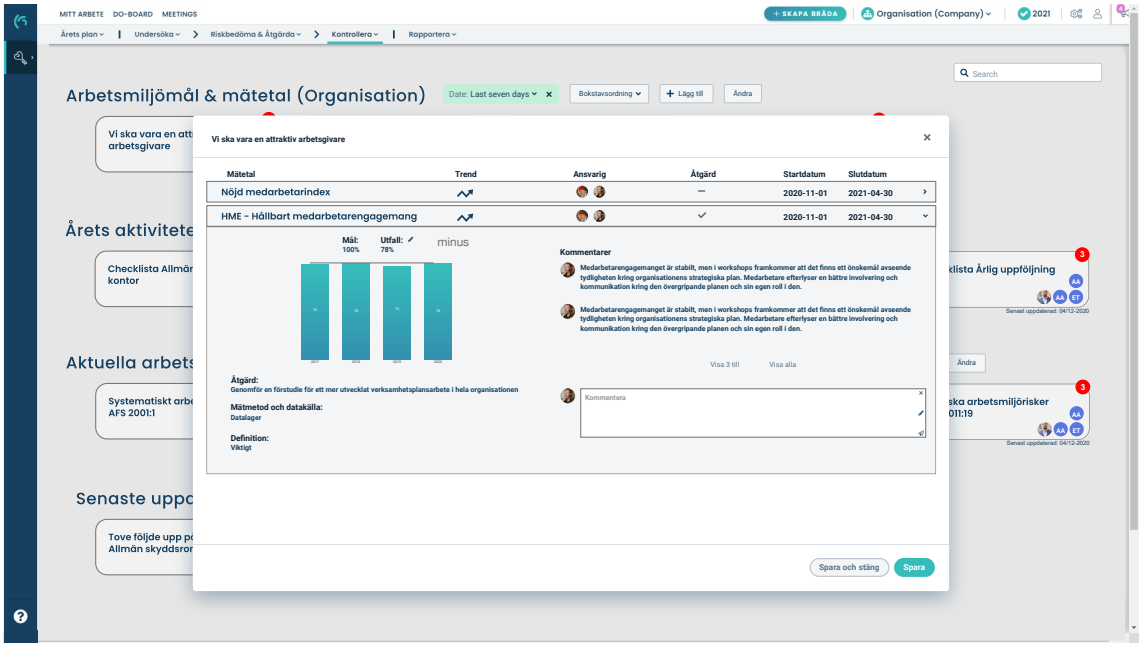

Figure 6.32: Goals Overview - Details represents how to access details in the Goals Overview from iteration 1.

Expandable Cards is a concept that focuses on providing an overview of the information that commonly occurs in checklists and regulations as well as measurements. The default layout of Expandable Cards is shown in figure 6.33. Three alternatives for how to accommodate the screen space while expanding a card were developed. Option A is illustrated in figure 6.34. In option A, the cards that are furthest away from the expanded card are reduced in size. The other two options can be found in appendix G, section G.3.

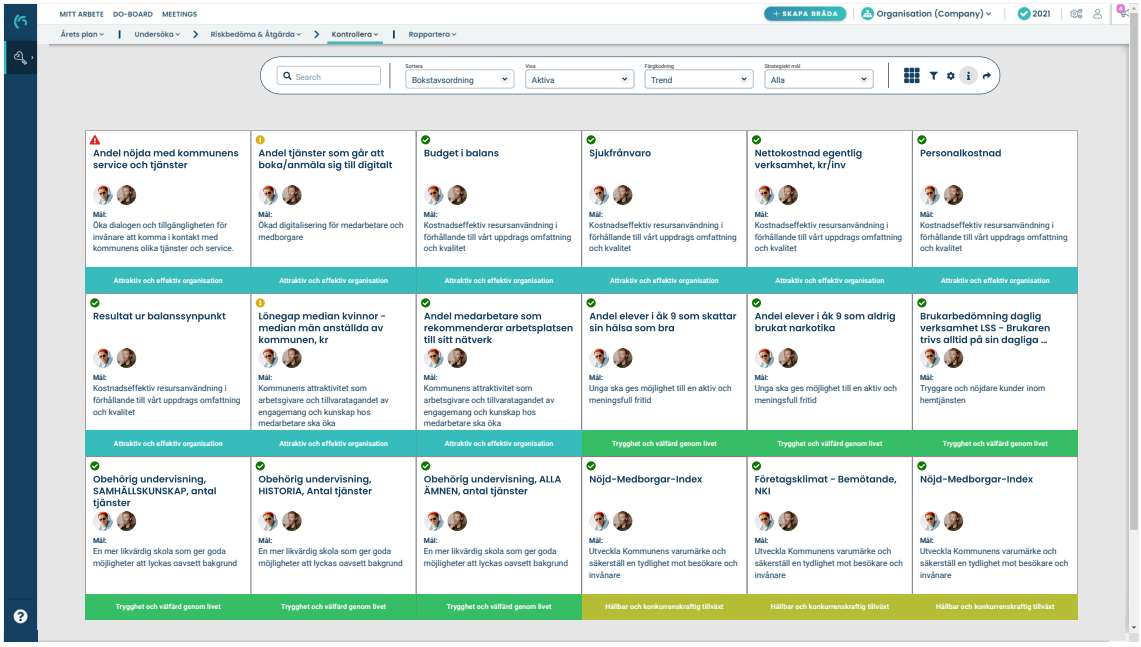

Figure 6.33: Expandable Cards provides an overview of measurements.

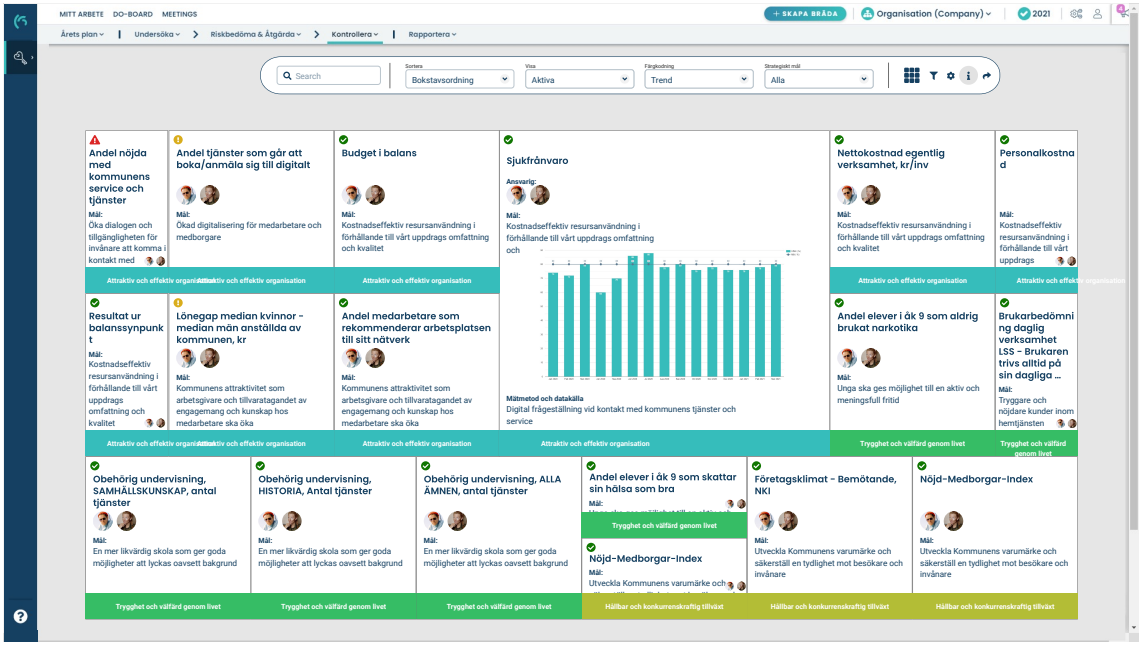

Figure 6.34: Expandable Cards - Details A shows an alternative for expanding cards, where the outermost cards gets smaller to provide space.

ENCLOSURE is a type of treemap that makes use of enclosure to visualise hierarchies. Every node is enclosed by the node that is its parent, and this is done recursively. In this iteration, three different styles of the concept have been evaluated.

In concept A, as seen in figure 6.35, the shape of the enclosing nodes are adapted to their content. This is done in an attempt to make the Enclosure idea more space-efficient, which was one of the issues that were raised in the evaluation of Iteration 1 6.3.5.

In concept B, as seen in figure G.18, the node on the top level is drawn out horizontally to form a rectangle. On the second level, the nodes are placed next to each other. On the third and final level, the nodes are placed on top of each other.

In concept C, as seen in figure 6.37, the nodes are placed next to each other on the top level. On all lower levels, the nodes are placed on top of each other.

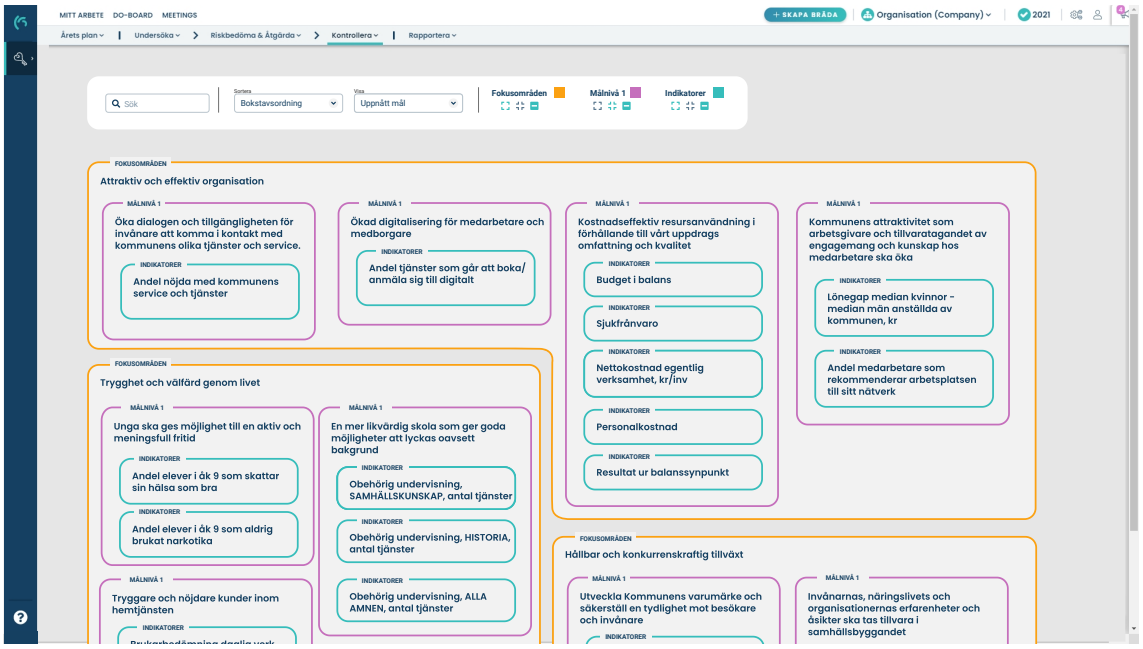

Figure 6.35: ENCLOSURE A with containers that adapts to their size and adjacent containers size.

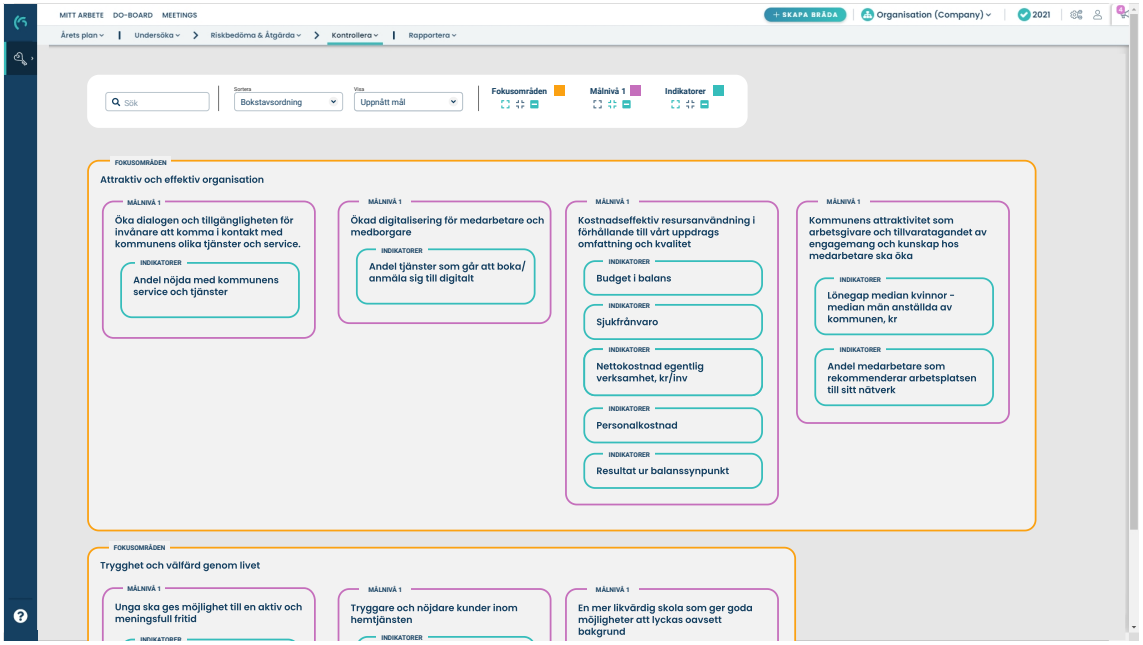

Figure 6.36: ENCLOSURE B - the highest node level is stacked vertically, the second is stacked horizontally, and the third is stacked vertically.

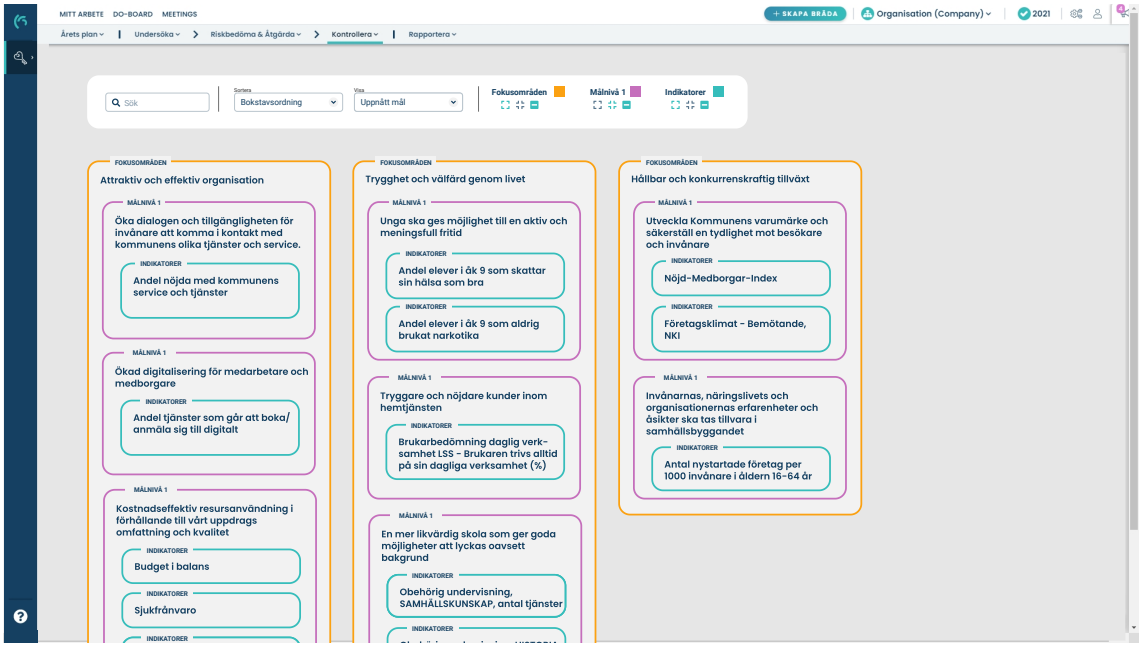

Figure 6.37: ENCLOSURE C with its content stacked horizontally. Additional nodes are put adjacent vertically. The view can be scrolled vertically.

Tree Structure is a concept that has been evolved into two different directions. In concept A, as seen in figure 6.38, the top-level nodes are placed together in the centre of the tree visualization, with their underlying nodes surrounding them. This makes all nodes on the same level create a somewhat circular shape, that can be colour coded to make the understanding of the structure more direct.

In concept B, as seen in figure 6.39, each top-level node is placed individually from the other top-level nodes. Each top node is placed in the horizontal centre of the screen, with its child nodes surrounding it to the sides and beneath, making each tree take the form of a half-circle. For every top-level node, there will be a similar tree. All trees are stacked on top of each other and can be accessed by vertical scrolling.

Both concepts can be combined with a details view, as seen in figure 6.40.

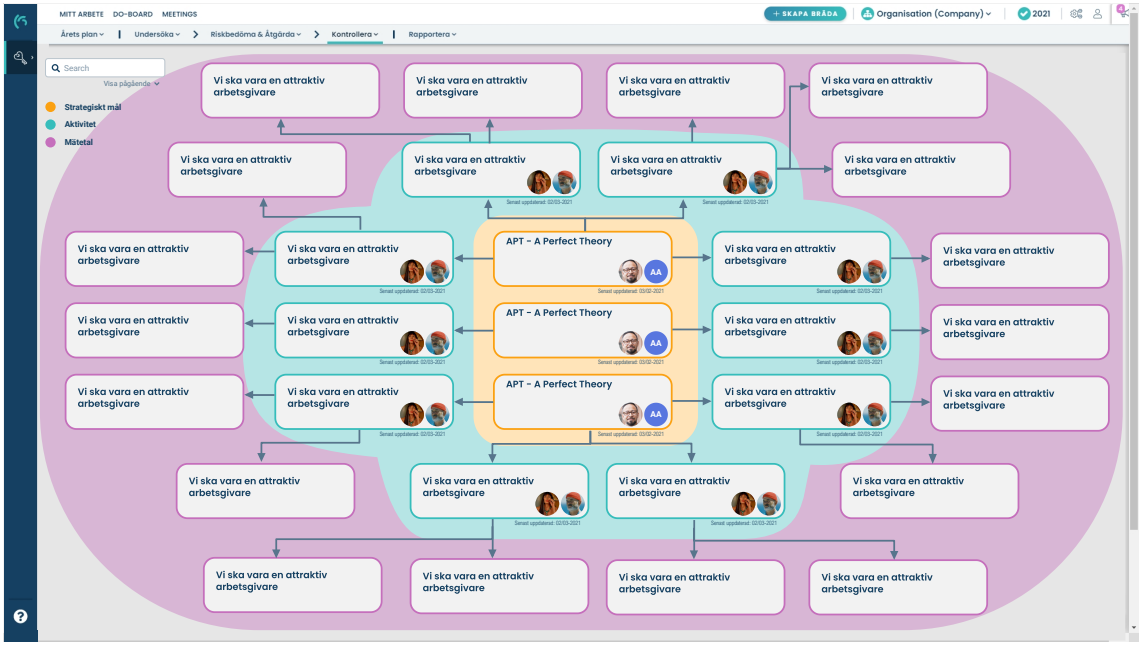

Figure 6.38: Tree Structure - Colour

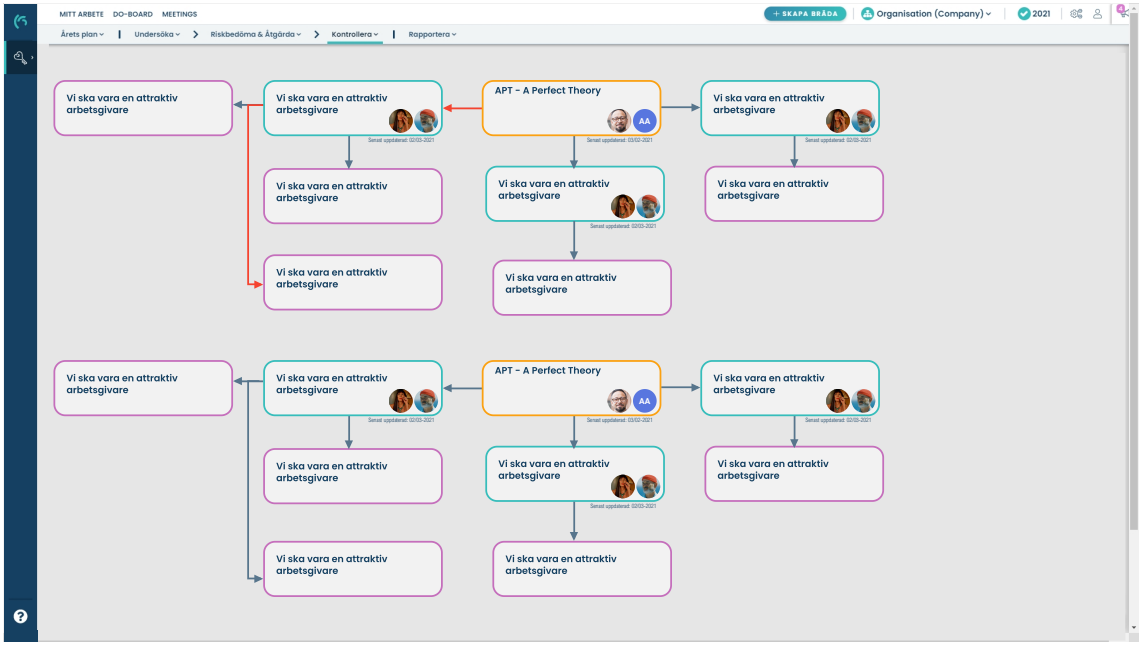

Figure 6.39: Tree Structure - Half Circles

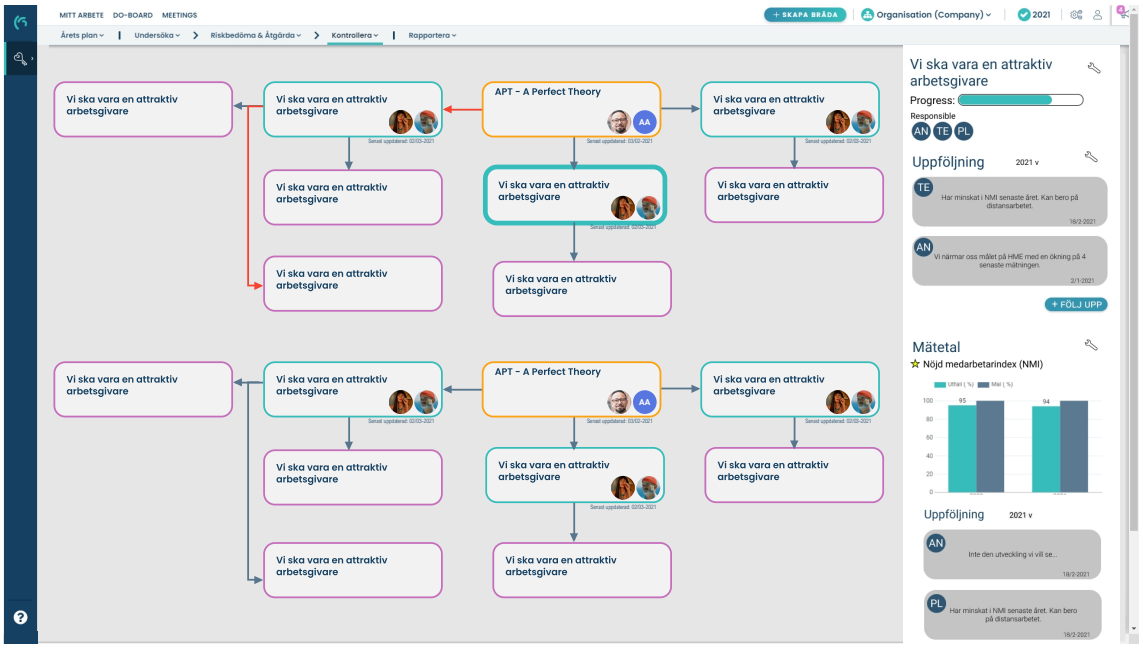

Figure 6.40: Tree Structure - Details

Evaluation Results - Iteration 2

The interview participants showed a preference of Scorecards and Tree Structure, whereas Goals Overview received the least enthusiasm. However, one of the interviewees stated that they could not understand the concept of Goals Overview. Another of the interviewees stated that they could not find any of our concepts to be relevant for them in their work and could therefore not suggest any preference.
After the evaluation and the meeting with Stratsys, the concepts that were deemed as most valuable for the users and Stratsys, based on the evaluation were Scorecards, Tree Structure and Expandable Cards. The evaluation also allowed us to compile a list of key takeaways that could be considered for Iteration 3. The list of takeaways is presented below.

Iteration 2 Takeaways

Colour Usage

Colour coded backgrounds may interfere with the contrast.

Colour coding can increase the comprehension of the structure.

Focus

Selected items should stand out visually, to increase the users focus.

Showing more information than is necessary for the user may be distracting.

Keeping detailed information close to the source may enhance focus for the users.

Being able to exclude irrelevant information may enhance the users' focus.

Showing detailed information in the same visualization, rather than a pop-up, may increase focus.

Legibility

Status icons may be preferred by the user, as opposed to colour-coded objects.

Allowing the user to customise what to be visualised may enhance readability for the user.

The direction in which information is presented should be adapted to the users' mental model.

Arrows are intuitive for the users to show connections and hierarchies.

Overview first, with ability to access more information, may increase focus and legibility.

Usability

Keep things simple for novice/seldom users.

Some users may prefer text over diagram, it should be up to the users to choose.

Individual customization of visualization is appreciated by the users.

Reduced navigation to access information may enhance the users' workflow.

Iteration 2 Takeaways

Space Efficiency

A solution that is very space efficient loses its value if it results in increased cognitive load for the user.

There is a fine balance between showing enough information at once on the screen and showing too much information at once.

Showing too much information at once may confuse the user.

6.4.6 Discussion - Iteration 2

This section will discuss the different parts of Iteration 2.

Ideation Discussion - Iteration 2

Focusing on qualitative ideation through sketching, rather than quantitative ideation such as brainstorming, may have resulted in ideas that are easier to prototype. However, conducting a more quantitative ideation method may have yielded a more nuanced result where more possible solutions could have been brought up. Due to this iteration focusing on refining, rather than creating new concepts, this should not have affected the results negatively.
Since the ideation phase was conducted remotely, the sketches created were only shown to each other when they were considered to be finished, which resulted in a lack of feedback during the sketching. Continuous feedback during the sketching could be beneficial, as incorporating the feedback may be easier before the sketches are done. Getting feedback after the sketches were done resulted in redoing the sketches to incorporate feedback, which may have affected how time-consuming the ideation process was.

Prototyping Discussion - Iteration 2

The prototyping of Iteration 2 focused on implementing improvements and solving suggested problems that were discovered from the evaluation of the concepts in Iteration 1, as described in section 6.3.5. However, since the concepts had not been evaluated by the actual users in Iteration 1, we could not fully know what to prioritise. This made the prototyping phase more time consuming and resulted in some of the prototypes being prototyped with higher fidelity, such as Scorecards. The concepts that were prototyped in higher fidelity were based on our motivation for the concept, rather than the anticipated value for the user. Furthermore, since we could not determine what is most valuable to the users or how the users interpret the prototypes, we could not set a limit for the fidelity that the prototypes should have reached to be considered as finished for this iteration. Developing selected concepts with higher fidelity likely affected the fidelity of other concepts negatively. Concepts with higher fidelity were also made interactive to some extent. By creating interactive prototypes, we were forced to think about what would happen if a button

was clicked. This lead to adding more views to the prototype. Thinking of what would happen in the next step also made it easier to see if all necessary functions and features are considered.

Evaluation Discussion - Iteration 2

The concepts developed in Iteration 2 were evaluated by showing images of the prototypes to the users. Even though some of the prototypes were made interactive, the users did not receive any interactive prototypes. The users were instead shown still images of the prototypes to facilitate understanding of how the concepts were intended to function.

We could not determine how well the participants in the evaluation understood the concepts. However, two of the concepts stand out as less easy to understand. The first was Goals Overview where one of the interviewees chose to skip the concept due to not fully understanding it after the interviewers had attempted to clarify it. The other concept that seemed to be hard to comprehend was Zoom and Pan, where two participants in the questionnaire wrote that they did not understand the concept.

The concept of Zoom and Pan was presented as a stand-alone concept in the questionnaire. In the interview, the concept was instead presented as an addition to the Tree Structure concept. This inconsistency may have affected the outcome, due to the interviewees not considering it as much and instead focused on the Tree Structure concept in general. However, the interviewees did comment on the Zoom and Pan and stated whether they believed it to be a good idea or not.

Interview Discussion - Iteration 2

After the first interview, question IQ6 and IQ7 were combined into one. Changing the interview schema during the interview would likely have been avoided if a pilot interview was conducted. However, removing one question from the interview does not seem to have affected the outcome negatively, but rather made the interviews flow better.

The interviewees were asked to focus on the functionality and features of the concepts rather than the aesthetics, which may have affected the outcome negatively. One of the interviewees stated *"but that is design-oriented"* after starting a sentence. The intention was not to prohibit thoughts and ideas on aesthetics, but rather to suggest that the concepts are not finished designs. By asking the user to think of the functionality rather than aesthetics may have made the users think through their replies more to provide answers that they believed are more relevant. This may in turn have affected all replies, not only the aesthetics oriented ones.

The interviews were finalised by asking the participants to rank the concepts on what they think are most valuable for them in their work. This was very difficult for the participants to do and most of them were reluctant to do so. This could be due to the participants feeling that they had too little information about the concepts to make the decision.

Questionnaire Discussion - Iteration 2

The questionnaire turned out to be quite long with a lot of questions and a lot of images and descriptions for the participants to consider. The length of the questionnaire may have affected the result, due to a high cognitive load to respond to it. We could see in the results that the participants' replies were becoming shorter towards the end of the questionnaire. Furthermore, one user reached out to us and told us that they will not be able to fill out the questionnaire as it was too time-consuming. Another issue was that the last question, where the participants were asked to rank the concepts based on what they think would be most useful in their work, seem to have been misinterpreted by some of the respondents. The concept that received the highest rank was the concept that most participants did not understand and therefore had nothing to say about.
In the ranking question, 1 was posed as the best option and 7 as the worst. In other questions where the users were asked to grade the concepts, 7 was the best option. The reasoning behind changing which value is deemed as positive was done due to the wording of *rank* and *grade* where it is common in a ranking for the first place to be best, i.e 1 is the best option. In grading a higher score is commonly deemed as better than a lower score, i.e 7 is the best option. After analysing the data, it was evident that shifting the meaning of the numbers may have confused the participants and the inconsistency may have been avoided if the questionnaire was piloted before sending it to the users. Since this question was meant to facilitate in prioritising which concept to pursue, the lack of a cohesive interpretation of it renders the result unusable and a different method of determining which concepts to pursue had to be conducted, which is why we scheduled an interview with employees of Stratsys to let them rank the concepts as well.

Analysis Discussion - Iteration 2

The results from the questionnaire and interviews were added to an adapted W/N analysis diagram. Since we did not ask the users about the concepts threats and opportunities, the diagram instead consisted of Strengths, Weaknesses, Use cases and Novelties. Visualising the results in a matrix made it easier to perceive the number of items in each category. However, as the data is mainly qualitative, a large effort had to be put into interpreting the data and the value of each item.
The results from the interviews and questionnaire were not enough to select which ideas to pursue. Only two of the concepts could be removed, which left us with five concepts. The number of concepts that remained was deemed as too high and additional evaluation and selection had to be done.

6.5 Iteration 3

In Iteration 3, the three concepts that remained after the evaluation of Iteration 2, described in section 6.4.5, were further developed into prototypes with as high fidelity as the time allowed for. The evaluation of these prototypes would also be the last evaluation during the project. This iteration was the first and only that was

conducted in co-location, which would have been the preferred process throughout the project if the limitations, discussed in section 1.6, were not in place.
Based on experiences from previous iterations and previous design projects, we felt that working remotely may have affected the outcome negatively.
Further discussion about the differences between working in co-location and remotely can be found in section 6.5.6.

6.5.1 Ideation - Iteration 3

The ideation phase in this iteration was planned to focus mainly on solving problems that had been noted in Iteration 2, as described in section 5.4. First out, results concerning the remaining problems within the three remaining concepts, that were compiled during the evaluation of Iteration 2, as described in section 6.4.5, were extracted.
The ideation phase consisted of setting up requirements and sketching solutions to fulfil these.

Requirements Gathering

The requirements focused on the core functionality of Stratsys' current software and the functionality that was found to be relevant during the user research, as described in section 6.2.1 and 6.2.2. The core functionality was divided into "important" and "nice to have" sections. The requirements were used as a guide while sketching to make sure that the core functionality was included and to make sure that the information gathered during the user research and previous evaluations was incorporated in the concepts.
The requirements were written on post-it notes and put on a whiteboard with different sections for the different categories of requirements. The categories consisted on sections such as: *editing data*, *creating structure* and *adapting the data*.
Aside from the core functionality, the takeaways from the evaluation in Iteration 2, as described in section 6.4.5 were also written on sticky notes and attached to the whiteboard in categories. This was done to give an overview of the users' wishes and concerns.

Solution Sketch

The solution sketches were to large extent a continuation of the wireframes created in Iteration 2, as described in section 5.4. However, the sketches created did not focus on the whole concept, but rather on smaller parts of the concepts that would later be combined during the prototyping phase.
The solution sketches focused on addressing the requirements and the information gathered through the evaluation phase in Iteration 2.
Each solution sketch focused on a limited part of the concept, such as in Expandable Cards where one sketch focused on the general structure of the cards, as shown in figure 6.41. Another sketch was then made to showcase how cards could change position to make room for an expanded card, as shown in figure 6.42. Each sketch focused on one problem to solve, and they are therefore not very detailed.

Since the content of each card is not important to showcase the structure, this information was left out of the sketches to save time.

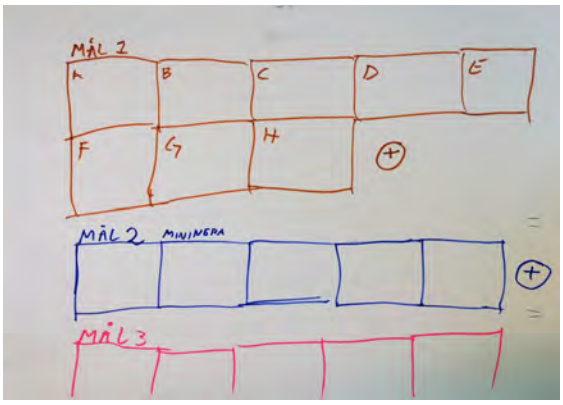

Figure 6.41: Sketch of the overall layout of the concept Expandable Cards, the cards are labeled to facilitate in sketching solutions for rearranging when card is expanded.

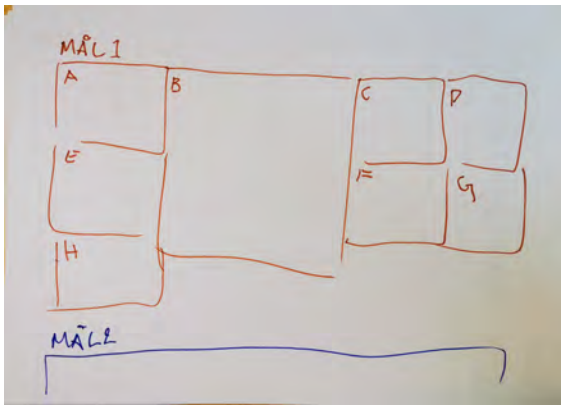

Figure 6.42: Sketch of the overall layout of the concept Expandable Cards with one card expanded, showcasing how the other cards will move away to make room for the larger cards.

This process of creating focused sketches was done for each concept to find solutions to the problems noted during the requirements gathering. The different solution sketches were combined to create the whole concept.
The sketches created were put on the whiteboard, next to the requirements and user concerns to facilitate in comparing the solution to the requirements. Figure 6.43 is an example of how the ideation concerning solution sketching and requirements was conducted.

6.5.2 Selecting Ideas to Pursue - Iteration 3

No formal idea selection method was conducted for this iteration. However, a selection among the sketches was done by comparing the solutions and assessing them based on the requirements that had been set up. The solutions that were considered to fulfil the requirements and to address the drawbacks established from the evaluation in Iteration 2 were implemented.

6.5.3 Prototyping - Iteration 3

The prototyping was done as interactive wireframes in Adobe XD. The concepts were a continuation of the selected concepts from Iteration 2. However, all the prototypes created in this iteration were constructed from scratch and only a limited amount of assets was reused from the previous iterations. For this iteration, the prototyping phase was conducted in co-location, which allowed us to collaborate more. The co-location also allowed both of us to work on the same concept, whereas in previous iterations, the prototyping was done individually. Since we collaborated on the same prototypes, a lot of discussion and ideation took place during the prototyping phase.

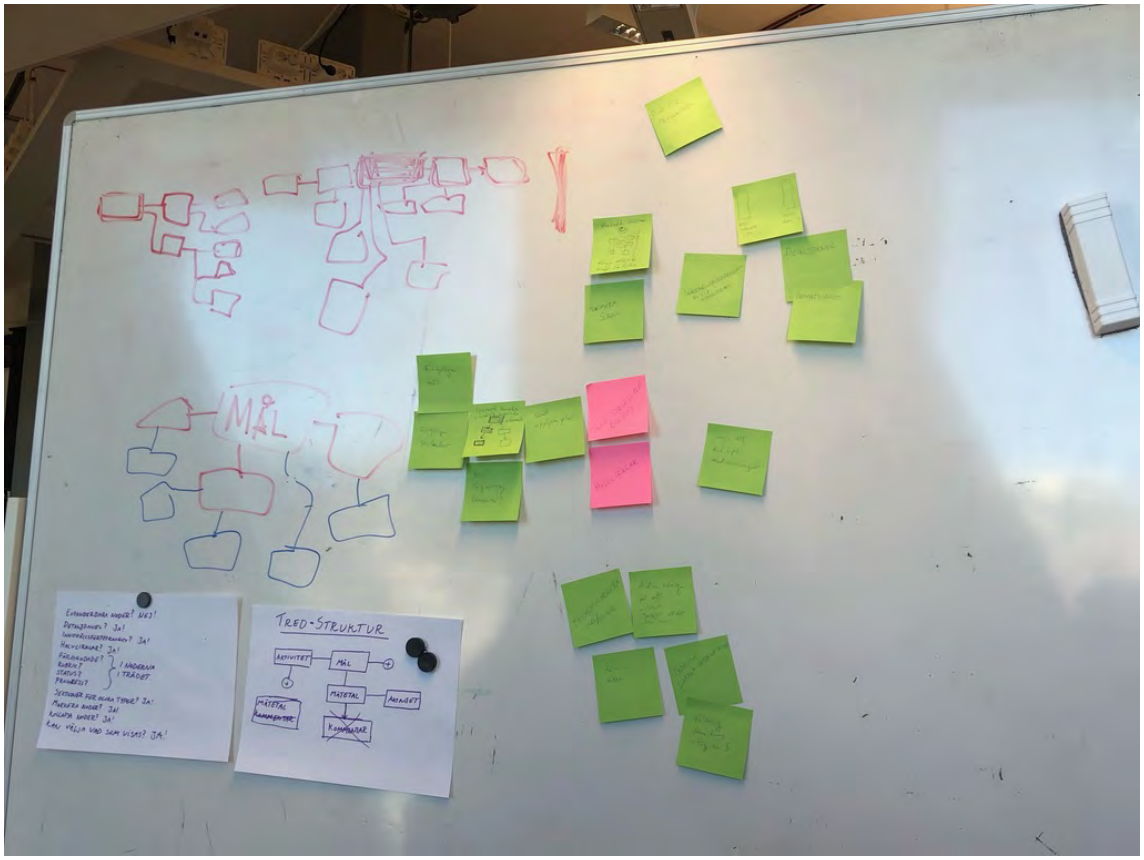

Figure 6.43: Sketches of the concept Tree Structure are placed on the whiteboard next to the sticky notes with requirements and user concerns.

Where questions arose concerning design decisions, we went back to the ideation and solution sketching to discuss the different available alternatives. This resulted in a large number of sketches being created during the prototyping phase.

6.5.4 Evaluation - Iteration 3

The evaluation was planned to be conducted primarily through interviews or questionnaire with current users of Stratsys, as described in section 5.4. A questionnaire was not conducted, as qualitative data was desired and the previous questionnaire showed to yield less valuable results than the interviews.
A total of five interviews were conducted, where only one of the interviewees was a Stratsys user within our target user group. Due to difficulties in finding participants for the interviews, three Stratsys employees with great insight into customer's usage of the platform were also included. Furthermore, two student colleagues were asked to participate in a semi-pilot interview. The semi-pilot was not considered as a formal pilot, since the data gathered in that interview was used as a part of the result. The decision to keep the data from the pilot interview was based on the shortage of available participants, as well as a lack of time to conduct more interviews. Furthermore, since the evaluation was part of the formative research and we wanted to gather the participants' opinions rather than collecting statistical data, including pilot data should not affect the outcome negatively. Due to the participants being design students, rather than real users, their input was treated more as expert feedback, rather than user input. The two student colleagues were interviewed together as one interview.
The interviews were initially planned to be conducted in a way where the user could interact with the prototypes by taking over the screen of the interviewer. However, in the first interview, we experienced technical problems when the interviewee tried to take over the screen. As a result, we instead shared the interviewer's screen and asked the participant what they would have done to perform certain tasks in the prototypes. The interviewer then carried out the interaction as described by the participant. In this solution, the participants are forced to think out loud instead of just clicking around without talking. As this solution turned out so well, we chose to stick to the same solution for the remainder of the interviews.
The participants were asked questions on how the concept makes them feel and how intuitive the interaction was. We also asked the user if the series of interactions to conduct a task seems reasonable for them to conduct their work. The questions asked were specific to the interactions shown, such as: *What do you think about doing this sequence of interactions to conduct this task?* and *What do you think about this window that you just opened?* After each concept had been presented, the participants were asked standardised questions to facilitate comparison. The standardised questions can be found in table 6.13 as IQ1 to IQ6. When the concepts had been presented, the participants were asked the question IQ7 to IQ10.
Between each interview, minor changes were made to the structure of the interview as well as to the prototypes. Changes made include: changing the colour of objects and changing icons to be consistent.
A notable change that was made between interviews was to change the order in

Table 6.13: List of the standardised interview questions from iteration 3. IQ = Interview Question.

#	**Interview Questions**
IQ1	What do you think are the strengths of this concept?
IQ2	What do you think are the weaknesses of this concept?
IQ3	Is there anything that you think is missing from this concept?
IQ4	How well do you believe this concept succeed in providing a space efficient representation of the information?
IQ5	How well do you believe this concept succeed in providing an overview of the information?
IQ6	Do you find this concept to be intuitive?
IQ7	What is you impression of the concept now that you have seen all three?
IQ8	Which concept do you like the most?
IQ9	Which concept do you like the least?
IQ10	Which concept do you believe would be most valuable to be implemented in Stratsys?

which the concepts were presented to the participants. This was done due to all of the interviewees rating the first concept the highest. By switching the order, we could counteract any potential bias to the first concept shown.

Evaluation Analysis - Iteration 3

The data gathered through the interviews was transferred to a Google Sheets document with one column for each interview. Transferring the data to the Google Sheets document was done so that all data would be located in one place and thereby facilitate analysis. The responses for each question could then be summarised in an additional column in the same document. The summary was then used to compile a list of takeaways for each of the concepts. For the questions where the participants were asked to state which of the concepts that they preferred, the data could be analysed quantitatively.

6.5.5 Results - Iteration 3

This iteration resulted in three interactive prototypes, as well as general takeaways from the evaluation. The takeaways could be used to further develop the concepts.

Prototyping Results - Iteration 3

The prototyping resulted in three interactive wireframes. The concepts kept their internal names from the previous iteration, Expandable Cards, as seen in figure 6.44, Tree Structure, as seen in figure 6.46, and Scorecards, as seen in figure 6.45. More images and figures of the prototypes can be found in appendix H.
Expandable Cards is a continuation of the concept from Iteration 2 with the

same name, described in appendix G section G.3. Changes made in this iteration include:

- Cards are grouped depending on which goal they belong to.
- Cards keep their initial size and visibility when another card is being expanded, they only move aside.
- Cards can be marked as favourites, which puts them as a duplicate in a separate section.
- Entire sections of cards can now be hidden.
- The user can now choose what to be displayed on each card in the minimised state.
- The ability to add new cards to a section is now added.

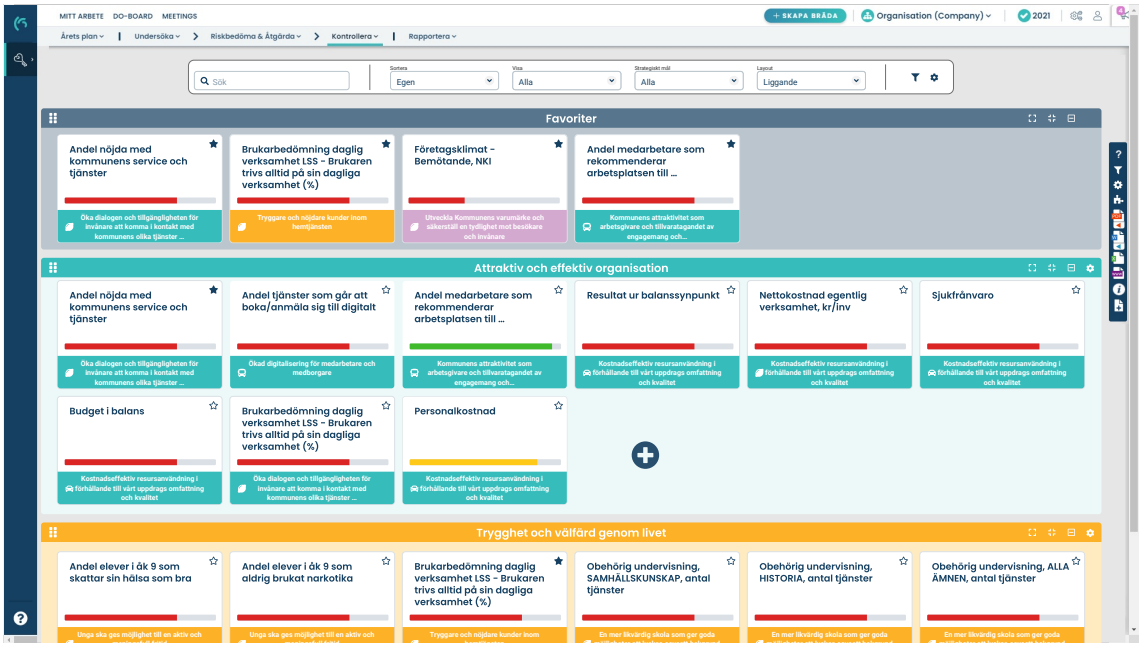

Figure 6.44: Example wireframe of the concept Expandable Cards.

Scorecards is a continuation of the concept from Iteration 2 with the same name, as described in appendix G section G.1.. Changes made during this iteration include:

- The background colour of each card is consistent and not used to signal the card's status.
- Information can now be visualised as icons, as a means to fit more information on the screen.
- The ability to change the size of the cards to display a certain amount of cards has been removed.
- The users can now select what they want to be displayed on the cards.
- The users can now select if they want their information in the form of an icon or text.
- The goal that the measurement belongs to is not placed at the top instead of the bottom of the cards.
- The cards can no longer be turned over. Instead, all information that is not available on the card is accessible from the side pane.

- The layout of the cards can be changed by the users, depending on what they prefer.

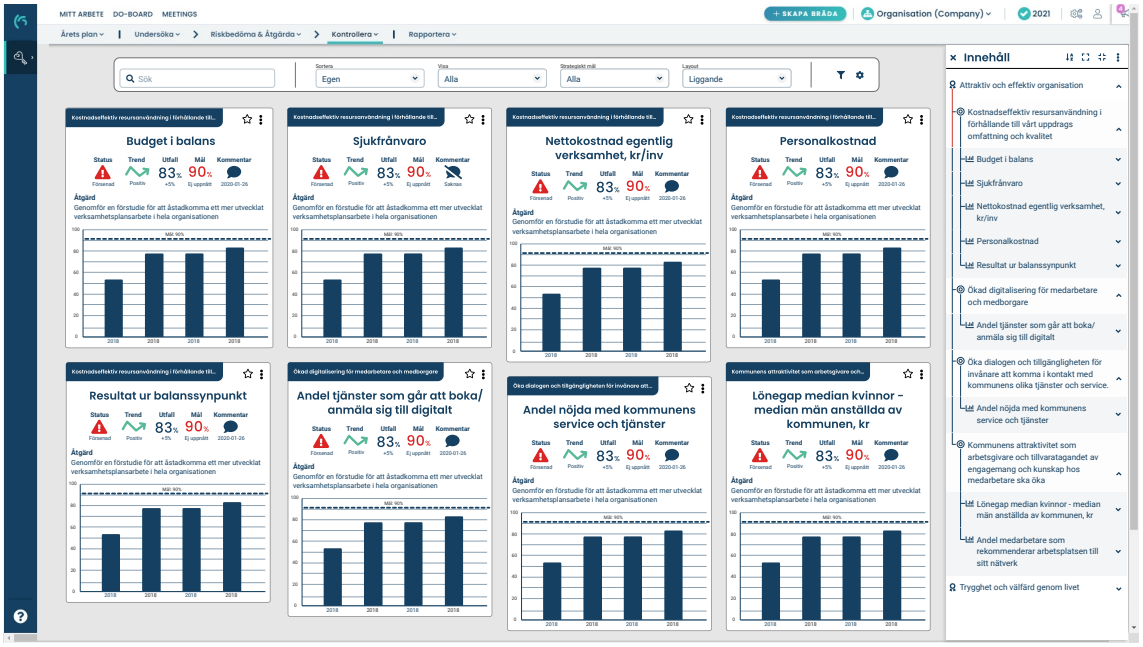

Figure 6.45: Example wireframe of the concept SCORECARDS with the side pane visible.

TREE STRUCTURE, shown in figure 6.46 is a continuation of the concept from Iteration 2 with the same name, as described in appendix G section G.5. Changes made during this iteration include:

- The nodes are now organised in half circles with the root node in the centre of the screen.
- The ability to add nodes has been added.
- The colour coding is made more clear.
- When a node is selected to be shown in the side pane, other nodes are now faded out.
- Each node is labelled to make it easier for the users to see what kind of data they are visualising.
- The parent node is made bigger and more distinct, to provide a more preattentive starting point for the users.
- Filtering options and a search function have been added.
- The colour scheme has been updated to be less distracting for the user.

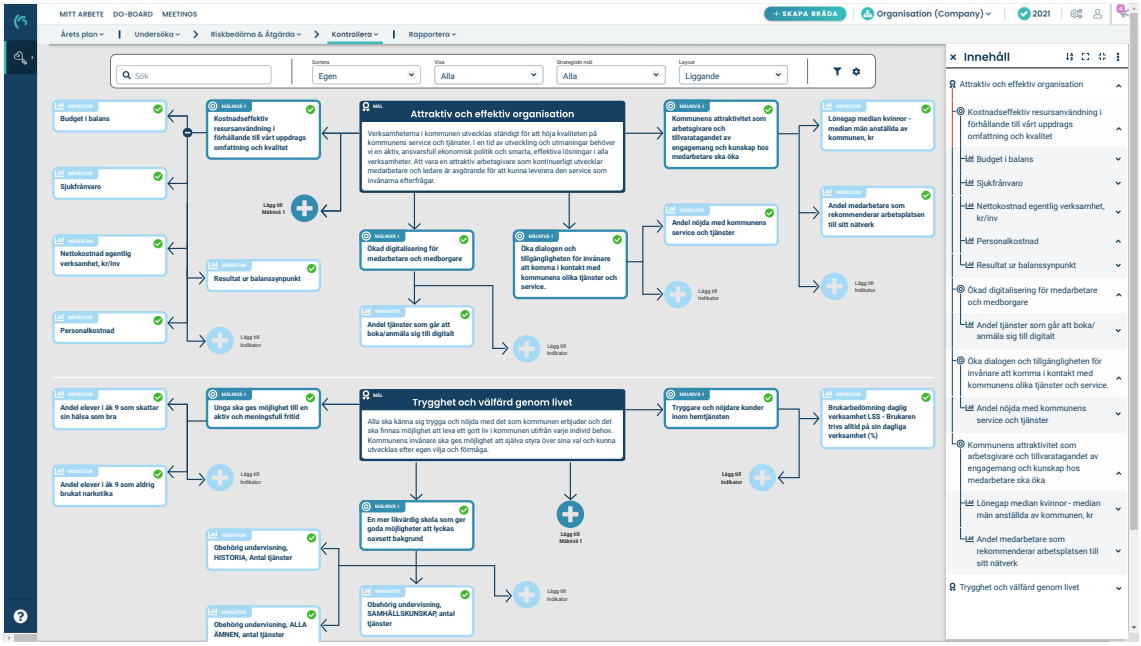

Figure 6.46: Example wireframe of the concept Tree Structure with the side pane visible.

Evaluation Results - Iteration 3

Based on the evaluation, a list of updates to be done for the concepts can be compiled. Furthermore, when the participants were asked to rank the concepts of which concept they prefer on what they think would be most useful in Stratsys, two of the concepts stand out as most wanted by the users.
The users ranked the concepts Scorecards and Expandable Cards as the most wanted, with two participant preferring the concept Scorecards and three participants preferring the concept Expandable Cards, as shown in figure 6.47.
Based on these rankings, Tree Structure may be the concept that offers the least value to the users in terms of usability and novelty. One major issue that Tree Structured faced during the interviews was that the users are more familiar with Stratsys version of a tree structure where the hierarchy is laid out from left to right. Several interview participants stated that the major drawback of Tree Structure may be that they are used to Stratsys current visualization.
Since this was the last iteration and the concepts were more refined than in earlier iterations, one list of takeaways was constructed for each of the concepts evaluated. The takeaways are based on the evaluation of the concepts and are presented below.

Takeaways for Expandable Cards

Colour Usage

The colour coding facilitates in seeing how the information is connected.

The colours can confuse the users if it is not made clear what the colours mean.

The meaning of some colours is not consistent, which may confuse the user.

Using colours of a wide range may confuse the user.

Takeaways for Expandable Cards

Focus

There is no distinct starting point, which makes it difficult for the user to know where to start.

Being able to hide irrelevant information may enable the user to focus.

Consistency

Stratsys uses coloured icons to show status, so it does not feel consistent to have a coloured progress bar.

The star icon changes position when the card is being expanded, which may confuse the user.

The progress bar is not visible in the expanded card, which may confuse the user.

The three dots menu is generally perceived as containing secondary options, such as "print", not primary features.

Legibility

The favourites section should stand out more so that the users can find it more easily.

The progress bar has no labels, which resulted in the users not knowing what it is visualising.

The order of information does not correspond to the users' mental model. For instance, the diagram to the right of the text and the parent goal placed at the bottom of the card.

The hierarchy of the information is not apparent.

The minimise section icon is not recognised by the user.

Placement of icons and buttons is important for legibility.

Usability

The ability to mark cards as favourites can enhance the workflow for the user.

There is no clear indication that the cards can be expanded.

Clicking a card to get more information is intuitive for the user.

Being able to expand multiple cards allows the user to compare the information.

Functions used often should be easily accessible and not be hidden in a menu

A vertical ellipsis menu with few options can be replaced with icons for the options.

Allowing the user to customise the visualization is appreciated.

Takeaways for Expandable Cards

Space Efficiency

Having the title to the left of the content creates unnecessary blank spaces.

Reading from top to bottom may result in a lot of scrolling.

Space efficient overview with the ability to access more detailed information may be preferred by the users.

Having the same width on each section may result in blank spaces.

Suggested Improvements

Provide notifications or symbols to visualise if anything has changed since the information was last checked.

Allow the users to select which information should be shown.

Allow the users to select colours for the colour-coding.

Show the parent title above the child on the cards.

Label the progress bar so that the users know what it is visualising.

Add minimum and maximum values to the progress bar.

Takeaways for Tree Structure

Colour Usage

Some colours have strong values connected to them, such as red and green.

Colour coding may facilitate in understanding the structure of the information.

Focus

Reducing visibility of non-selected information may increase focus.

Hiding irrelevant information may increase focus.

Consistency

Icons should only have one meaning, reuse of icons may confuse the user.

Legibility

Showing detailed information far away from where the user clicks may reduce legibility.

Nodes that are connected should be placed closely.

Information is commonly read from left to right, different order may reduce legibility.

Commonly accessed information and important information should be placed at the beginning of a list of information.

The user may find it easier to focus on the information if it is located in the centre of the screen.

The order in which information appears may be interpreted as having meaning.

Takeaways for Tree Structure

Usability

Showing two different visualizations of the information may facilitate comprehension.

Showing detailed information in the same window may be preferred from pop up windows.

The user should be able to choose where the information is shown, and in what size.

Hiding and showing certain information should be easily done with as few interactions as possible.

Primary functions should be easy to access and not be hidden inside menus.

Suggested Improvements

Being consistent with the direction of arrows may facilitate understanding.

The nodes should have a hover effect to facilitate in finding where the mouse pointer is located.

Nodes should be possible to rearrange through drag and drop.

There should be a way to add content in the parent category.

Adding help texts may facilitate learning.

Takeaways for Scorecards

Colour Usage

Using strong colours may be distracting for the user.

Focus

Showing a lot of information at the same time may be overwhelming for the user.

Consistency

Not using a straight line as start position may be distracting for the user.

The vertical ellipsis menu should not be used for primary functions.

Icons should only have one meaning and not be reused for other actions.

If actions are available for some, but not all, information, it should be made clear why.

Legibility

Clickable objects should indicate that they are clickable.

Reading long texts in a hover pop-up box may not be efficient.

Titles should be accessible and visible for as long as the information connected to it is, to reduce short term memory load.

Visualising the users' selection may facilitate legibility.

Takeaways for Scorecards

Usability

The user should be able to select which information is shown.

Primary and often used functions should be easily accessible.

Providing an overview of the information and allowing the user to actively show more information may be preferred to showing all information at once.

Allowing the user to customise the visualization may enhance the user experience.

Customisation of the visualization should allow for customisation of individual properties.

Space Efficiency

The ability to adapt how much information is shown may either increase or reduce space efficiency.

Suggested Improvements

It should be possible to make cards smaller to fit more overview information on the screen.

It should be possible to make cards larger to fit more detailed information about select cards.

Enable minimisation of secondary assets, such as the top menu, to fit more information on the screen.

Enable the user to mark cards as favourites.

Give all cards the same height or adjust the position of the cards so that their top edges are aligned.

6.5.6 Discussion - Iteration 3

As this iteration was the only one that took place in co-location, the discussion will mainly focus on the differences between doing design work in co-location as opposed to remote work.

Ideation Discussion - Iteration 3

The ideation phase took place in co-location which resulted in more living discussions and more inspiring sketching than in the remotely based ideation phases. Usage of real sticky notes rather than virtual resulted in less frustration and less focus on the tool, thereby allowing more focus on the task at hand.
Sketching in co-location allowed for more immediate feedback during the sketching, instead of showing a finished sketch online. Furthermore, seeing how the sketch is being drawn facilitate understanding the concept being sketched and the immediate feedback may have facilitated in saving time by preventing us from creating advanced

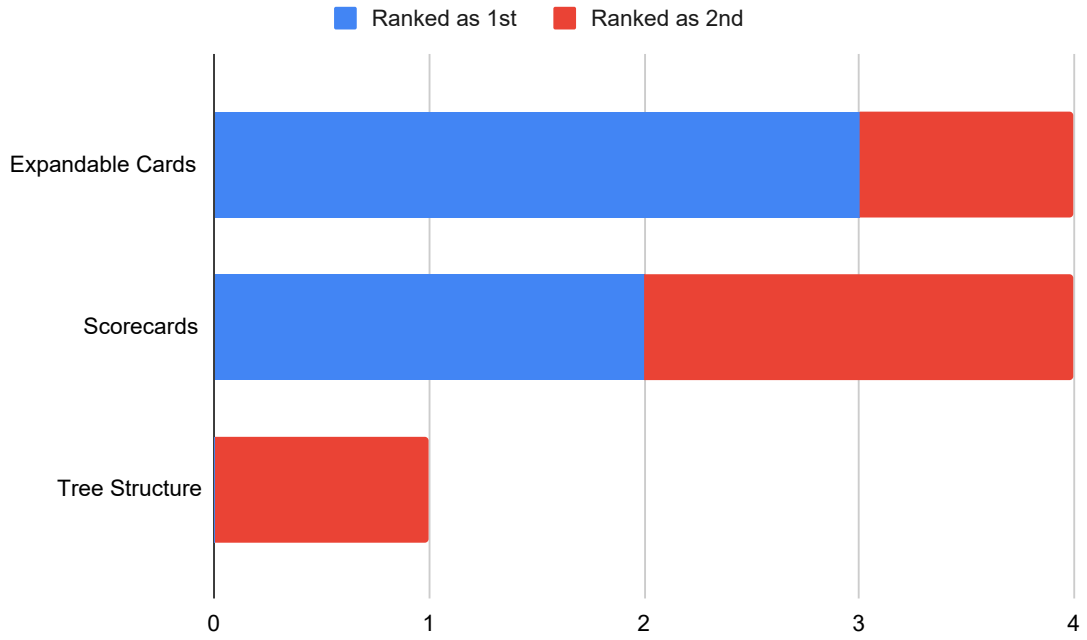

Figure 6.47: Results from the participants' ranking of the concepts. All participants did not rank the concepts, therefore the sum of the votes does not correspond to the number of participants.

sketches of concepts that would not be feasible.
The requirements gathering that was done in this iteration was considered very helpful to make sure that all aspects of the design and functionality are thought through. In hindsight, a more formal requirements gathering should have been done earlier in the project. The requirement gathering that took place in the User Research phase of the project, as described in section 6.2, were conducted remotely, which resulted in less discussion and a less structured outcome.

Prototyping Discussion - Iteration 3

The prototyping phase also took place in co-location. This allowed us to jump between the prototyping phase and ideation phase more freely than in previous iterations. Having both of us working on the prototypes at the same time encouraged discussion about the implementation and design choices. By discussing every design decision concerning the prototypes, the outcome may have been affected positively and the prototypes felt more thought-through than in earlier iterations where these discussions took place after the prototypes had already been implemented.
Furthermore, having both of us working on the same prototypes facilitated achieving a sense of shared ownership of the prototypes and concepts created. The sense of shared ownership may have been lacking in earlier iterations, where the one constructing the prototype had a better insight into how the concept was meant to behave.
The decision of creating entirely new wireframes rather than reworking the wire-

frames from Iteration 2 may have affected the prototypes positively due to reworking old prototypes may result in getting stuck in old thinking. Creating new prototypes allowed us to focus on the new concept that was created in the ideation phase without being affected by how the previous prototype was implemented. However, creating new prototypes can be more time consuming than using old foundations, which implies that building from the old wireframes could have given room for creating more refined results in the end.

Evaluation Discussion - Iteration 3

The interviews were done remotely, since meeting the participants in co-location with the current limitations, described in 1.6, would not be ethical. Furthermore, conducting interviews remotely have worked well in previous interviews in the project and we could see no reason to change that. Furthermore, conducting the interviews remotely may be beneficial since it does not require us or the participant to travel anywhere and thereby saving time, which allows us to conduct more interviews and facilitating the participant to make room for the interview in their schedule. Furthermore, remote interviews allowed us to include participants that are located far away from us, such as in a different city, which would not be possible to interview in co-location.
Only one of the participants in the interviews was to be considered as a part of the target users. The other five participants were either employed by Stratsys or student colleagues. This may have affected the results. Two of the interviewees were design students and therefore they may have focused on more design-oriented aspects than a real user would. Furthermore, we had a personal relation to the students participating, which may also have affected the results. Three of the participants were employees at Stratsys, with the primary focus of customer contact and supporting the customers. This means that these participants had a great insight into the regular customers and the tasks that they usually perform in the platform. However, since these participants were to be considered advanced users, they were not a part of our target group. Interviewing more advanced users may have affected the results due to them focusing on more detailed aspects than the regular user, such as keyboard shortcuts and customisation. Since these participants know the regular users very well, they could provide us with nuanced insight into how they believe the users would react to our concepts, as well as their interpretations.
In the interviews, we planned to allow the participants to interact with our prototypes by sharing our screen and allowing them to take control of it. This did not work out as planned due to technical issues with the software and hardware used. Instead of allowing the user to interact themselves, we asked the user to think aloud and asked them where they would click to complete certain tasks, we then carried out the interactions that they said they would do. Conducting the user test this way may have encouraged the users to think aloud and talk more. However, the participants may have felt as being more guided and therefore less exploratory while testing the concepts. Due to the limited amount of interactions implemented in the prototypes, this may not have affected the results negatively since all available interactions were made sure to be included in the test.

7
Results

This chapter will summarise and present the results of the project. Subresults of the project are described and discussed in chapter 6. A summary of the resulting concepts, developed during the iterative design process will be presented here. Furthermore, a compiled list of takeaways from the project that may be used as visualization design guidelines to answer the research question: *Which design principles, leaning on novel and well-known research on information visualization and transitions, can support overview and comprehension of large amounts of data in a strategic planning platform?* will be presented.
Due to strategic planning consisting of several distinct stages, as discussed in section 2.3, the requirements on the visualization in each stage differs. To achieve a platform that can fulfil the needs for each phase, multiple visualizations could be used for the different stages. An other solution is to use a visualization that provides a lot of customisability with presets for each stage. Throughout this project, we could see a tendency that the users prefer the more adaptable solutions, rather than using different visualizations. Furthermore, during the user research phase, several users stated that being able to access an overview of their information as well as an overview of the structure of the information would greatly benefit them in their work. Therefore, the concepts developed in this project aimed to provide more customisability as well as a better overview for the users.

7.1 Final Concepts

The two concepts that were considered to provide the most value for the users of Stratsys' platform are Scorecards and Expandable Cards, therefore these are the two concepts that we propose to be further developed.
More images of the concepts are available in appendix H. Suggested improvements are discussed in section 8.5.

7.1.1 Expandable Cards

Expandable Cards is a concept that focuses on showing a compact overview of the information, such as measurements. The information is structured in categories where the category represents the goal that the measurement belongs to. Each category is colour-coded to indicate that the nodes with the same colour belong to the same goal, which is especially valuable when nodes are marked as favourites and placed in the favourites section. In the prototype, as seen in figure 7.1, the cards

consist of the measurement title, a progress bar and the parent node title. The progress bar is visualising how close to the set goal the latest measure is.

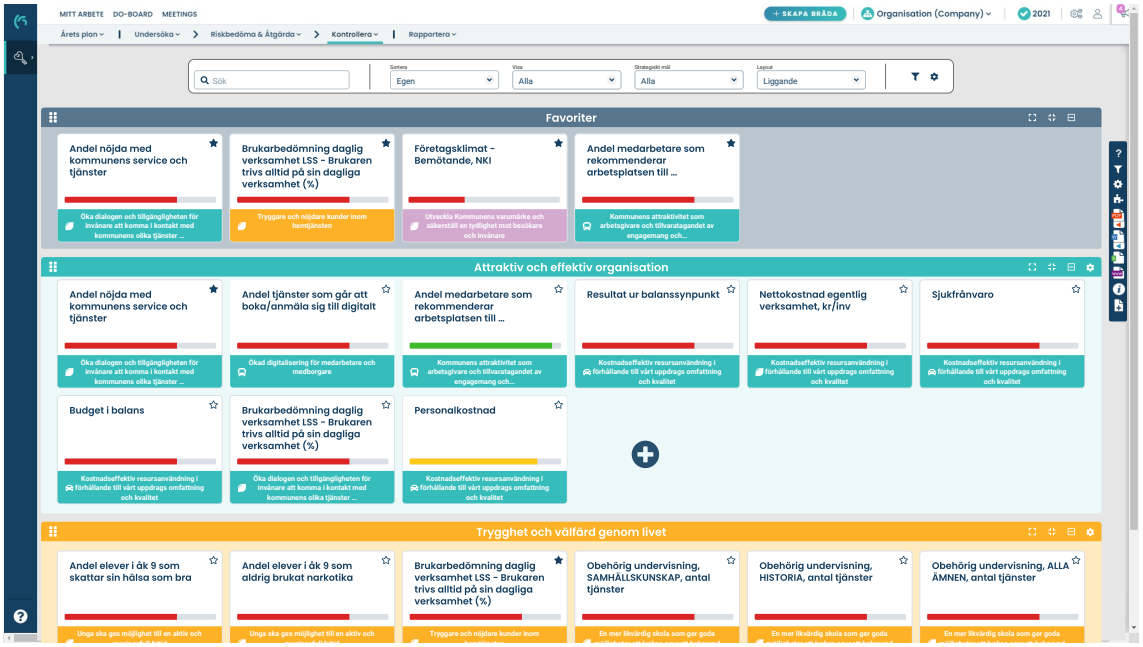

Figure 7.1: Example wireframe of the concept Expandable Cards.

The cards can be expanded to show more detailed information. By allowing the cards to be expanded, the detailed information ends up close to where the user interacted with the information, which reduces the need for the user to search for the information and thereby reduces cognitive load.
The concept allows for a lot of customisation by the user. The colour codes used can be changed by the user to fulfil their needs or preference. The information that is shown in each card when they are not expanded can also be changed by the user. For instance, if the user wants to be able to see the latest comments in their overview, they can do so. The user's customisation settings are saved for the next time they open the view, and presets can be saved so that the user can change the layout depending on which task they are performing. Both individual cards and entire sections can be rearranged by drag and drop. The user can also choose to minimise entire sections to only show its title.
The concept allows the user to expand multiple cards at once in cases where comparing information is necessary. The user can also choose to expand all cards at once when desired, which minimises the amount of clicking. The top menu bar allows the user to filter information, search in the information as well as apply visualization settings.
New child nodes can be added by clicking the plus icon under the appropriate node.

7.1.2 Scorecards

Scorecards is a concept that focuses mainly on measurements. The hierarchy between nodes is not in focus but can be seen in the side panel that is included.

The concept is presented in figure 7.2.

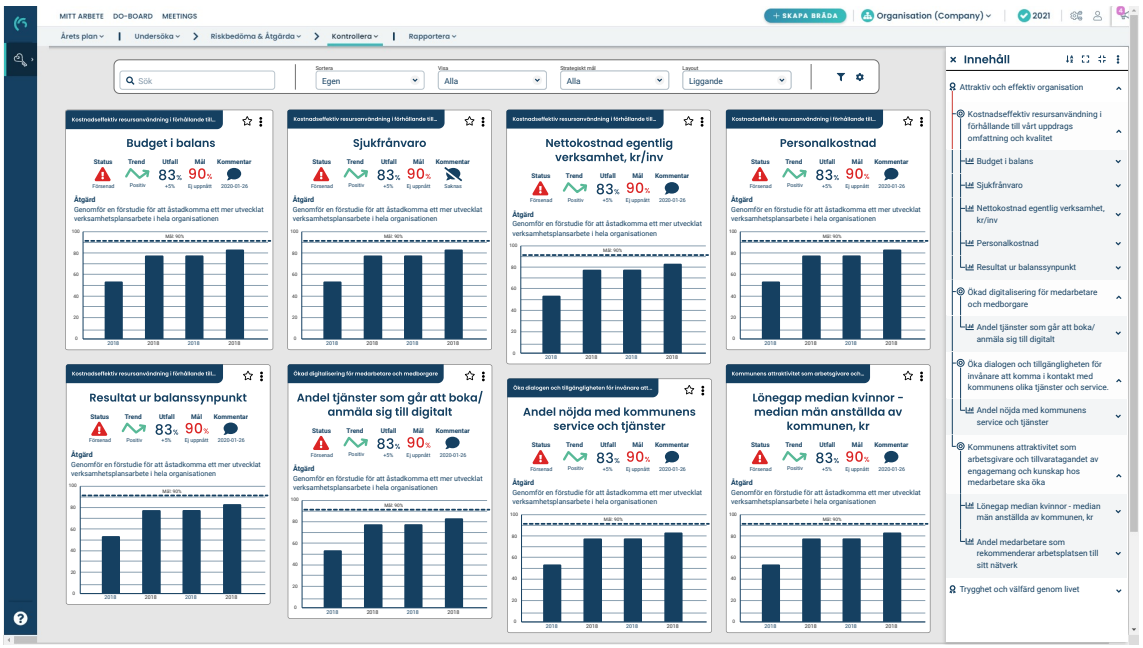

Figure 7.2: Example wireframe of the concept SCORECARDS with the side pane visible.

Each card corresponds to a measurement. The cards are divided into five parts and consist from top to bottom of:

- Header, with parent node title, favourite icon, a menu for additional options.
- Title section.
- Icons sections, where the user can choose which icons to be shown on the cards. The icons are interactive.
- Text section, where information is shown as text, such as comments and definitions. The user can choose which types of information are displayed here by selecting them in the top menu bar.
- Visualization section, with either a table or a graph. The user can choose what kind of visualization to be shown here, or choose to hide it if desired. These choices are made in the top menu bar.

The header section and title section are static and cannot be removed, the content in these sections is also static. The other sections can be removed entirely by the user if desired, and their content can also be changed. For instance, the user can choose to hide the status icon. The user can also decide if messages are displayed as either text or as icons, or if they are hidden.

The side panel to the right is used to show the hierarchy of the data, as well as detailed information. The fields with detailed data in the detail panel can be expanded either by clicking a headline in the side panel or by selecting a card in the main visualization.

The layout can be changed by the user if they want the graph part to receive more vertical space. The graph is then placed on the side, next to the other information.

7.2 Information Visualization Guidelines for Strategic Planning Platforms

The guidelines listed here are a compilation based on the takeaways from Iteration 2, presented in table 6.12 on page 99 in section 6.4 and Iteration 3, presented in table 6.14 on page 111, table 6.15 on page 112, and table 6.16 on page 113, in section 6.5. The guidelines are based on tendencies discovered during a limited amount of research, and should be seen as indications rather than strict rules. The guidelines focus on: *Colour Usage, User Focus and Cognitive Load, Legibility and comprehension, Usability,* and *Customisation.* The guidelines also provide considerations to be aware of during design and evaluation, in the sections: *Considerations Concerning Design* and *Considerations Concerning Evaluation.*

7.2.1 Colour Usage

Colours should be used with care, as they can have a strong visual and emotional impact. During the evaluations, several notes on the usage of colour were made. Therefore, we believe considering colour usage during the design process may affect the outcome positively. As an example, in the concept Scorecards, as seen in appendix G.1, the colour coded background resulted in less contrast and legibility. Thus, the colour coded background was removed in the next iteration, as seen in appendix H.2. The guidelines are further motivated by the established design principles from literature listed in section 3.5.

To avoid confusion among the users, and to increase legibility, the guidelines presented in table 7.1 could be taken into account.

Table 7.1: Colour usage guidelines derived from the evaluations and literature studies.

#	**1. Guidelines for Colour Usage**
1.1	Colours that bear meaning for the user, within the platform or elsewhere, should be avoided in places where the colour is not bearing meaning.
1.2	Some colours, for instance, red and green, may have a strong relative meaning connected to them to be used in conjunction if that meaning is not desired.
1.3	Colour coding may facilitate in showing connections between information and increase understanding of the information structure.
1.4	Using too many colours at the same time may confuse the users.
1.5	Using colour coded background may reduce contrast and thereby visibility.

7.2.2 User Focus and Cognitive Load

While working with visualizations, the cognitive load and the users' ability to focus on the task at hand is of great importance, as seen in the design principles listed in section 3.5. For instance, Guideline 2.9 presented in table 7.2 is closely connected to Shneiderman's information-seeking mantra.
During the evaluations, the users commented on how easy or difficult it was to locate the information after changes had been made in the visualizations. The users also commented on how they perceived information to be connected. As an example for guideline 7, in the concept Expandable Cards in Iteration 2, as seen in appendix G.3, the cards are colour coded to signal what parent node they belong to. However, the participants suggested that separating the cards would reduce the effort to see the categories. This was done in Iteration 3, as seen in appendix H.1. An example for guideline 1 and 2 is shown in the concept Goals Overview, seen in appendix G.2, where details are displayed in a pop-up window. In the concept Expandable Cards, seen in appendix G.3, the details are displayed where the user interacts with the card. In the concept Tree Structure, seen in appendix G.5, where detailed information is shown in the side panel. The most preferred way to show additional information was as in Expandable Cards and the least preferred was the pop-up window in Goals Overview.
The users' focus may be increased, and their cognitive load may be decreased by considering the guidelines presented in table 7.2.

Table 7.2: User focus and cognitive load guidelines derived from the evaluations and literature studies.

#	**2. Guidelines Concerning User Focus & Cognitive Load**
2.1	Showing detailed information close to the source.
2.2	Showing detailed information in the same visualization, rather than a pop-up window.
2.3	Avoid showing more information than necessary for the user.
2.4	Allowing the user to hide irrelevant information.
2.5	Animating the movement of the information when changing the layout.
2.6	Increasing visibility of marked objects, as well as decreasing visibility of non-marked objects.
2.7	Having distinct separation between sections in the visualization.
2.8	Positioning pieces of information that are related close to each other.
2.9	Providing an overview of the information and making the user actively access detailed information, rather than showing all information at once.
2.10	Using a straight line for the starting position of information.
2.11	Having a clear starting point in the visualization.
2.12	Increasing the space efficiency may sometimes result in increased cognitive load for the user and may therefore not be valuable.

7.2.3 Usability

The usability of the visualizations is important to consider and evaluate. As an example for guideline 4.1, in concept Expandable Cards, as seen in appendix H.1, where the "follow up" button, which is commonly used by Stratsys' users, was located in the vertical ellipsis menu. The participants in the evaluation suggested making this easier to access.
The usability may be increased by following the guidelines presented in table 7.3.

Table 7.3: Usability guidelines derived from the evaluations and literature studies.

#	3. Guidelines Concerning Usability
3.1	Reducing the number of interactions to access important or commonly used information and functionality.
3.2	Making the most important or most commonly accessed information the most prominent.
3.3	Labelling components, such as bars in a graph.
3.4	Using icons that speak the users' language and are adapted to their mental model.
3.5	Providing a simple layout with fewer options for novice users.
3.6	Allowing the user to see the visualization as pure text.
3.7	Avoid using the same or similar icons for different functionalities
3.8	Providing icons or other means to make it clear when a component is interactive.

7.2.4 Customisation

The participants in the evaluations showed an appreciation towards concepts where the users were able to adapt and customise the visualization to fit their needs. This was recurring during the project, which is evident in the takeaways from Iteration 2, seen in section 6.4.5 and Iteration 3, seen in section 6.5.5, making it an area of great interest. The concept Scorecards, as seen in appendix H.2, is an example that allows the user to change what information to be displayed as well as how the information is displayed.
While designing visualizations, the guidelines concerning customisation presented in table 7.4 could be useful to consider.

7.2.5 Considerations Concerning Evaluation

During the evaluations of the concepts, notes were made on how the evaluation could be done more efficiently and more reliably. As an example for guideline 5.2, in the concept Scorecards, as seen in appendix H.2, all of the cards used the same bar graph. Participants suggested that it would be easier to evaluate the concept if the data used in the prototype was of greater variety. The considerations in table 7.5 were brought to our attention during evaluation of the concepts.

Table 7.4: Customisation guidelines derived from the evaluations.

#	**4. Guidelines Concerning Customisation**
4.1	Allowing the users to choose what is included in the visualization, as well as how it is visualised, may increase usability, legibility and focus for the users.
4.2	Allowing the users to rearrange the information visualised may increase the users' sense of being in control.
4.3	Allowing the users to change the size of the visualization area on the screen may increase focus and legibility for the users.
4.4	Allowing the users to select the amount of visible information, as well as what type of information is visible, may increase focus and legibility for the user.

Table 7.5: The following considerations concerning evaluation emerged during the project.

#	**5. Considerations Concerning Evaluation**
5.1	For evaluation purposes, using information in the visualization that the user can easily relate to may facilitate the user in understanding the concept.
5.2	For evaluation purposes, using varying types of information to showcase flexibility and use cases may increase the understanding of the concept for the user.

By providing these guidelines, we answer the research question that was the foundation of this project. The guidelines' different target areas: *Colour Usage, User Focus and Cognitive Load, Usability,* and *Customisation*, all aid the users in finding, understanding and getting an overview of large amounts of data within a strategic planning platform. The final section, *Considerations Concerning Evaluation*, consists of takeaways found during the project that could be meaningful for designers to have in mind while conducting similar work.

8

Discussion

In this chapter, we will discuss the process, the results, generalisability and ethical issues. We will also state the future work that we believe would be meaningful to finalise the concepts.

8.1 Results from the Project

The results from the three iterations were two concepts, presented as wireframes, and a set of design guidelines for visualizations in strategic planning platforms. The amount of concepts is satisfactory, as it is equal to what we aimed for.

8.1.1 The Final Concepts

The two concepts developed during the process were well received by the participants, who are part of the intended user base and showed great interest in the functionality that we designed. The participants stated that the proposed concepts may be valuable in Stratsys' platform since they are fundamentally different from the current visualizations. One of the participants stated that *"I can not wait for this to be implemented in Stratsys"*.
The concepts were chosen out of a large number of ideas, during a thorough process of heuristic evaluation together with user interviews and questionnaires. Providing the participants with a lot of concept alternatives allowed them to select what they prefer. All the initial concepts were found as a result of ideation building on an extensive amount of literature research on existing visualization styles, as well as on benchmarking of several data visualization platforms. Furthermore, the aim of the concepts is based on the user research that was conducted as a part of the process. The design decisions made during the construction of the prototypes are influenced by the information visualization principles, as presented in section 3.5, that were compiled as a part of the initial research.
The large number of concepts in early iterations was used to capture as many visualization alternatives as possible to give the participants the possibility to compare the designs. Through iterative designing and evaluating, the concepts that provide the most value to the users could systematically be selected. Thus, we are confident that the final two concepts are the ones that provide the most value for the user.
However, the fidelity of the prototypes could have been somewhat higher. One of the reasons that the concepts did not achieve a higher fidelity may be due to us not being able to focus on the resulting concepts early on in the project since we had

many other concepts to implement as well. The intention of the project was to find new ways of visualising the data model of Stratsys, which meant that we needed to try out and evaluate a great variety of different concepts. The trade-off was that none of the concepts was implemented in great detail.

We believe that the trade-off between fidelity and number of ideas was valid for this project, even if we would have been happy to see end products with somewhat higher fidelity.

In Iteration 3 we chose to move forward with three concepts instead of one or two as intended in the planning stage, as described in section 5.4. This deviation from the planned process is something that might have affected the fidelity negatively.

Since the aim of this project was not to implement a finished design, the fidelity of the prototypes is satisfactory. However, if the designs were to be implemented in Stratsys' software, there is still a lot to do. Possible upcoming work is described in section 8.5.

8.1.2 Derived Guidelines

The guidelines developed are based on the evaluation of the concepts created. Hence, the participants were able to compare different visualizations and thereby state which design decision is most beneficial for them. The guidelines are derived from comparing design decisions, as well as from feedback on the concepts. Thus, the proposed guidelines are well tested on the participants in the study.

Furthermore, the guidelines are derived from visualization concepts specific for the strategic planning platforms which include a lot of qualitative information. Therefore, the guidelines should be especially useful while designing information visualizations with large amounts of data in a strategic planning platform.

The guidelines are generalisations based on the takeaways from the evaluations throughout the project. The guidelines are not meant to be an exhaustive list of design guidelines but an initial contribution to a set of guidelines on designing information visualizations for strategic planning platforms. Furthermore, the list of guidelines has not been tested on a large number of people and this project cannot confirm that these guidelines are generally true for all people. Thus, the guidelines are phrased as indicators to point out the direction that we believe information visualization should be designed towards. The guidelines are not trying to establish rules, but rather point out tendencies that were discovered throughout the project.

8.2 Process Discussion

In this section, we will discuss the general process, as well as trying to acknowledge how working remotely may have affected the project. More detailed discussion concerning the user research and the iterations can be found in their respective sections in chapter 6.

8.2.1 Planning and Outcome

The project plan included several design methods that were not used during the project. In the user research phase, three planned analysis methods were not included and thematic content analysis was conducted instead. For instance, the user journey mapping was planned to be based on the data gathered through the observations. However, as discussed in section 6.2.1, the adapted version of observations did not generate the information that we had anticipated and user journey mapping was therefore not feasible to conduct. The thematic content analysis was seen as a sufficient replacement for the analysis methods.
The preliminary schedule and planned methods were adapted during the process to suit the tasks at hand as well as the time constraints. The selection of ideas to pursue between the ideation and prototyping were based on informal decisions rather than formal idea selection methods as planned, which was discussed in sections 6.3.2, 6.4.2, and 6.5.2. There is no indication that the informal idea selection affected the outcome negatively.
The evaluations of the prototypes were planned to be done through a combination of user evaluation and expert evaluation methods. However, since this project focused on the user experience, it was considered more valuable to allocate the available time towards user evaluations. For instance, the heuristic evaluation of the concepts that was planned to be included in each of the three iterations, but was only carried out in Iteration 1. The reason for not conducting the method in the later iterations was mainly based on the outcome of the method, as discussed in 6.3.6. As a result, the heuristic evaluation was abandoned for Iteration 2. In Iteration 3, the prototyping took a longer time than planned, and we realised that the evaluation would take a long time as well. Therefore, the number of evaluation methods needed to be reduced. Based on the outcome of previous evaluations and the user-centred aim of the project, the heuristic evaluation and SWOT analysis were excluded at this stage.

8.2.2 Working Remotely

Due to the restrictions posed by the current pandemic, as described in section 1.6, some methods that were planned to be conducted needed to be adapted for working remotely, other methods were left out of the planning due to the restrictions.

Conducting Interviews and Observations Remotely

The user interviews and questionnaires were all conducted remotely. Conducting the interviews remotely may have facilitated the participants' scheduling by allowing the participant to choose their location and time for the interviews.
Note-taking from the interviews may also have benefited from conducting the interviews remotely, as we were able to take notes without the participant seeing it and therefore being affected by it. The participants were informed that we were taking notes. However, they could not see the note-taking process. Showing the note-taking to the users may aid the user in finding a phase of talking that may facilitate both note-taking and in making the participant feel confident. By showing

the note-taking process, the participant may take small breaks in their responses to make sure that we are done writing, which may facilitate follow-up questions and in achieving more complete documentation.
As a result, we believe that conducting interviews remotely does not affect the outcome negatively and can in some circumstances be beneficial to the research. However, as discussed in section 8.2.2 and 6.4.6, we have seen that the adapted observations made during the interviews did not give a satisfactory result. Therefore, we believe that conducting observations in a different format could have been beneficial for the project.

Conducting Evaluation Remotely

During the evaluation of the concepts developed in Iteration 2, section 6.4, and Iteration 3, section 6.5, current users of Stratsys and other participants were involved. For Iteration 2, the evaluation was planned to consist of presenting the concepts to the users and ask them a set of questions and hearing what they generally think of the concepts. This evaluation method conducted was well suited for this iteration, due to the fidelity of the concepts and the lack of interactions being incorporated. The concepts were both presented in interviews and as a part of a questionnaire.
The interviews were considered successful and a lot of insight and takeaways could be compiled. However, the questionnaire did not provide as valuable insights as the interviews did. This is likely due to the questionnaire being more quantitative than the interview.
Furthermore, the questionnaire created in Iteration 2 was not pilot tested, which may have resulted in some questions being difficult for the participants to comprehend. The responses to the questions in the questionnaire were generally shorter than the responses from the interviews.
As a result, we believe that questions that can not be quantified are better suited to be asked during an interview, rather than in a questionnaire. However, ranking questions and quantifiable questions are well suited for questionnaires.

Ideating Remotely

As discussed in section 6.3.6 and 6.4.6, the ideation in Iteration 1 and 2 was carried out remotely. Since the concepts were to a large extent ideated individually, the prototypes of the concepts were to a large extent created by the same person who sketched them. This may have affected the sense of shared ownership of the concept as well as resulted in a lack of common understanding of how the concepts are meant to be used.
Conducting ideation remotely has proven to be more time consuming than doing it co-located. This may have affected the time plan of the project, with delays of about one to two days per iteration.

Prototyping Remotely

The prototyping of Iteration 1 and 2 were also conducted remotely. The wireframes created were done in a shared document in Adobe XD, however as discussed before,

the wireframes were to a large extent developed by the team member who had done the sketches for it. This resulted in having to present the concept to the other team member when it was done, to keep both of us up to track.
Presenting the concepts to each other after it was finished meant that there was no ongoing feedback and discussion on design decisions as well as no consistency between prototypes created. The lack of ongoing feedback may have resulted in large portions of the prototypes having to be redesigned after they were considered as finished, which may be more time consuming than incorporating the feedback continuously.
The lack of consistency may have resulted in the same component being designed multiple times, such as a menu bar or a side panel. By having both team members designing the same components individually, more alternative designs were developed. However, this may have been more time-consuming.
Furthermore, the inconsistency in look and feel, as well as inconsistency in fidelity, may have affected the evaluation results, as the participants might focus on different aspects in a prototype with higher fidelity than in a one with low fidelity.

Digital Tools

While utilising digital tools to enable remote working, the focus may be guided to the tools rather than the wanted outcome or the process. In this project, virtual sticky notes were used for brainstorming and analysis purposes. However, while using these tools, a lot of frustration arose due to limitations in the tools' functionality. Furthermore, the lack of tangible feedback in the digital tools prohibits the sense of interacting with the information.
The outcome as a digital image in these tools may have affected the amount of time spent to make the outcome aesthetically pleasing, which may have negatively affected how time-consuming each task was.

8.2.3 Working in Co-location

Iteration 3 was partly conducted in co-location, as described in section 6.5. The ideation and prototyping phases were conducted in co-location, which allowed for more discussion and more instant feedback. Furthermore, conducting the ideation and prototyping in co-location facilitated collaboration and exchanging ideas. More discussion on working in co-location can be found in section 6.5.6.

Ideation in Co-location

Since the sketching was done in co-location in Iteration 3, the entire sketching process was visible to both team members, which allowed for ongoing feedback that could be incorporated into the sketches, which may have saved time and allowed us to create more refined and thought through sketches.
Less time was put into each sketch and the concept being sketched was presented to the other team member at the same time as it was being sketched. This may have enhanced the understanding of the concepts, as well as allowing us to create less detailed sketches for presentation to the team.

Prototyping in Co-location

Prototyping in co-location facilitated collaboration whilst constructing the prototypes. The co-location facilitated ongoing feedback and thereby continuously refined designs. Each design decision could be discussed and ideated on, which may have affected the prototypes positively.

As a result, we believe that prototyping in co-location during an early stage of the work facilitates a sense of shared ownership of the concepts created, as well as more thought-through design decisions.

8.3 Generalisability

This project has focused on strategic planning software with a lot of qualitative data. The prototypes created are designed mainly with Stratsys' use cases in mind. Furthermore, the target users of the concepts created are current users of Stratsys. The takeaways from the evaluations and user research are specific to this project. However, the compiled guidelines are generalisations of the takeaways and they may therefore be applied in other projects as well.

8.4 Ethical Issues

Since this project involved participants outside of the team members, a large concern had to be put into preserving participant privacy. The privacy concerns were well thought through and how we handled the participants' information throughout the project is stated in section 6.1. We cannot see that any participants' privacy has been compromised during the project.

The ethical concerns, stated in section 5.6, were to a large extent considered. However, due to not including any participants with special accessibility needs, this concern might have been down prioritised during the project. This is unfortunate and may have affected the results of the project negatively.

Since the concepts are in an early stage, the colours used in the concepts are not final. However, accessibility concerning colour deficiency has been thought through and wherever colours are used to carry meaning, the intention is that the users should be able to change the colours to their preferences.

The guidelines compiled focuses on reducing the cognitive load for the user, reduce confusion, as well as to increase legibility, and focus. The guidelines also suggest that the users should be able to customise the visualizations to support their needs. We believe that a reduced cognitive load and a more adaptive design may enhance the user experience, increase accessibility and lower the stress level for the users. The tools should be adaptable to fit the user, the user should not have to adapt to fit the tools.

8.5 Future Work

The developed concepts are in an early stage and further work needs to be done for the concepts to be usable. If the concepts are to be implemented by Stratsys, they should be adjusted to better suit the current design standards of the company.
During the evaluation phase of Iteration 3, some issues surfaced in the two remaining concepts. For future work, the following takeaways and suggested changes from the evaluation should be incorporated and evaluated with end-users.
Possible fixes to be incorporated for the concept Expandable Cards include:

- Use a more standardised and unified colour scheme.
- Avoid using colours that can be interpreted as meaningful where they lack meaning.
- Avoid using colours that are used for coding on items that are not part of the coding. For instance, this applies to the colour yellow that is used as a "status" indicator.
- Make the favourites section stand out more, to provide a starting point and to enhance focus.
- Be consistent in the placement of the star icon between small and big cards.
- Move the parent node title to the top of the cards, to better suit the users' mental model.
- Evaluate the icons used, for instance, the minimise section icon that was not commonly recognised by the users.
- Add visual indication that the cards can be interacted with and expanded, for example, an expansion icon in a suitable corner.
- Put the "Follow Up" button directly on the card, instead of in the vertical ellipsis menu.
- Make the expanded card more space-efficient by aligning the titles above the text.
- Incorporate the use of notifications to alert the user if any information has changed since they last checked it.
- Add the ability for the user to change which information is shown on the cards, similar as in Scorecards.
- Add the ability for the users to change which colour scheme is used in the visualization.
- Use colour coded icons to show status, rather than the colour coded progress bar.
- Add labels to the progress bar.
- Show minimum and maximum values on the progress bar.

Possible fixes to be incorporated for the concept Scorecards include:

- Use a less distracting colour scheme for the visualizations.
- Make all cards the same height so that all cards start in a straight line. Preferably by always allocating the same amount of space for all sections regardless of the text length. For instance, headlines could have space for two rows of text.
- Put the "Follow up" button directly on the cards instead of in the vertical ellipsis menu.

- Make sure that icons are not reused for different functionalities.
- Clarify why some options are not available, such as displaying the "status" as text.
- Make the icons look more interactive.
- Find a different solution to display comments when they are visualised as icons, instead of a tooltip.
- Put the titles outside of the scrolling window in the standing layout, so that they remain visible when the users read long comments.
- Enable the users to change the visualization settings for individual cards, not only all cards at once.
- Allow the user to decrease the size of the cards to fit more overview data on the screen.
- Allow the user to increase the size of the cards to fit more detailed information on each card.
- Allow the user to hide the menu bar at the top.
- Design a favourites section where cards marked as favourites are placed. Alternatively, only show cards marked as favourite on the screen and visualise the rest in the side panel.

9
Conclusion

The purpose of this project was to develop new ways of visualising quantitative data within a strategic planning software, as well as to compile a list of design guidelines that can answer the research question: *Which design principles, leaning on novel and well-known research on information visualization and transitions, can support overview and comprehension of large amounts of data in a strategic planning platform?*
The project was carried out iteratively where the first iteration was aimed at providing a large number of alternative visualizations. Later iterations focused on narrowing down and refining the concepts that were considered to be most valuable for the users. The project resulted in two proposed concepts and a set of information visualization design guidelines for designing strategic planning platforms. Thus, this project has answered the research question.
The concepts that the users deemed as most valuable for their work in Stratsys are Expandable Cards and Scorecards. They are based on the users' concerns and requirements that were established during the user research phase, as well as on the extensive literature research conducted. The concepts have been incrementally refined through evaluation, redesigning and further evaluation.
The design guidelines are categorised as *Colour Usage, User Focus and Cognitive Load, Usability,* and *Customisation*. The considerations are defined as *Considerations Concerning Evaluation*. The design guidelines are based on the evaluation of the concepts, providing insights that were made during the project regarding how to implement a visualization well suited for strategic planning software. The guidelines aim to facilitate finding, understanding and getting an overview of large amounts of data within a strategic planning platform and are based on takeaways found during the project that could be meaningful for designers to have in mind while conducting similar work.
The resulting guidelines are specific to information visualization design within strategic planning platforms to provide a more niche set of guidelines for this specific area within information visualization. Further work is needed to finalise the developed concepts as well as to make the list of guidelines more exhaustive.

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Appendix A

Interview Manuscript - User Research

The interview manuscripts is written in Swedish, this is due to all of users participating speaks Swedish as their native language. The manuscript is included on the following page.

Intro

Tack för att du ställer upp på den här användarintervjun!

1. **Vi heter Tove och Alexander** och läser masterprogrammet Interaction Design and Technologies på Chalmers. Vi gör vårt examensarbete kring **Stratsys visualiseringar**. Jag kommer att ställa frågorna och X antecknar.

2. Vi vill ta reda på **hur du jobbar** med Stratsys och **vad du oftast gör** i plattformen. Vi kommer att **fokusera på de olika vyerna** där information och data visas. Exempel på vad vi menar med "vyer" är "Röda Tråden" (som du kan se här), "Tabell" och "Gantt".

Vi vill veta hur du använder de olika vyerna och om det finns några **problem**, någonting som du **tycker behöver förbättras** eller om det finns någonting du **tycker fungerar extra bra** med de olika vyerna.

3. Vi gör den här intervjun för att se vad som **fungerar i dagens design** och vad som skulle kunna **förbättras**. Alla svar kommer att **anonymiseras** och vi kommer **inte att dela någon information** som kan knytas till dig med någon utanför intervjun.

Att delta i intervjun är helt **frivilligt** och det är okej att **avbryta** när som helst eller att välja att **inte svara** på en fråga.

Vi skulle gärna **spela in intervjun** för att använda när vi **analyserar** de svaren vi fått. Inspelningen kommer **inte att delas** med någon annan än de som är med i intervjun. **Är det okej för dig om vi spelar in intervjun?**

> **JA ->** Okej, då sätter vi igång inspelningen nu. (Sätt igång inspelningen)
>
> **NEJ ->** Okej, då för vi bara anteckningar i stället.

Person och bakgrund

1. Vilken roll har du i din organisation?
2. Hur länge har du jobbat här?
3. Vad har du jobbat med tidigare?
4. Hur datorkunnig är du? (På en skala från 1-5)
5. Använder du smartphone och/eller padda på jobbet?
6. Har du stor/liten skärm/laptop?

Dagliga arbetet

- Beskriv en vanlig arbetsdag med de processer du arbetar utifrån – det behöver inte vara relaterat till Stratsys
- Beskriv de smärtpunkter du eventuellt upplever i ditt dagliga arbete

Arbete med Stratsys

1. Hur länge har du nu arbetat med Stratsys?
2. Hur ofta använder du Stratsys?
3. Har du arbetat med andra liknande system tidigare? (Någon typ av planeringsverktyg)
4. Har du fått någon introduktion eller utbildning i Stratsys?

Skärmdelning?

Nu kommer några frågor där vi skulle vilja **veta mer om hur du jobbar** med Stratsys.
Är det okej med dig att dela skärm så att vi kan se hur ditt vardagliga arbete i programmet ser ut?
Annars går det bra att **bara beskriva muntligt.**

JA -> Okej, vad bra! Vet du hur man delar skärm i Teams? --- osv, ev hjälp till, tills skärmen delas.
NEJ -> Okej, ingen fara! Då tar vi det muntligt i stället.

Hur ofta är du inne i Stratsys och jobbar?
Kan du beskriva och visa **vad du gör i Stratsys och varför?** Visa gärna **vilka vyer** du använder och **beskriv vad** du använder just den vyn till och **hur ofta**. Vi skulle också vilja veta om det är någonting som du tycker är **bra eller dåligt** med den vyn.

- Kan du beskriva de vanligaste uppgifterna du gör i Stratsys?
- Vad gör du?
- Vad är syftet med uppgiften?
- Vad fungerar bra/dåligt?

Per vy som du använder:

Träd - Drag and drop, Tabell - Trädstruktur, Tabell, Stående, Kontrollrum, Strategikarta, Riskmatris, Gantt

- Har du använt den här vyn?
- Hur ofta?
- Vad använder du vyn till?
- Vad är bra/dåligt?

Avslutning:

Tack så mycket för att du ville vara med i intervjun!
Har du något du vill tillägga eller något du vill fråga oss?

Appendix B

Interview Manuscript - Iteration 2

The interview manuscripts is written in Swedish, this is due to all of users participating speaks Swedish as their native language. The manuscript is included on the following page.

1. **Vi heter Tove och Alexander** och läser masterprogrammet Interaction Design and Technologies på Chalmers. Vi gör vårt examensarbete kring **Stratsys visualiseringar**. Jag kommer att ställa frågorna och X antecknar.

2. Vi kommer att visa upp några prototyper och designförslag som vi har tagit fram. De designförslag som vi har tagit fram kan komma att påverka Stratsys funktionalitet och/eller utseende.

3. Tänk på de bilder vi visar som skisser, snarare än färdiga designer och din input är viktig för att vi ska kunna utveckla skisserna vidare. Det är därför välkommet med både positiv och negativ kritik. Då prototyperna är i ett tidigt stadie så kan det vara svårt att ge ett analytiskt svar och det är helt okej att säga sin första tanke. Det finns inga rätt eller fel svar.

4. Det vi vill ta reda på är vad du tror eller tycker om de olika koncepten, vad du tror att de olika koncepten kan användas till och hur eller varför du skulle använda/inte använda dig av konceptet. Vi vill också veta vad du tycker är bra eller dåligt i de olika koncepten och om det är någonting som du tycker saknas i konceptet. Förslag på förbättringar är också välkomna.

5. Vi kommer att presentera designförslagen och du kan när som helst avbryta med frågor eller be om förtydliganden. Vi kan också alltid gå tillbaka till tidigare slides om du vill.

6. Alla svar kommer att **anonymiseras** och vi kommer **inte att dela någon information** som kan knytas till dig med någon utanför intervjun.

Att delta i intervjun är helt **frivilligt** och det är okej att **avbryta** när som helst eller att välja att **inte svara** på en fråga.

Vi skulle gärna **spela in intervjun** för att använda när vi **analyserar** de svaren vi fått. Inspelningen kommer **inte att delas** med någon annan än de som är med i intervjun. **Är det okej för dig om vi spelar in intervjun?**

JA -> Okej, då sätter vi igång inspelningen nu. (Sätt igång inspelningen)

NEJ -> Okej, då för vi bara anteckningar i stället.

<Visa prototyp och ev. beskriva den.>

1. Vad är ditt första intryck av det här konceptet?
2. Är det någonting som du tycker är oklart i det här konceptet?
3. Vad tror du att det här konceptets styrkor är?
4. Vad tycker du fungerar dåligt i det här konceptet?
5. Tror du att du skulle använda den här vyn i ditt arbete?
6. Har du några förslag på vad som skulle kunna förbättras eller förändras?

Appendix C

Interview Manuscript - Iteration 3

The interview manuscripts is written in Swedish, this is due to all of users participating speaks Swedish as their native language. The manuscript is included on the following page.

1. **Vi heter Tove och Alexander** och läser masterprogrammet Interaction Design and Technologies på Chalmers. Vi gör vårt examensarbete kring **Stratsys visualiseringar**. Jag kommer att ställa frågorna och X antecknar.

2. Vi kommer att gå igenom tre designförslag som vi har tagit fram.

3. Vi vill gärna att du tänker högt och berättar dina spontana reaktioner. Vi vill veta vilka känslor koncepten väcker och hur du förstår koncepten. Det finns alltså inga rätt eller fel svar. All kritik är välkommen, både positiv och negativ.

4. Det vi vill veta är vad du tänker om de olika koncepten och vad du tror att de kan användas till. Vi vill också veta vad du tycker är bra eller dåligt och om det är någonting som du tycker saknas i konceptet. Du får gärna komma med förslag på förbättringar också.

5. Alla svar kommer att **anonymiseras** och vi kommer **inte att dela någon information** som kan knytas till dig med någon utomstående.

Att delta i intervjun är helt **frivilligt** och det är okej att **avbryta** när som helst eller att välja att **inte svara** på en fråga.

Vi skulle gärna **spela in intervjun** för att använda när vi **analyserar** de svaren vi fått. Inspelningen kommer **inte att delas** med någon annan än de som är med i intervjun. **Är det okej för dig om vi spelar in intervjun?**

> **JA ->** Okej, då sätter vi igång inspelningen nu. (Sätt igång inspelningen)
> **NEJ ->** Okej, då för vi bara anteckningar i stället.

Flödestest

Flöde = interaktioner/navigeringar/klickningar & hovringar

Expanderbara kort

1. **Scrolla i vyn**
    a. Vad tänker du om den här vyn?
2. **Favoritmarkera Resultat ur balanssynpunkt.**
    a. Vad tänker du om att kort kan favoritmarkeras och läggas i en egen sektion?
3. **Avmarkera kortet som favorit.**

4. **Expandera kortet Brukarbedömning daglig verksamhet under avdelningen Attraktiv och effektiv organisation.**
    a. Vad tänker du om att visa informationen på det här sättet?
    b. Vad tänker du om flödet för att ta fram mer information?
5. **Hur gör du kortet mindre igen?**
6. **Nu kan du testa att expandera Personalkostnad och sedan Resultat ur balanssynpunkt.**
7. **Titta vad som finns under de tre prickarna i det expanderade kortet.**
    a. Vad tänker du om det här sättet att komma fram till Följa upp och Ändra?
8. **Dölj alla kort i Attraktiv och effektiv organisation.**
    a. Vad tänker du om att hela sektioner kan döljas?

Nu när du har testat att klicka runt lite, vad är din känsla av vyn?

1. Styrkor?
2. Svagheter?
3. Något som saknas?
4. Överblick?
5. Yteffektivitet?
6. Känns vyn intuitiv?

Trädstruktur

1. **Scrolla i trädet.**
    a. Vad tänker du om den här vyn?
        i.
2. **De olika nivåerna är färgkodade**
    a. Vad tänker du om det?
3. **Klicka på Personalkostnad i trädet.**
    a. Vad tycker du om den här detaljpanelen?
    b. Vad tänker du om att andra noder fejdas ut?
4. **Klicka på Personalkostnad i trädet igen.**
5. **Titta på detaljpanelen utan Personalkostnad expanderat.**
    a. Vad tänker du om den här vyn?
6. **Klicka på Personalkostnad i detaljpanelen**
    a. Vad tänker du om den här interaktionen?
7. **Klicka på Följ upp.**
    a. Vad tänker du om flödet för att följa upp?
8. **Stäng fönstret (klicka varsomhelst)**
9. **Dölj alla Indikatorer under noden Kostnadseffektiv resursanvändning… i Målnivå 1.**
    a. Vad tänker du om att noder kan döljas i trädet?

Nu när du har testat att klicka runt lite, vad är din känsla av vyn?

1. Styrkor?
2. Svagheter?
3. Något som saknas?
4. Överblick?
5. Yteffektivitet?

6. Känns vyn intuitiv?

Scorecards

1. **Vad tänker du om den här vyn?**
2. **Det finns en Detaljpanel. Hur tror du att du ska göra för att visa den? (Klicka på Pilen eller Personalkostnad)**
    a. Vad tänker du om det här sättet att öppna panelen på?
    b. Stäng Detaljpanelen.
    c. Det finns ett annat sätt att öppna panelen. Hur?
3. **Hur skulle du göra för att stänga/öppna den detaljerade informationen om Personalkostnad?**
4. **Se till att Personalkostnad är stängd. Titta vad som finns under de 3 prickarna i högerhörnet på Budget i balans.**
    a. Vad tänker du om att ha de här valen(alternativen) under de tre prickarna?
5. **Visa kommentar på Budget i balans.**
    a. Vad tänker du om det här sättet att visa kommentarer?
    ~~b. Vad tänker du om det flödet för att visa kommentarer?~~
6. **Ändra layout till Stående kort. (KLICKA EJ I DETALJPANELEN)**
    a. Vad tänker du om den här vyn?
7. **Scrolla i listan med kommentarer.**
    a. Vad tänker du om den här lösningen för att kunna läsa långa kommentarer?
8. **Ändra tillbaka till Liggande.**
9. **Klicka på Kugghjulet.**
    a. Vad tänker du om menyn som dyker upp?
    b. Vad tror du händer om man klickar på de olika ikonerna?
10. **Klicka på Status i menyraden.**
    a. Vad tänker du om att ikoner på korten kan döljas?
11. **Klicka på Kommentar.**
    a. Vad tänker du om att Kommentar, Definition och Åtgärd kan visas som antingen ikon eller ren text?

Nu när du har testat att klicka runt lite, vad är din känsla av vyn?

1. Styrkor?
2. Svagheter?
3. Något som saknas?
4. Överblick?
5. Yteffektivitet?
6. Känns vyn intuitiv?

Sammanfattning:

Vad tänker du om de olika vyerna nu när du har sett alla tre?

Vilken vy föredrar du? Kan du rangordna de olika vyerna efter vad du tycker?

Vilken vy tror du skulle vara mest användbar att ha i Stratsys?

Appendix D

SWOT analysis - Iteration 1

SWOT Analysis			
Tree Structure			
Strengths	**Weaknesses**	**Opportunities**	**Threats**
Details in same view Supports overview No scrolling Interactive Clear overview of the amount of data	Limited details in overview Messy to read Items changing position	Filtering Similar to the connecting Thread	Lots of data Unclear Algorithm Colour coded data Lots of reading to find data
Enclosure			
Strengths	**Weaknesses**	**Opportunities**	**Threats**
Clear Hierarchies	Navigation to reach details Lengths of largest enclosing level Unusual representation of hierarchies Uneven numbers generate blank space	Space efficiency	Lots of scrolling with many nodes
List Overview			
Strengths	**Weaknesses**	**Opportunities**	**Threats**
Good overview of goals Clear hierarchies Drill-down	Lots of blank space No overview of everything	Interactive	Lots of scrolling with many nodes Cannot compare child nodes Lots of navigation
Goals Overview + List Overview			
Strengths	**Weaknesses**	**Opportunities**	**Threats**

Utilizes entire screen Filtering options Good overview of goals Structure is intuitive	Pop-up/tooltip cover a lot of the visualization	Drill-down Interactive	Hard to locate node if many is available Cannot compare activites

Tags

Strengths	Weaknesses	Opportunities	Threats
		Can be incorporated in other visualizations	
Common element in design Known to users	Needs to be memorised	May enable personal filtering May facilitate in searching May facilitate in filtering	Might become cluttery Takes up space

Zoom and Pan / Mini Map

Strengths	Weaknesses	Opportunities	Threats
		Can be very large	Can be very large
Good overview Flexible Interactive	Map may cover the visualization Nodes may change place	Can be used with different visualizations Side panel may facilitate in navigation Gamification	Hard to navigate for beginners May be difficult to locate nodes May be difficult to implement Unclear how to access details

Indentation List

Strengths	Weaknesses	Opportunities	Threats
Common design Good overview Space efficient Fits a lot of information on the screen Can show details	May appear as boring Text provides no feeling of the content	Icons may improve Intuitive hierarchies Can be combined with other visualizations	Feels static

Goals Overview

Strengths	Weaknesses	Opportunities	Threats

Overview of all goals Easy access to common goals Uses entire screen Shows where there is new information Lots of filtering options	Can not overview child nodes	Filtering options Similar to a dashboard	May be too difficult to access detailed data May be confusing for first time users

Focus View Vertical

Strengths	Weaknesses	Opportunities	Threats
Focus on progress Everything in one place Good overview of the content inside a selection	Bad overview of parent nodes No overview of content inside a different parent node	More focus on selected node Can focus more on progress Inviting for interactions	Space efficiency Not suitable for too small screens Unclear how show more child nodes

Focus View Reversed

Strengths	Weaknesses	Opportunities	Threats
Good overview of parent nodes and their content	Each node takes up a large space	Node size may be adjustable Level of details may be adjustable	Lots of scrolling Lack of overview if scrolling is needed Space efficiency

Checklist

Strengths	Weaknesses	Opportunities	Threats
Simple layout Fits a lot on the screen Hides details to provide overview	Numbering does not feel right Text gives suboptimal feeling of the content Two columns does to facilitate in reading	One column could be replaces with other information Width of column may be adjustable	Feels static Lots of navigation to access data

Table D.1: Compiled results from the SWOT analysis.

Appendix E

Decision Matrices - Iteration 2

The qualitative data is was transferred to 2x2 decision matrices. The resulting matrices are presented in figure E.1 to figure E.6. Each figure corresponds to the qualitative result for each of the concepts and each colour represent one participant. The *Notes/Comments* section was used for suggested improvements or comments that did not fit into any of the four sections. Blank notes represents questionnaire participants that did not leave any reply to the corresponding question.

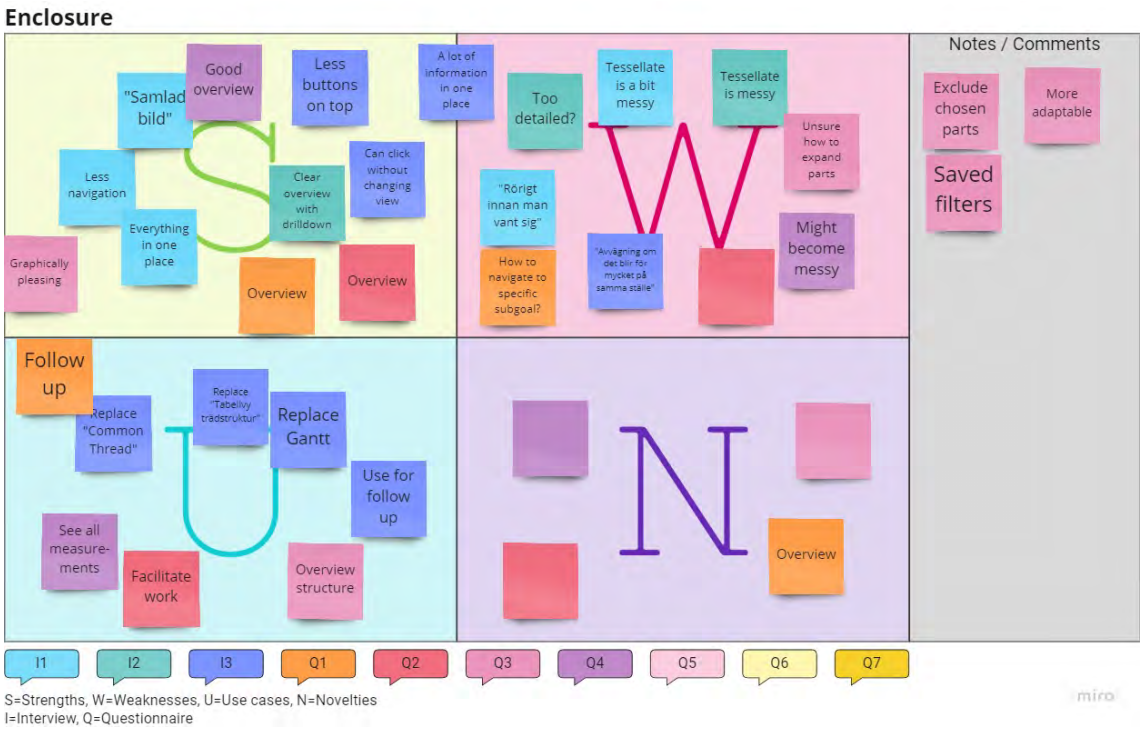

Figure E.1: 2x2 Decision Matrix for the concept ENCLOSURE.

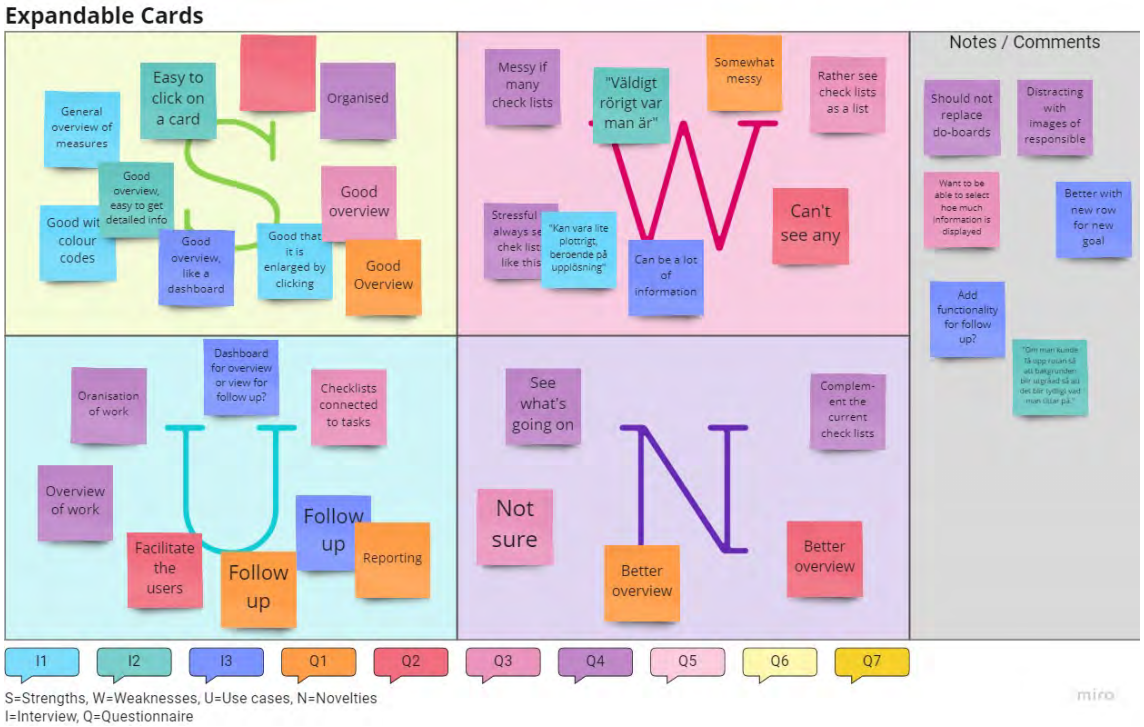

Figure E.2: 2x2 Decision Matrix for the concept EXPANDABLE CARDS.

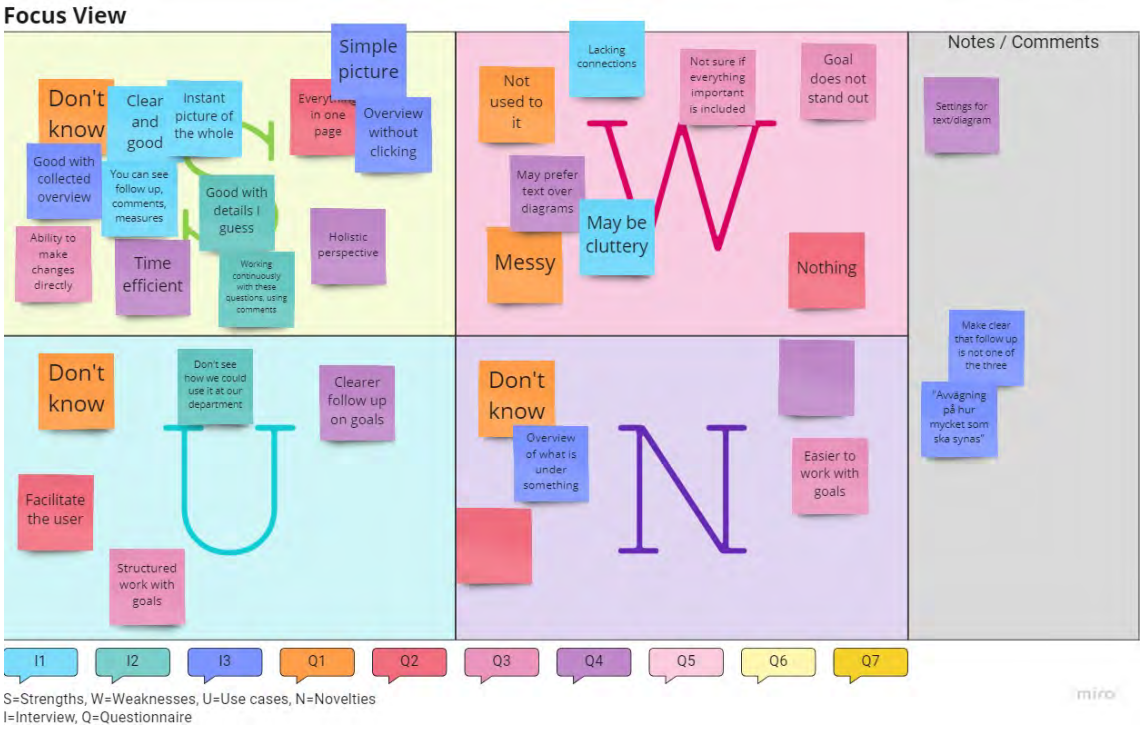

Figure E.3: 2x2 Decision Matrix for the concept Focus View.

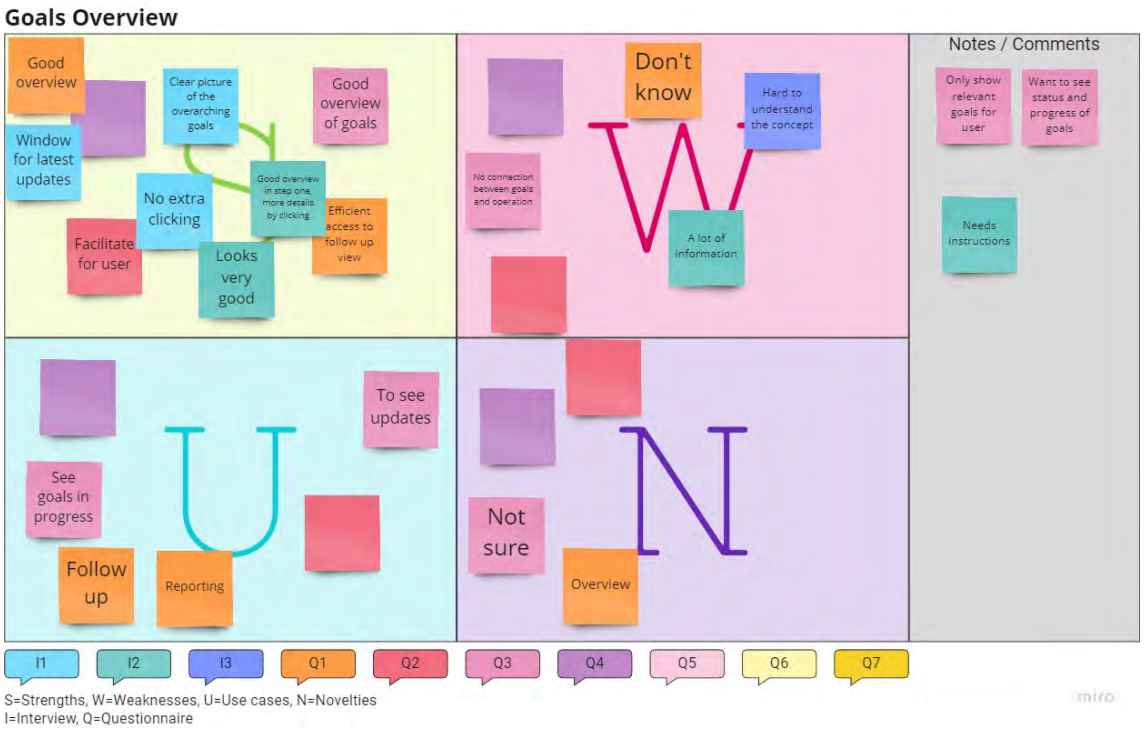

Figure E.4: 2x2 Decision Matrix for the concept Goals Overview.

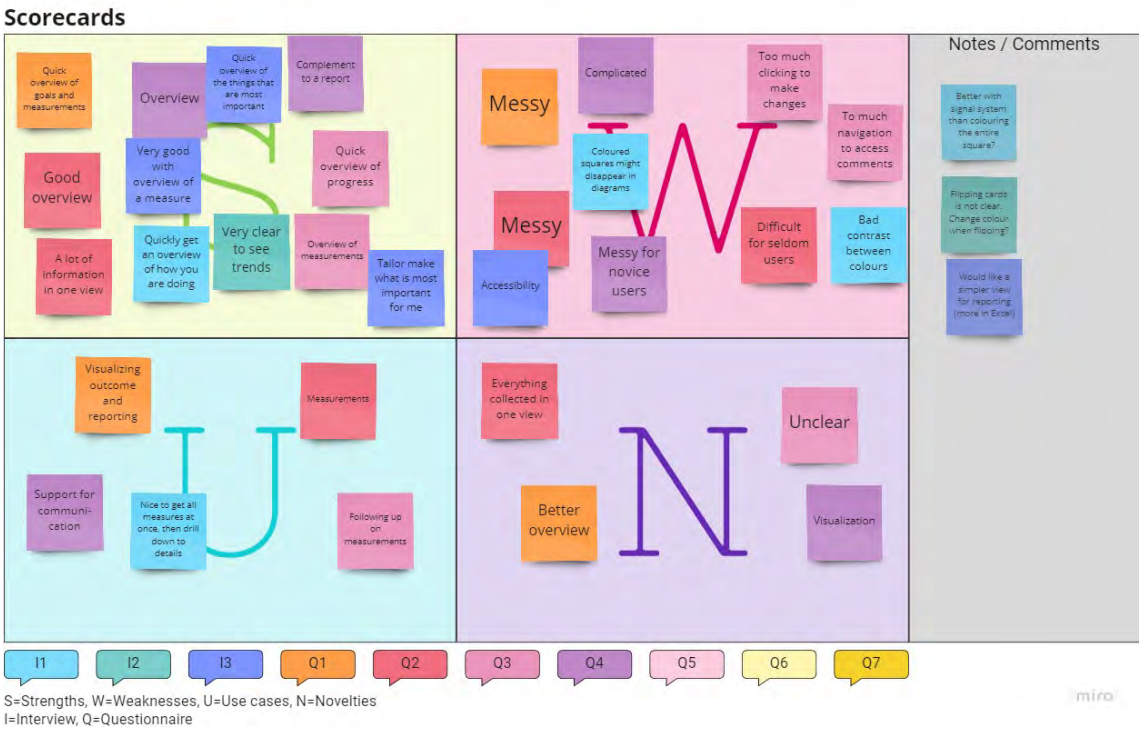

Figure E.5: 2x2 Decision Matrix for the concept SCORECARDS.

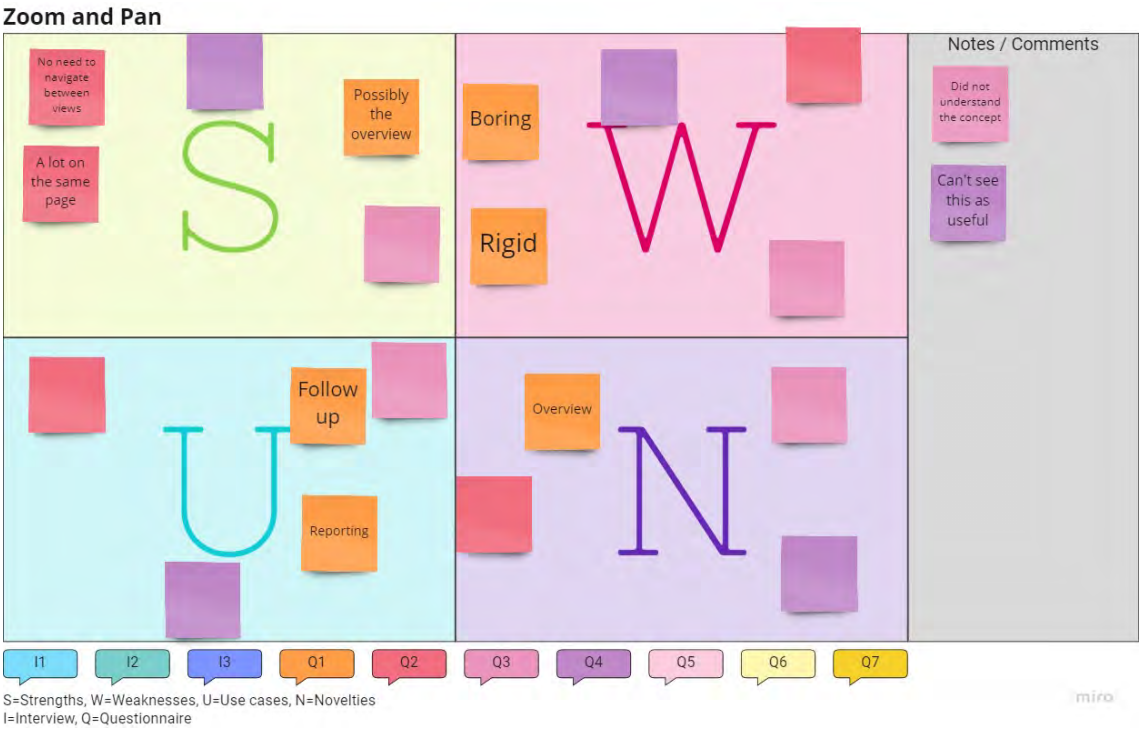

Figure E.6: 2x2 Decision Matrix for the concept ZOOM AND PAN.

Appendix F

Prototypes - Iteration 1

F.1 Checklist

The prototype Checklist, as seen in figure F.1, was constructed to reduce the amount of scrolling that is required to access all items in a list and thereby provide better overview. By dividing the list into two columns and hiding detailed information, less vertical space is required. The Checklist - Expanded, as seen in figure F.2, shows the view with one element expanded to show details. Checklist - All Expanded, as seen in figure F.3, shows the view with all details visible, where there is more detailed information. The list items that are not expanded here does not have any additional information to show, which is indicated by the minus icon as opposed to the checkbox icon.

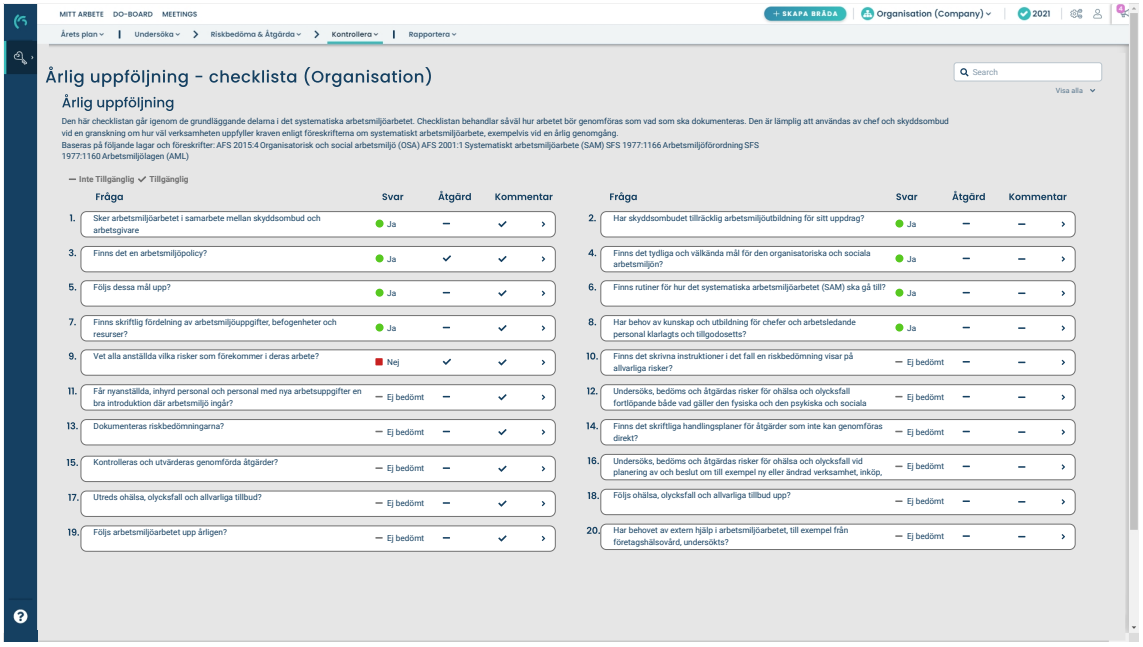

Figure F.1: The Checklist prototype with two columns.

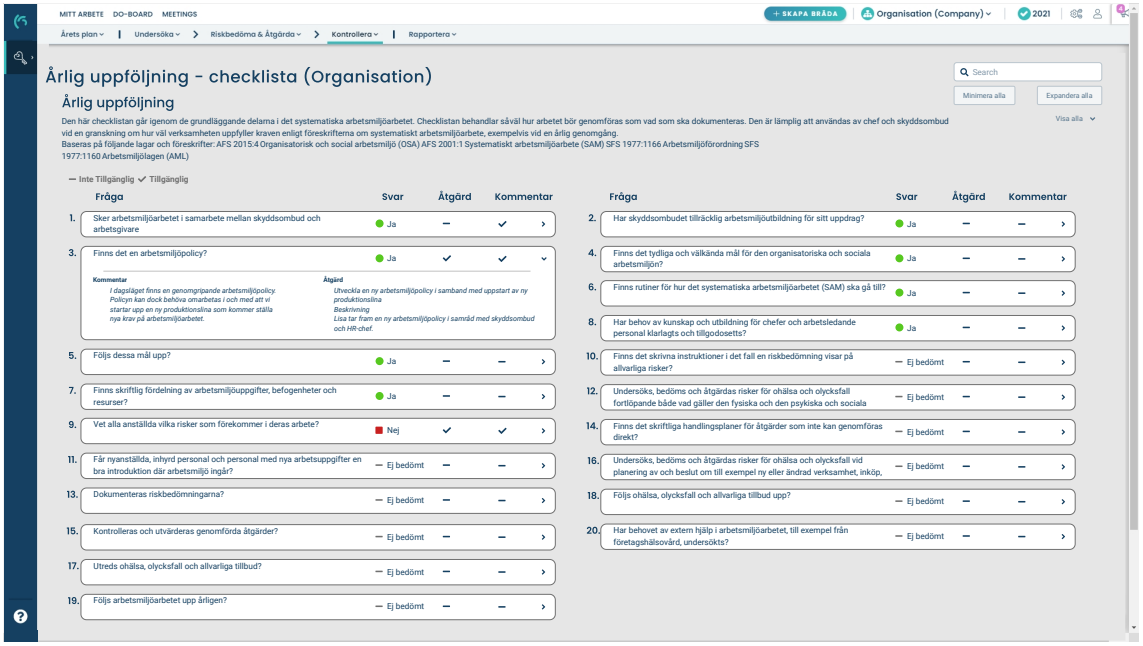

Figure F.2: The CHECKLIST prototype, here with one element expanded to reveal detailed data.

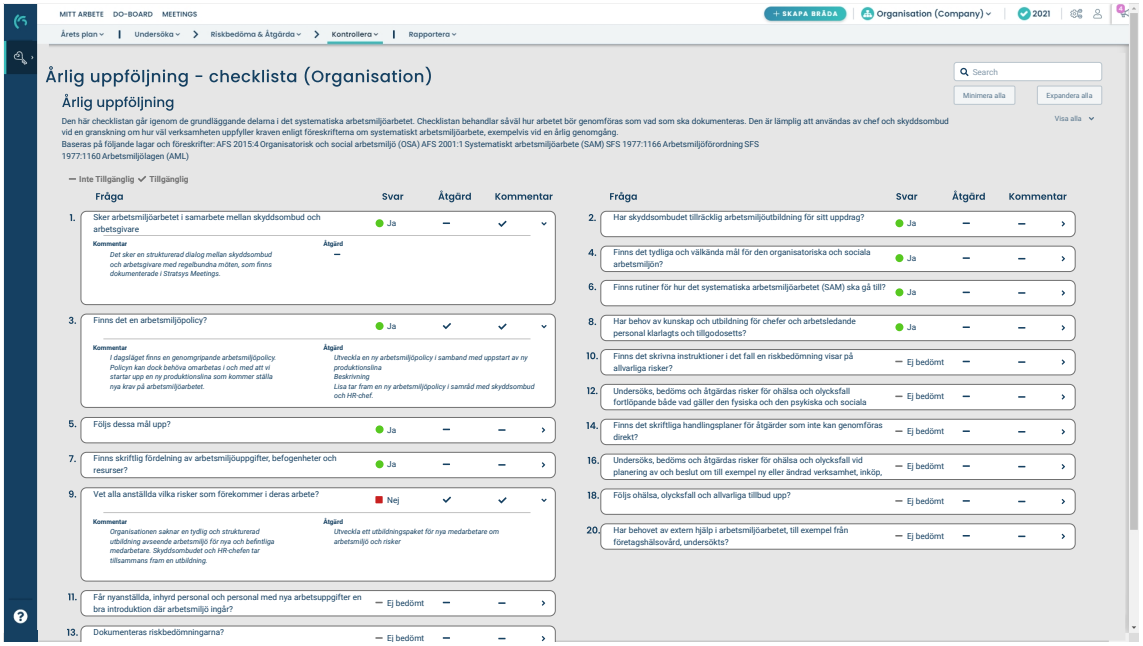

Figure F.3: CHECKLIST with all elements expanded.

F.2 Enclosure

Enclosure, as seen in figure F.4, was constructed to provide an overview of the data, and at the same time showcase the hierarchies in a clear way. It is inspired by the Tree Map, which uses enclosure to visualise hierarchies. Each parent node encloses all of its child nodes, and this is done recursively.
The elements in the view is expandable and minimizable, to preserve space and to enhance focus. Enclosure Expanded displays how an element can be expanded to show more details in the view.

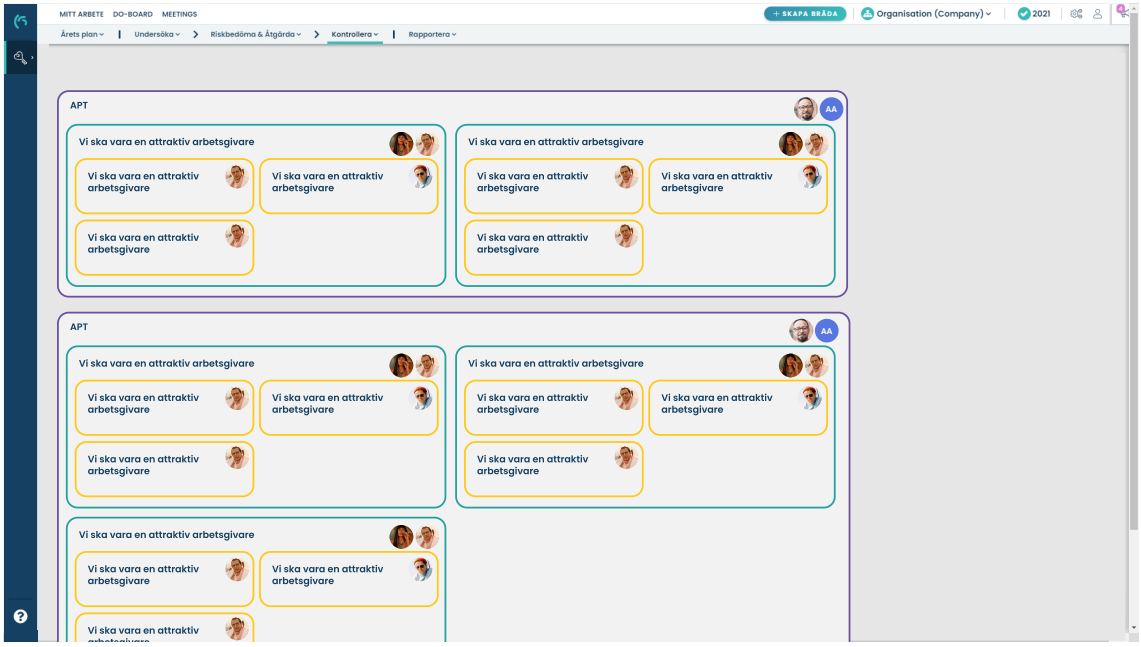

Figure F.4: Enclosure utilizes enclosing elements to show hierarchies.

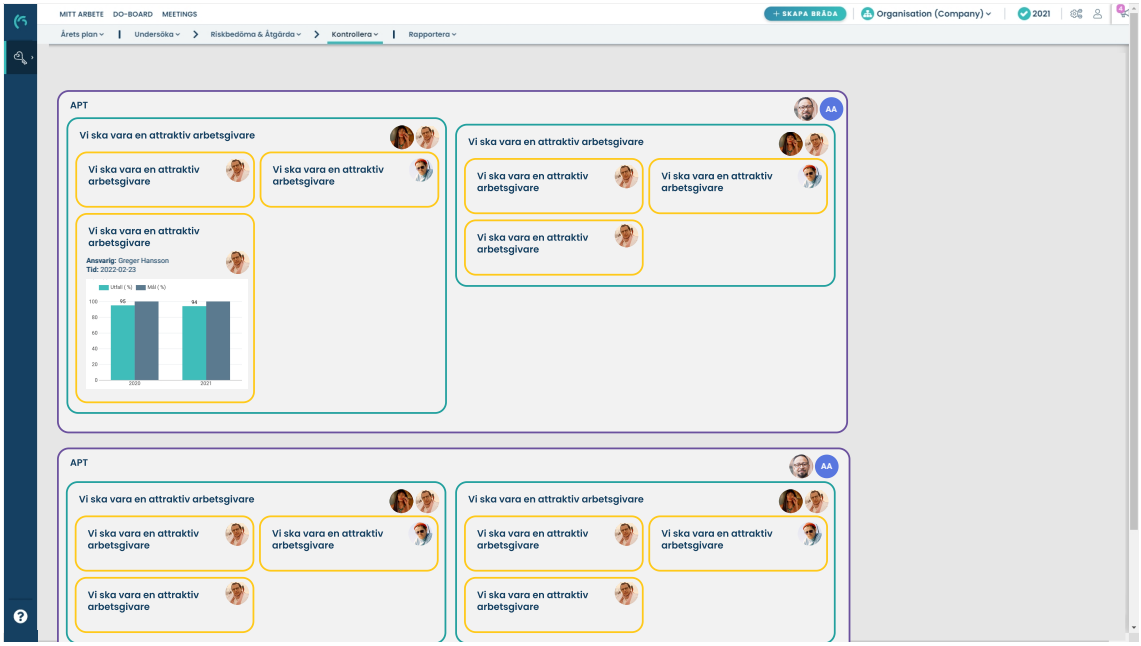

Figure F.5: Elements in ENCLOSURE can be expanded to show more details.

F.3 Indentation List

The Indentation List, as seen in figure F.6, is based on a common design element to show hierarchies within in a list of text. The list consists of only text and can therefore be made more compact than the other concepts prototyped in this iteration. This type of list may not be suitable to be used as a stand-alone visualization, as text does not provide easily comprehensible visual aid in understanding the data structure, but it could rather function as a tool for navigation as a complement to another type of visualization.

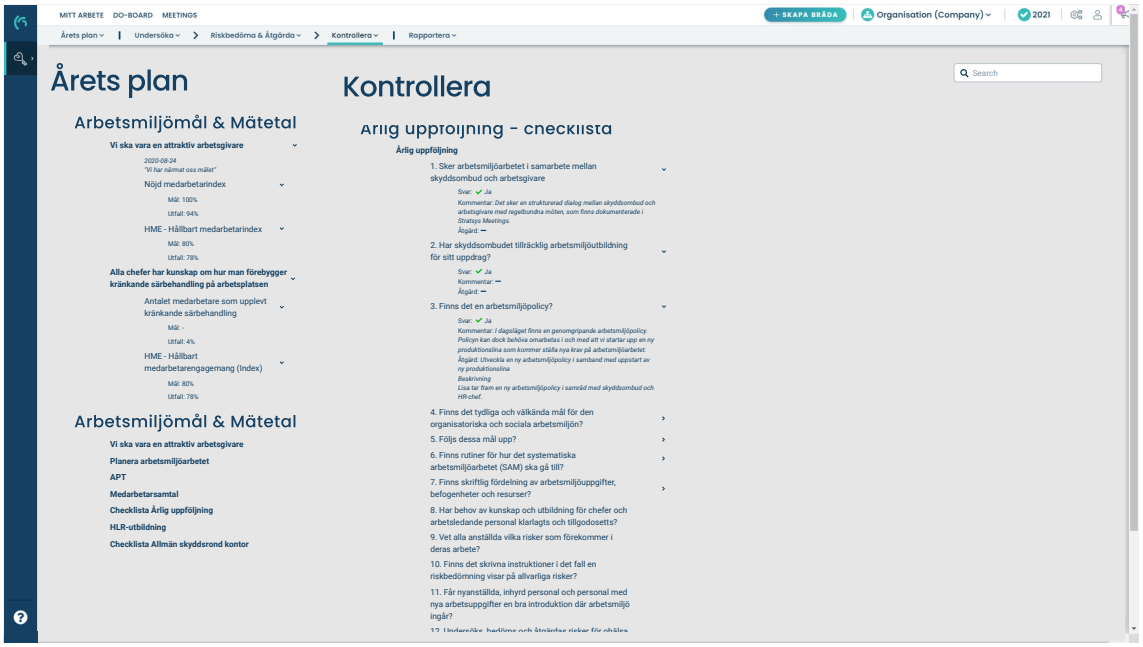

Figure F.6: Indentation List is a space efficient list that show hierarchies by indentations in a list of text.

F.4 List Overview

List Overview, as seen in figure F.7, uses juxtapose lists to showcase hierarchies in the data. The user hovers the mouse over an element to reveal child elements next to it. The list is interactive and clicking an element navigates to a different view with more details. The hierarchies in List Overview are commonly displayed in this way in menus.

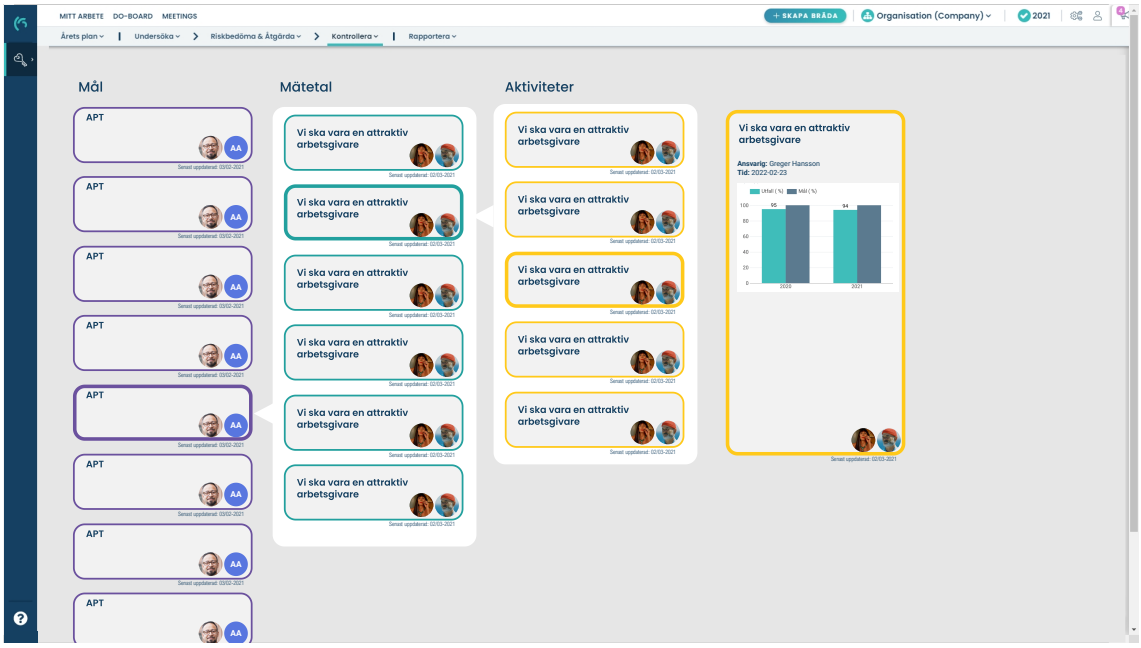

Figure F.7: List Overview shows hierarchies by expanding subelements next to the parent element.

F.5 Mini Map

The prototype Mini Map, as seen in figure F.8, is meant to be used in an interface such as in the concept Zoom and Pan where the user can navigate their way through the visualization in multipe directions. The Mini Map uses a design language that is commonly used in games, but also in some visualizations.

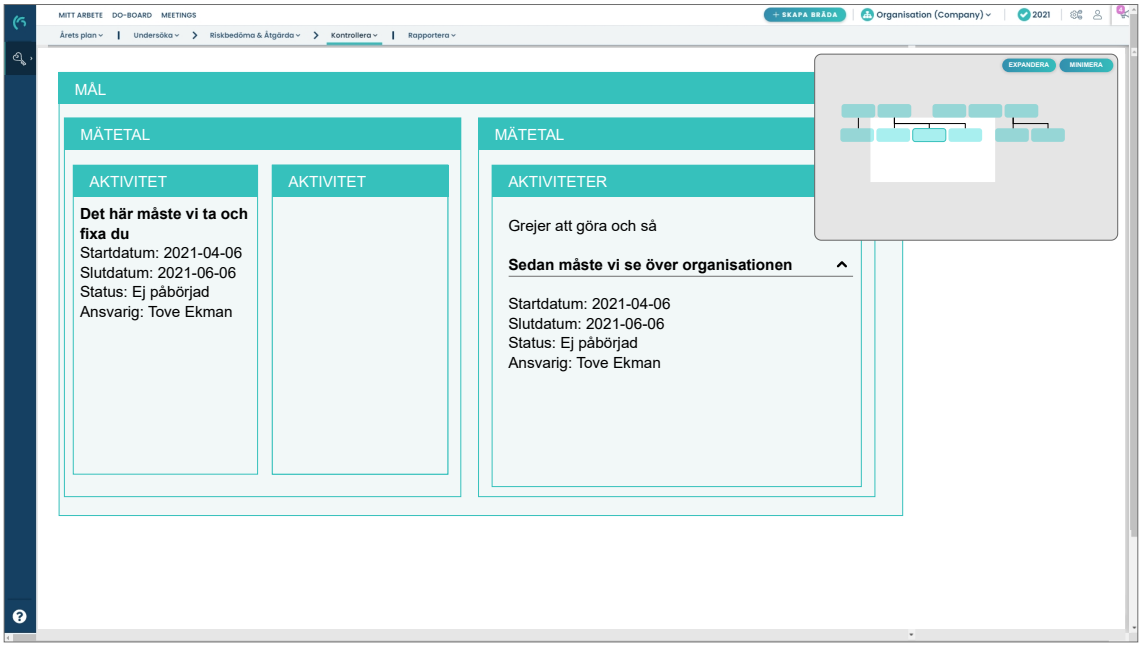

Figure F.8: Mini Map is similar to Zoom and Pan and allows the user to navigate through the visualization by clicking and dragging in the mini map or the main screen.

F.6 Goals Overview

Goals Overview, as seen in figure F.9, hides the child elements to make room for more parent elements on the screen. The idea is to reduce scrolling and thereby provide a better overview of the data. Tool tips were not included in the wireframe, but were discussed to include information of the child elements that it contains. Goals that do not fit on the screen can be accessed through clicking a button to show more, as seen in Goals Overview - Expanded, as seen in figure F.10.

Goals Overview Scroll, as seen in figure F.11, is the same concept as Goals Overview. The only difference is how the user can access elements that did not fit on the screen initially. This prototype allows for horizontal scrolling, rather than adding another row of elements to show those that did not fit on the screen.

Goals Overview + List Overview, as seen in figure F.12, is combination of the Goals Overview and List Overview. This prototype was constructed to showcase how different concepts and prototypes can be combined.

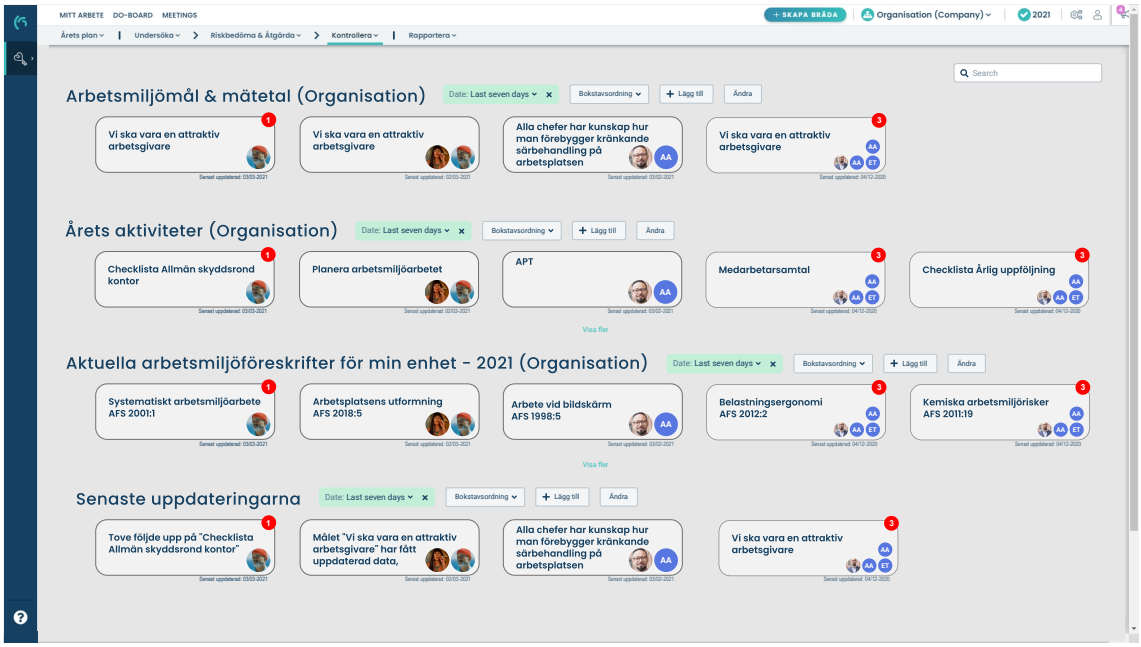

Figure F.9: Goals Overview is similar to the one with horizontal scroll (figure F.11), but allows the user to expand a category to see nodes that did not fit on the screen, rather than scrolling horizontally.

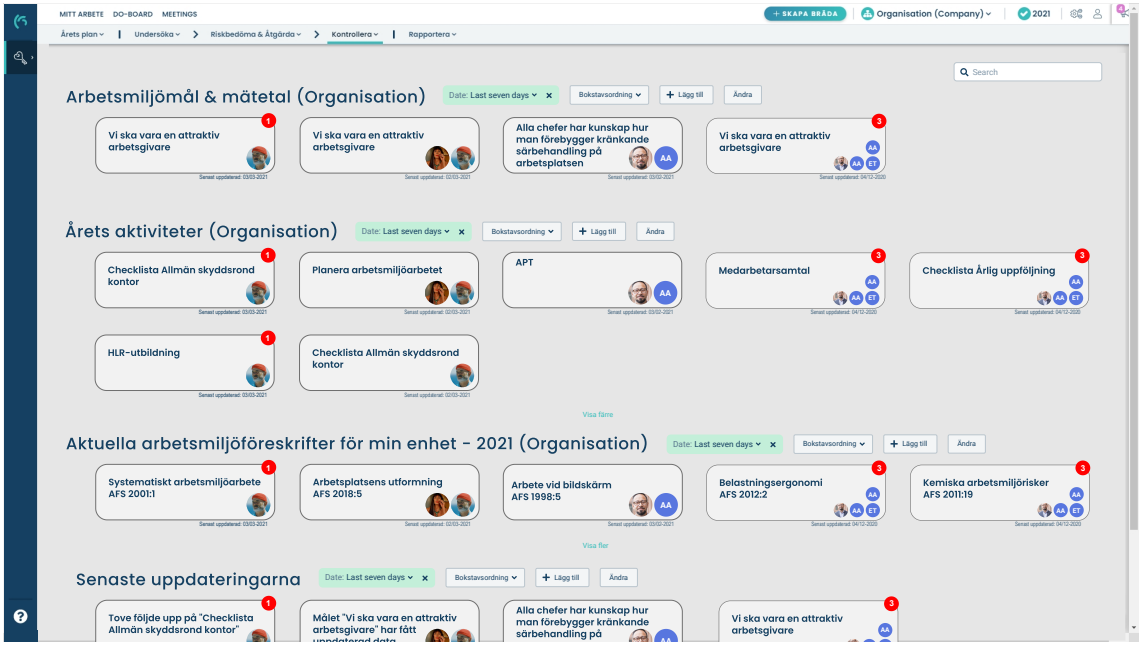

Figure F.10: Goals Overview - Expanded shows how Goals Overview (figure F.9) looks when one category is expanded.

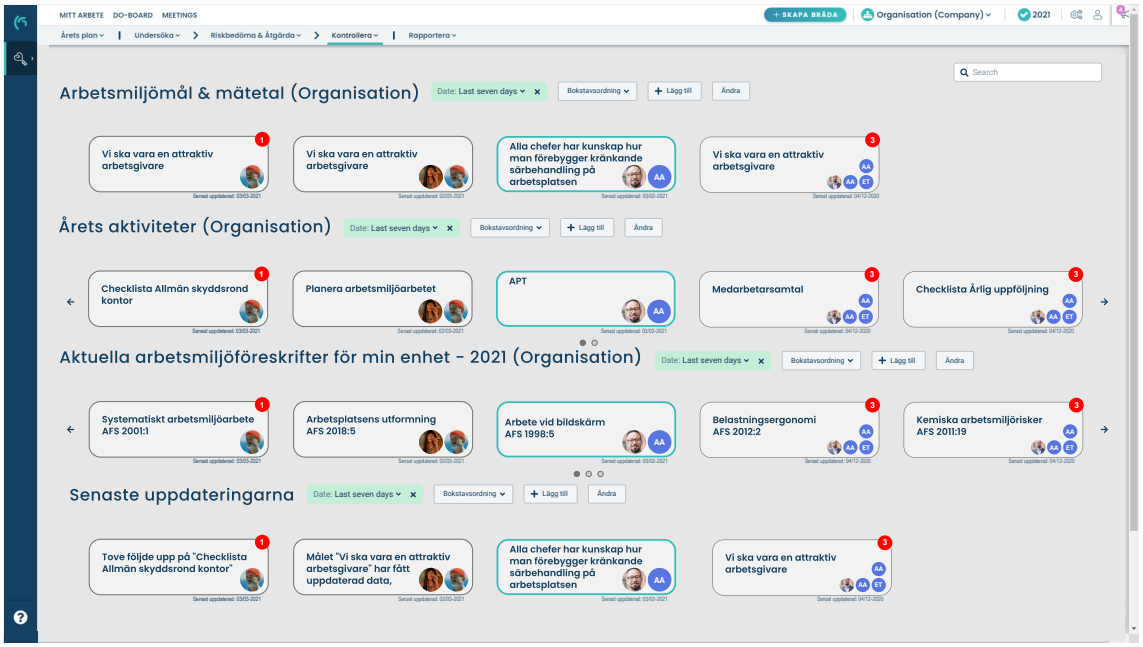

Figure F.11: Goals Overview - Scroll provides an overview of all available parent nodes, mainly strategic goals. The visualization uses horizontal scrolling where there are more nodes than can fit on screen.

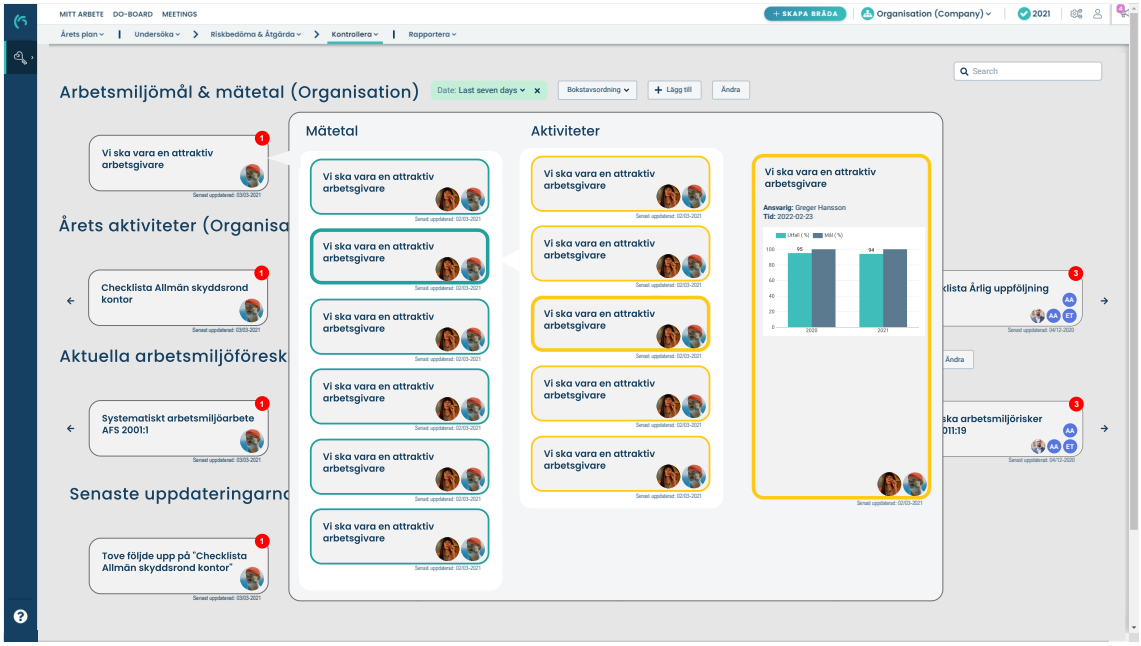

Figure F.12: Goals Overview + List Overview is a combination of Goals Overview (figure F.9) and List Overview (figure F.7) to showcase how the visualizations can be combined.

F.7 Focus View

Focus View Vertical, as seen in figure F.13, is a concept that aims to provide increased focus on the task or goal that the user has selected. The idea is to make it easier for the user to see which actions, options and data is available for the selected goal. Focus View Vertical does not focus on providing an overview for all of the parent elements. The Focus View Vertical allows the user to navigate to other parent elements through the navigation panel located to the left.

Focus View Horizontal, as seen in figure F.15, is basically the same concept as in Focus View Vertical. The only difference is the location of the navigation panel that is placed at the bottom and scrolls vertically in this concept.

Focus View Reversed, as seen in figure F.14, is a variation of the concept used in Focus View Vertical. In this version, the parent elements and the more detailed child elements have reversed position and focus on the screen. In Focus View Reversed, the larger area of the screen is used to provide an overview of the available parent elements with some additional details. The details panel, located to the right, is used to access more details about an element.

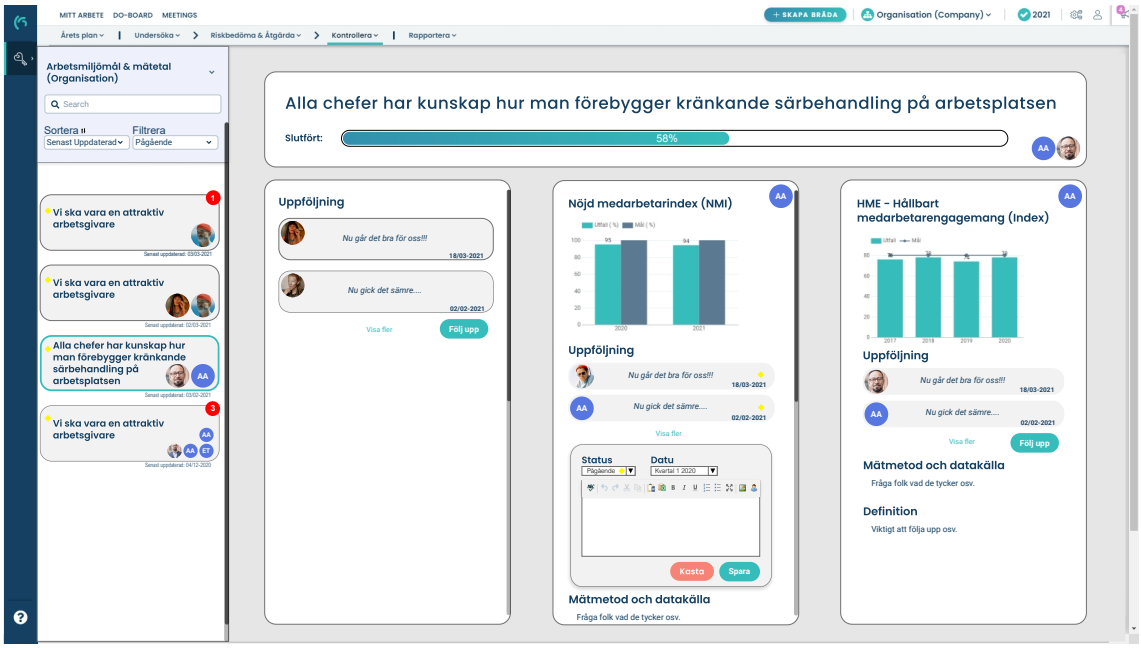

Figure F.13: Focus View - Vertical aims to provide an overview of the child elements when a parent element have been selected.

Figure F.14: Focus View - Reversed i similar to the Focus View - Vertical (figure F.13), but aims to provide an overview of the parent nodes instead.

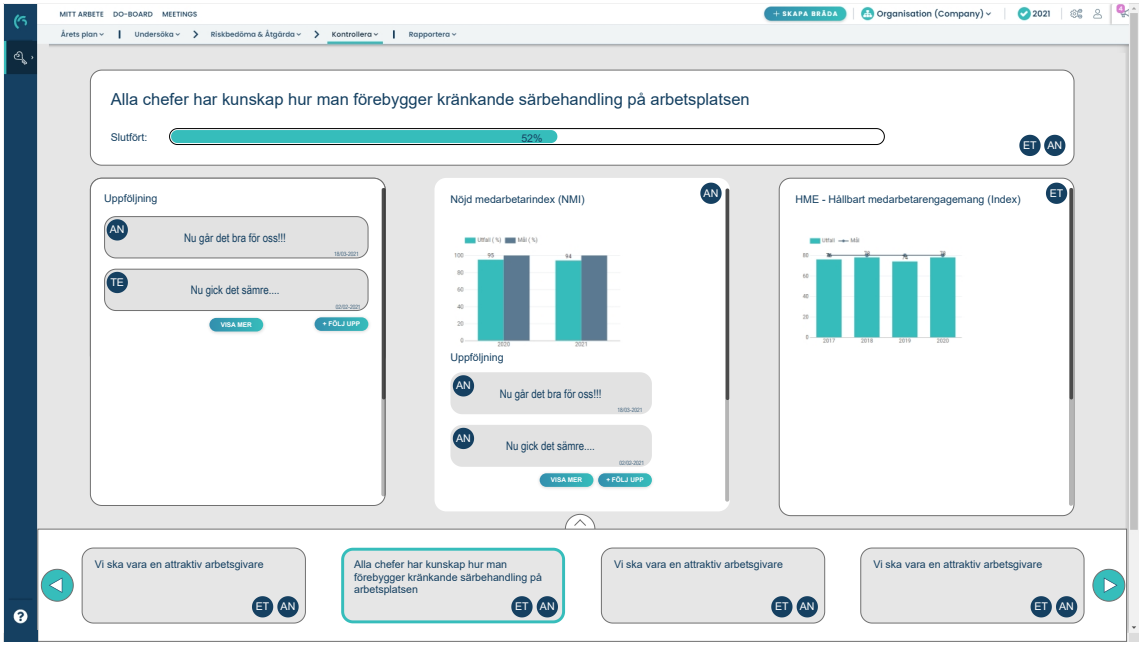

Figure F.15: Focus View - Horizontal is very similar to Focus View - Vertical (figure F.13), with the only difference that the location of the parent elements are displayed horizontally rather than vertically.

F.8 Tags

Tags, as seen in figure F.16, is a concept well known to many users. It makes use of so called tags, that can be attached to objects, to highlight attributes or themes of the object. A tag can also be called a keyword. A main benefit is that tagging enables making flexible groups that can be used for filtering and searching.
Tags is not a stand alone concept, but rather an idea that could be incorporated within several other concepts to give more filtering options. The Tags can also have different colouring, making it easier to for the user to distinguish objects with similar characteristics.

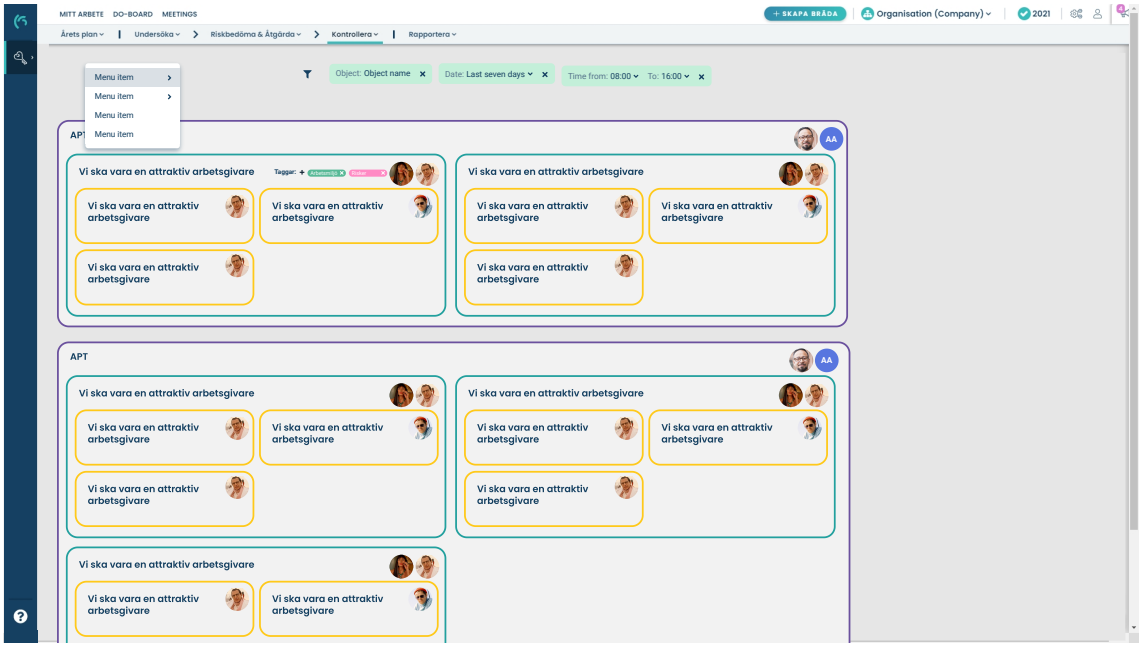

Figure F.16: Tags is an experimentation of allowing the users to tag their information to facilitate in sorting, filtration, searching and comparison. It is not a stand-alone view, but rather a complement to any other visualization.

F.9 Tree Structure

Tree Structure, as seen in figure F.17, is an attempt at reducing the amount of white space in Stratsys' Connecting Thread view. The structure is the same as in Connecting Thread, but it is arranged in a way that is more space efficient. As the number of nodes is commonly increasing for every step downwards in Stratsys' hierarchies, the highest level node is placed in the centre. For every new level, the nodes are placed on the outside of the level before, which gives an area that is expanding together with the diameter of the content on the previous level.

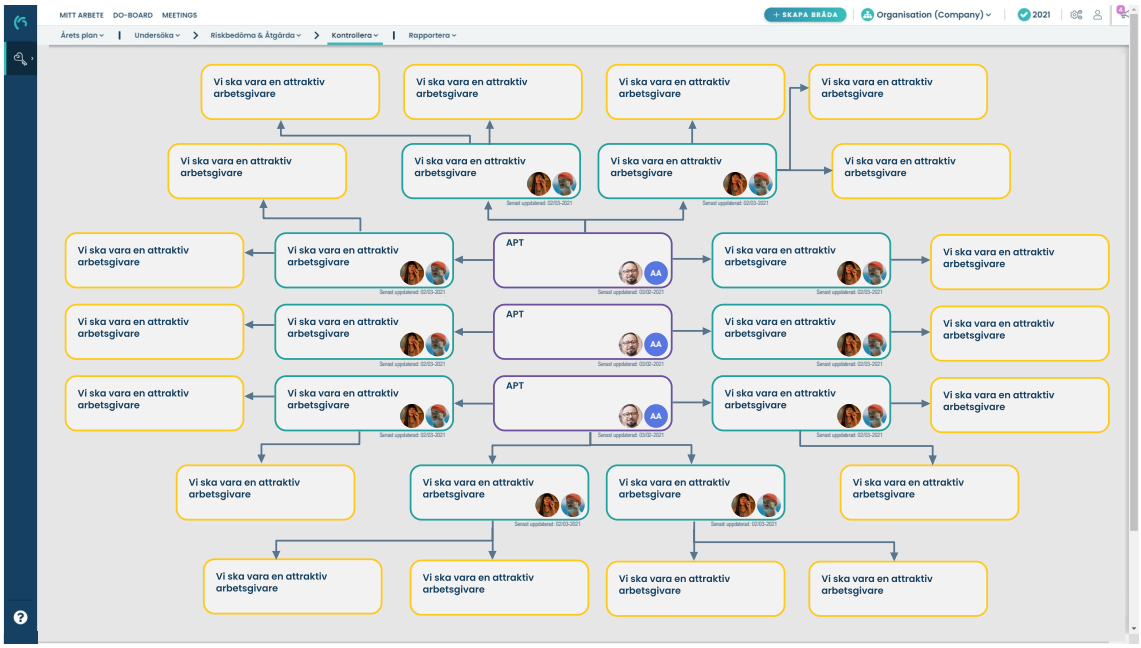

Figure F.17: Tree Structure aims to show as much data as possible on the screen while at the same time showing the structure of the data.

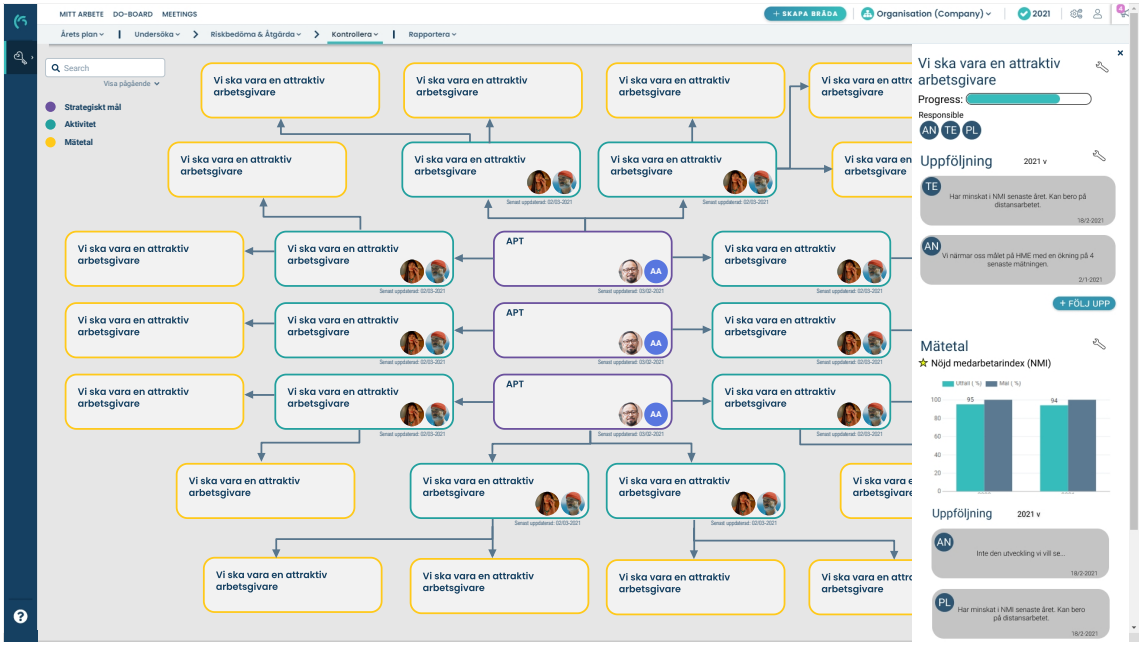

Figure F.18: Tree Structure - Details is an example of how to access more detailed information from the Tree Structure (figure F.17) visualization.

F.10 Zoom and Pan

Zoom and Pan, as seen in figure F.19, is a concept that is not stand-alone, but can be used together with other concepts, for instance Tree Structure or Enclosure. The concept's main benefit is that it enables the user to see the entire structure at once, and be able to zoom in on chosen objects. The Mini Map in the top right corner can be used to see where in the structure the visible objects are. The Mini Map can also be used to navigate within the structure, if the user clicks in the map. The Mini Map can be hidden by the user and the size of it can be changed by dragging its corners. This version of Zoom and Pan also includes a List Overview to the left, which gives a clear and compact compilation of the data structure. The List Overview could also be used to navigate to a chosen section of the data structure in the main view.

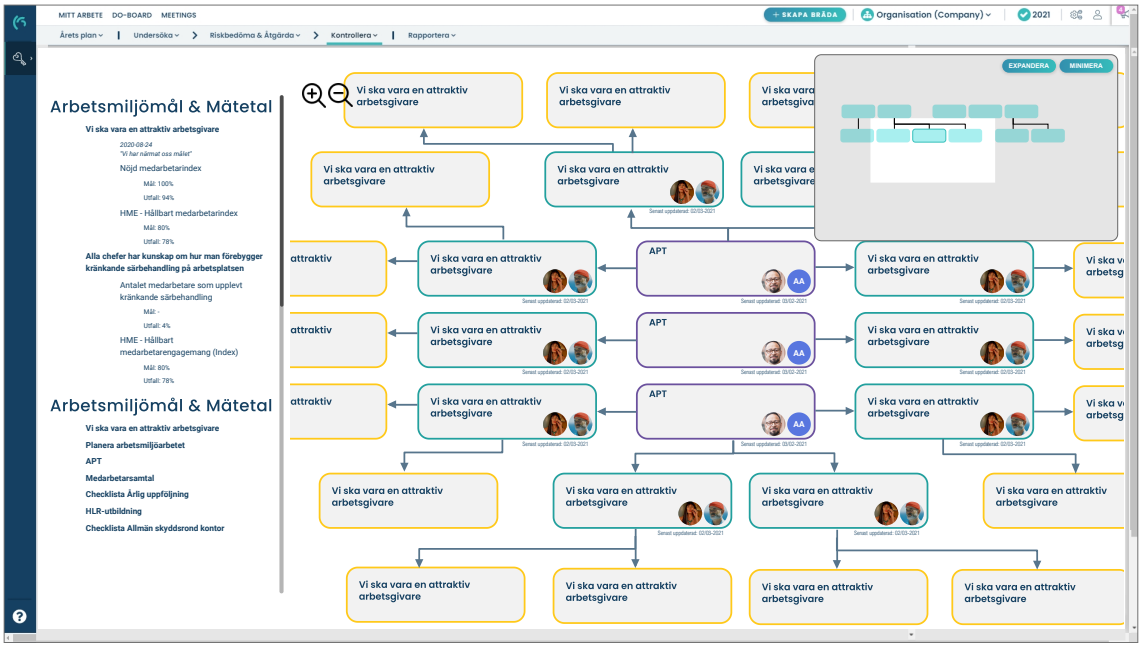

Figure F.19: Zoom and Pan is an example of how larger amounts of data could be handled by the Tree Structure (figure F.17) visualization. It incorporates elements from the Indentation List (figure F.6) and the Mini Map (figure F.8).

Appendix G

Prototypes - Iteration 2

In this section there is a presentation for each of the concepts that were expanded upon in Iteration 2. All of them build on concepts that were present in Iteration 1 6.3.5, but here they may be combined or have changed names since then.

G.1 Scorecards

Scorecards is a concept that focuses on visualising measurements and trends for the measurements. Scorecards is a continuation of the Focus View - Reversed from Iteration 1. The information is laid out in cards and the background colour of each card visualizes the progress of the measurement. The user can decide if the colour coding should be based on the trend, the outcome or something else. The colours used can also be changed by the user to accommodate their needs and preferences. The amount of measurements can be changed by the user as shown in Scorecards - 4 in figure G.1, Scorecards - 9 in figure G.2 and Scorecards - 16 in figure G.3. To access comments for a measurement, a card can be clicked on to be *turned over* as shown in Scorecards - 9 with Comment in figure G.6. Furthermore, to access detailed information, clicking the *i* icon in the menu makes the side panel to the left appear, as shown in Scorecards - 4 with Details in figure G.4 and Scorecards - 16 with Details in figure G.5. To access more comments and to add comments, the user clicks the *Show more and comment* button below the last comment in Scorecards - 9 with Comment and a pop up window appears as shown in Scorecards - Comments in figure G.10. In this pop up window, the user can access all the comments, add their own comments as well as still accessing the measurement. Each measurement also include a pen icon that be clicked to edit the measurement, when doing so a pop up window appears as shown in Scorecards - Edit in figure G.9. From this window, the user can select what type of visualization to be used for the measurement, as well as changing the data and to select what trends and threshold are considered as good and bad.

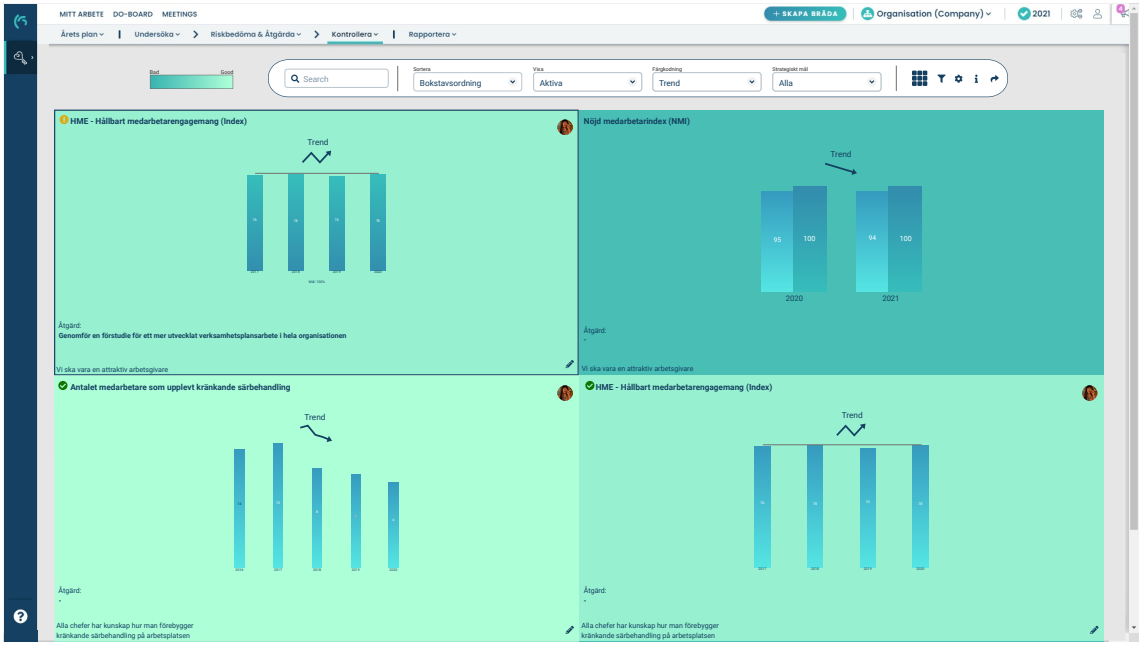

Figure G.1: SCORECARDS - 4 showing four nodes at the same time.

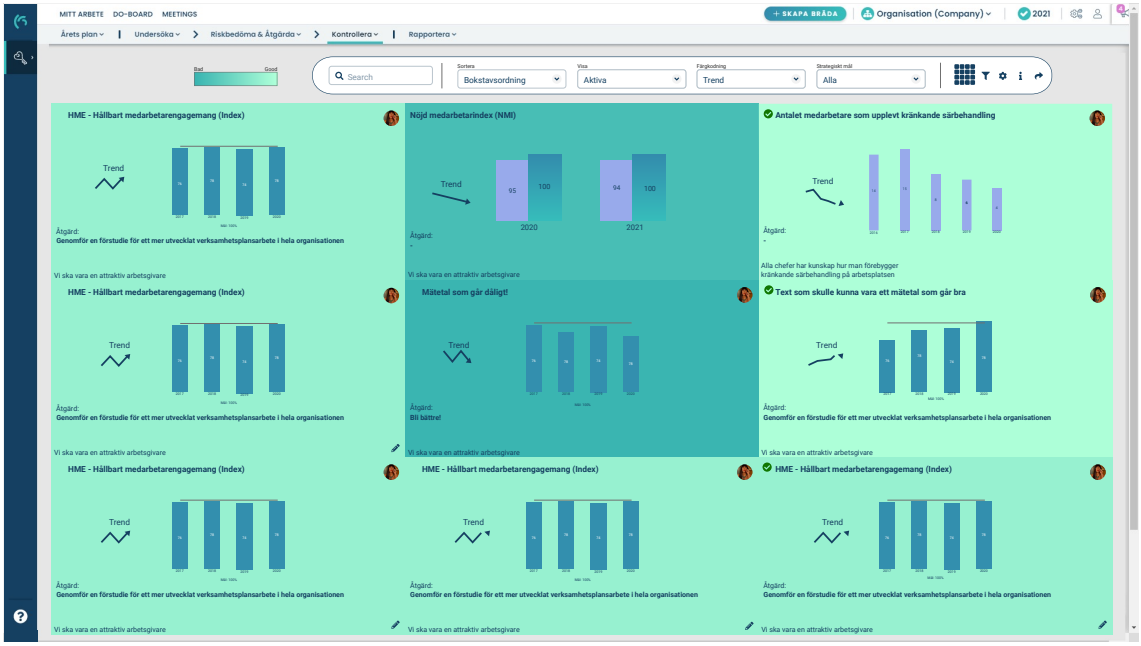

Figure G.2: SCORECARDS - 9 showing scorecards with nine nodes.

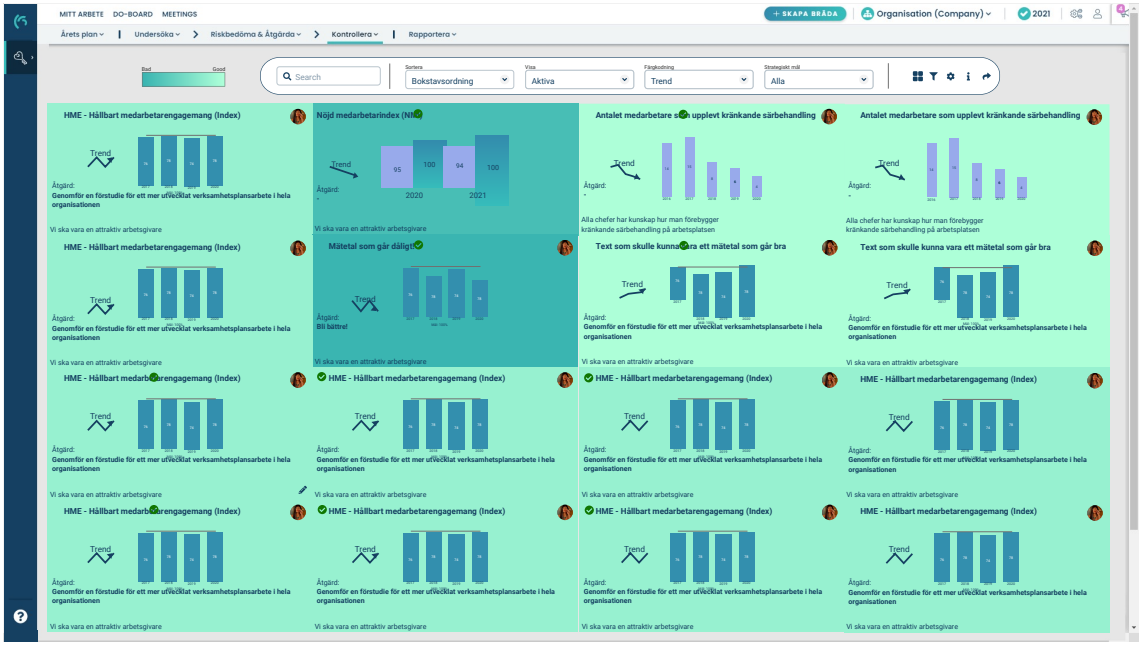

Figure G.3: SCORECARDS - 16 showing scorecards with 16 nodes.

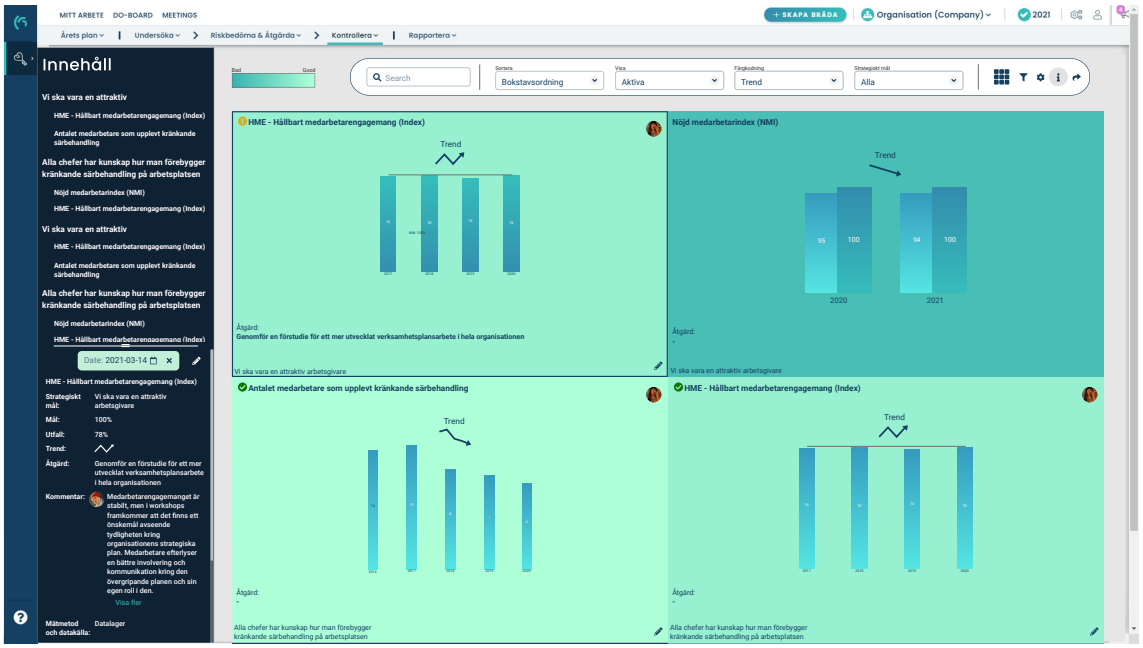

Figure G.4: Scorecards - 4 with Details showing four nodes and the details and table of contents view.

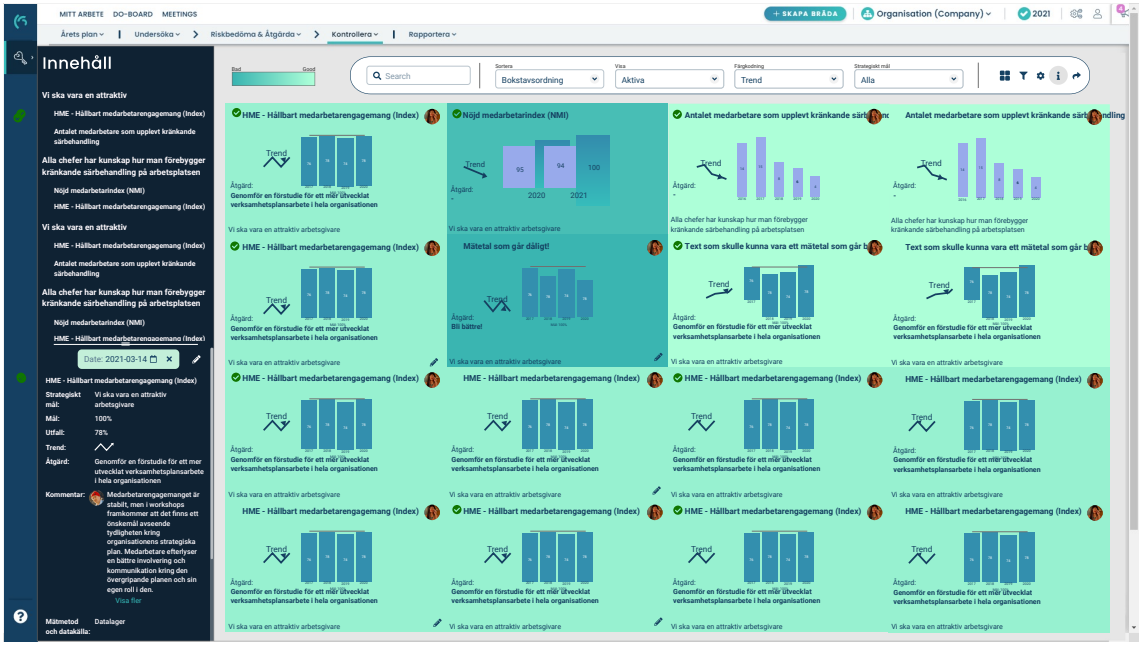

Figure G.5: Scorecards - 16 with details showing scorecards with 16 nodes and the details view and table of contents on the left side.

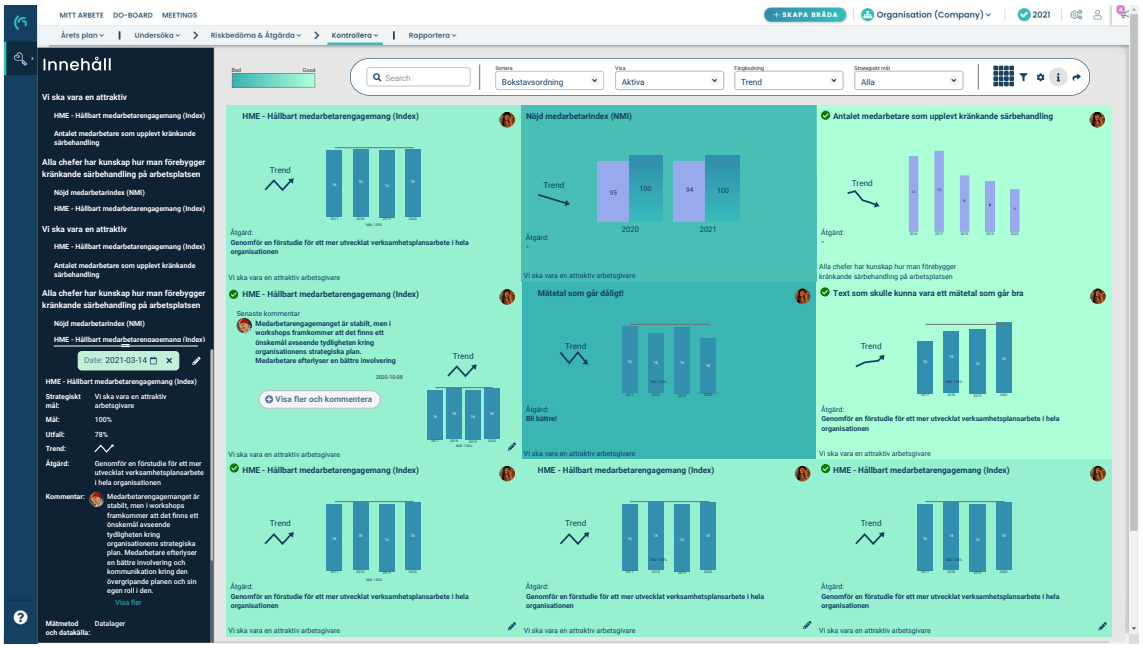

Figure G.6: Scorecards - 9 with Comment showing the leftmost card in the centre being turned over to show the latest comment.

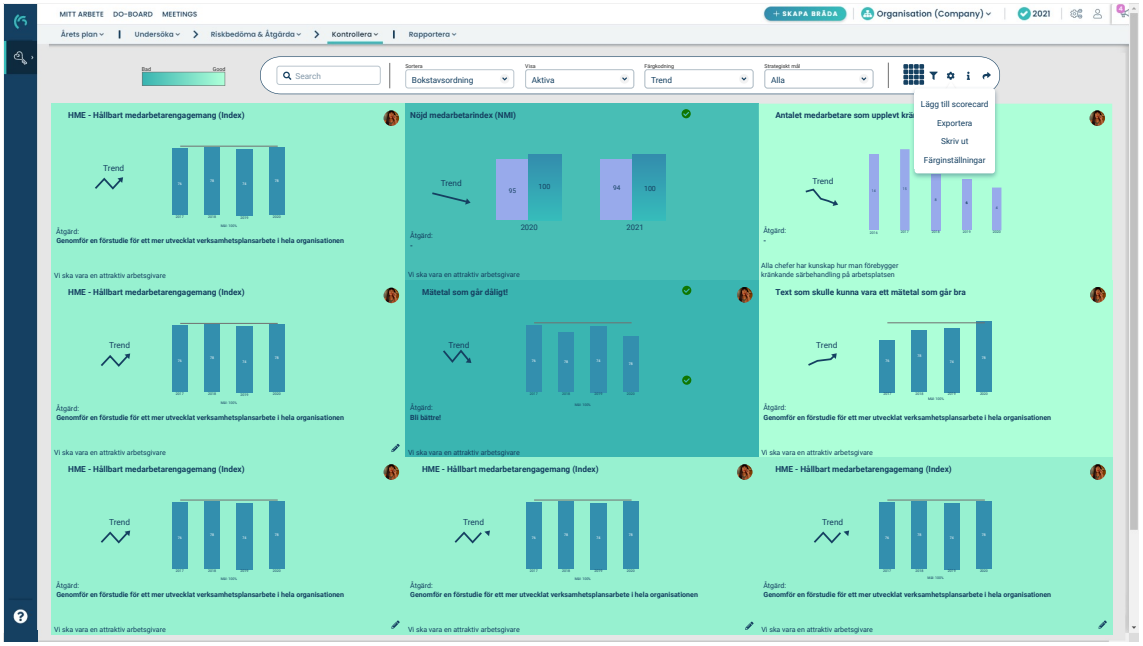

Figure G.7: Scorecards - 9 with settings showing the settings menu expanded.

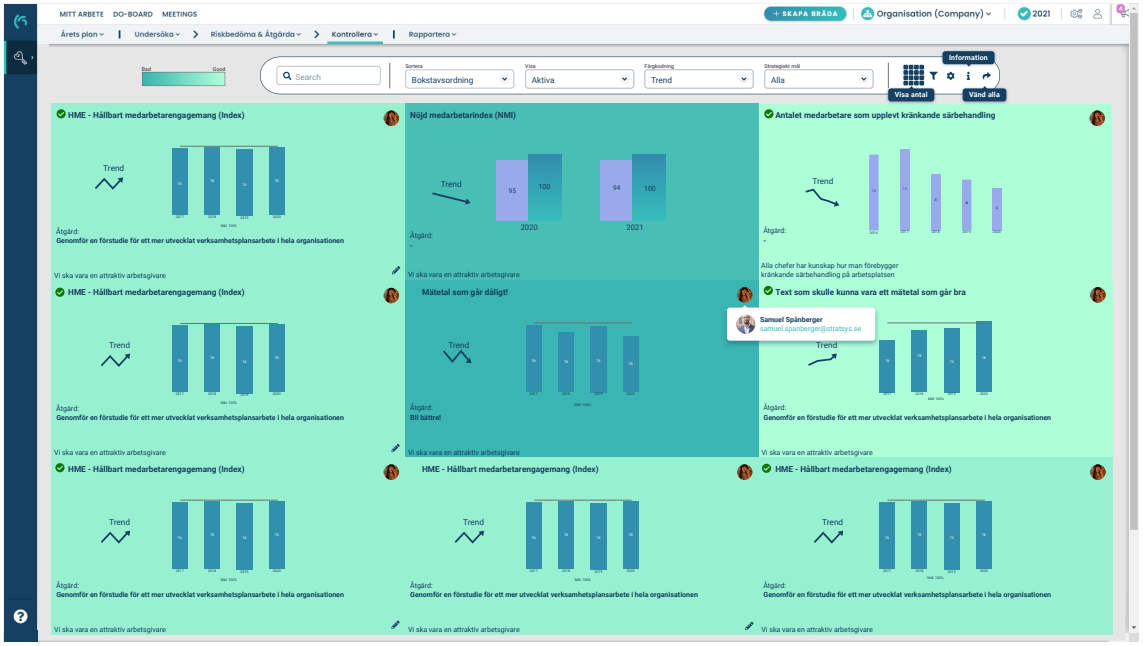

Figure G.8: Scorecards - 9 with tooltips.

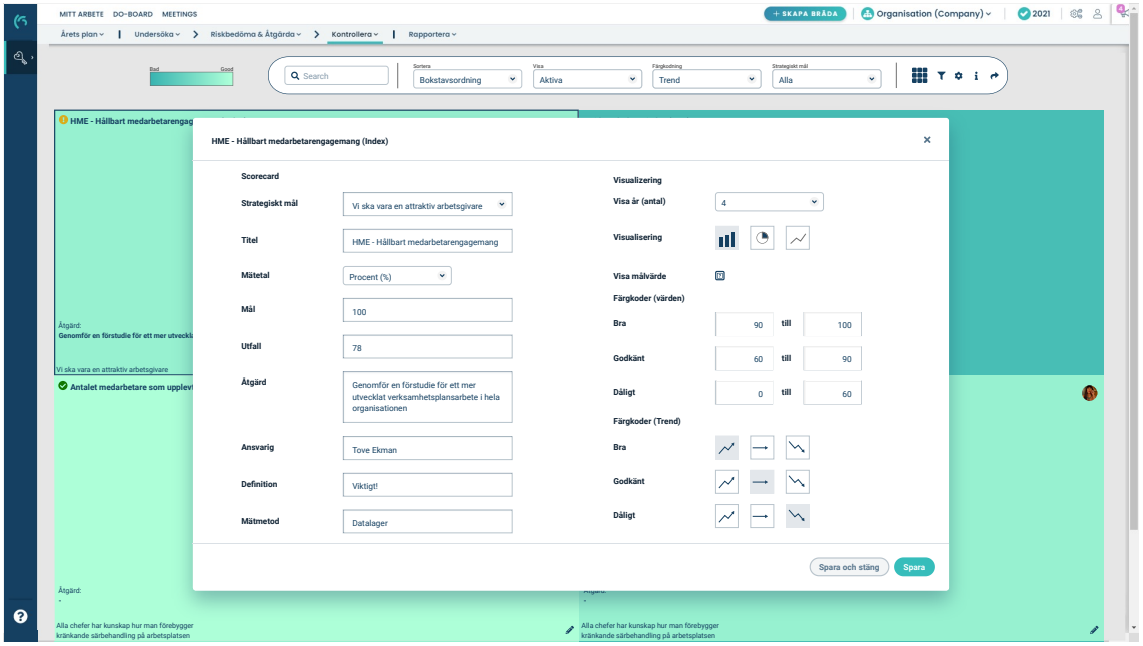

Figure G.9: Scorecards - Edit showing the pop up window where measurements can be edited after clicking the pen icon.

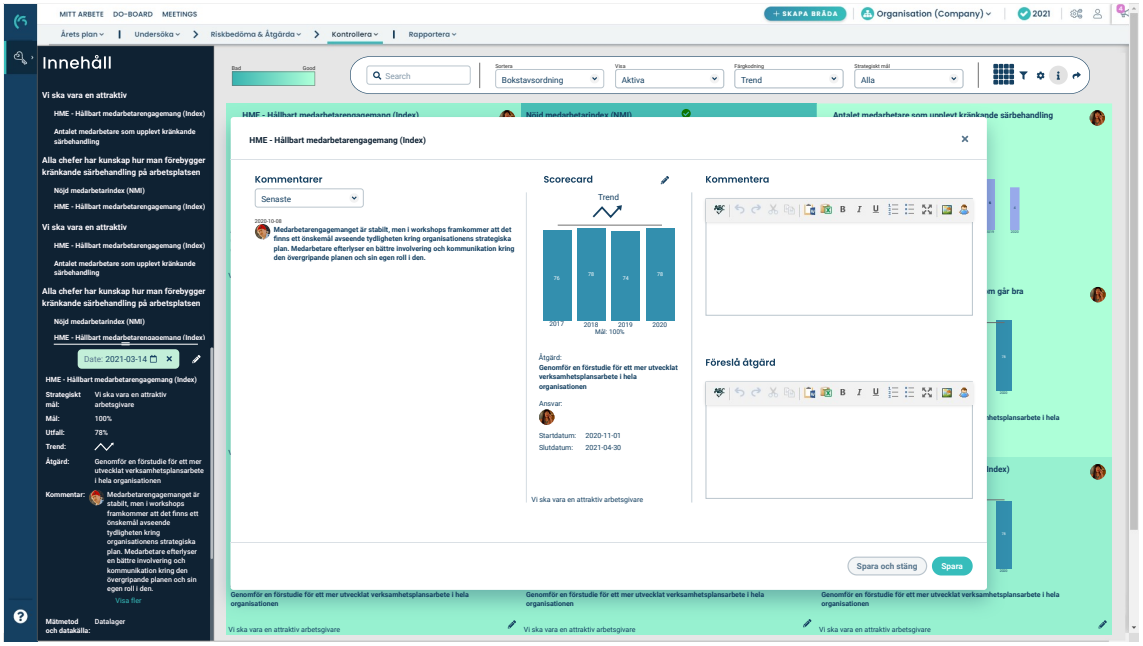

Figure G.10: Scorecards - Comments showing the pop up window where the user can access all comments as well as adding their own.

G.2 Goals Overview

Goals Overview is a continuation of the concept developed in Iteration 1. The prototype is described in section 6.3.5 on page 69. The first view of Goals Overview in figure G.11 has not changed at all from the previous iteration. The view Goals Overview - Details in figure G.12 were constructed in this iteration to showcase how to access measurements and activities that are linked to a goal. The information is displayed in an expandable list inside a pop-up window. While elements in the list are minimized, only information such as title, trends, responsible and dates are visible. When an item is expanded more detailed information such as comments, ability to add comment, graphs, goal, outcome and description is available.

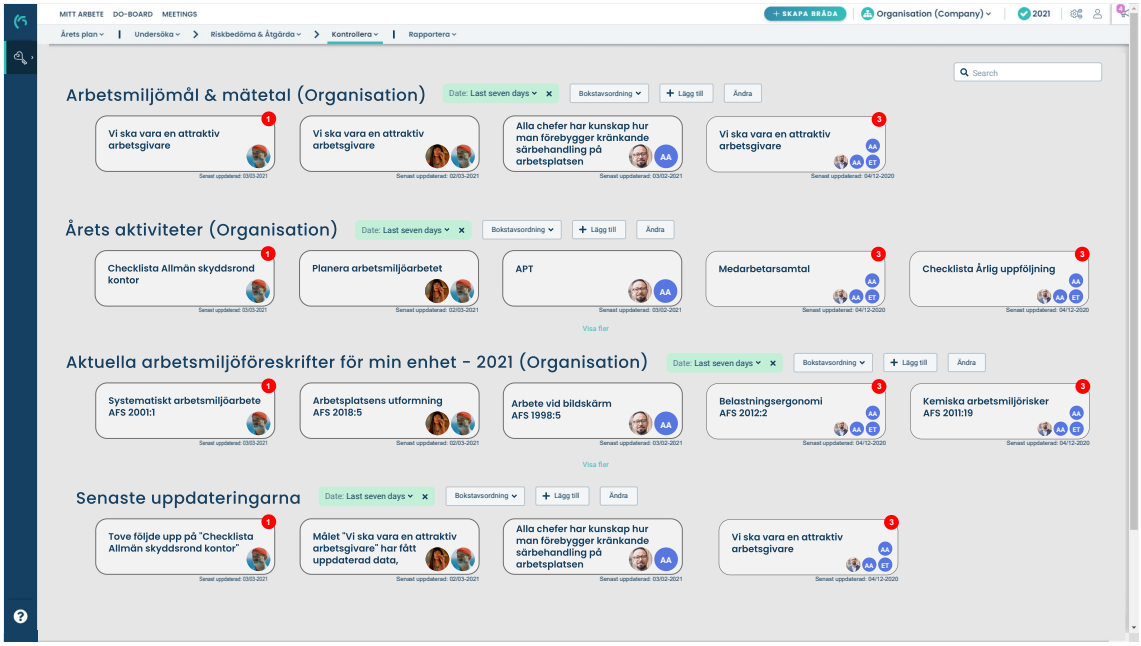

Figure G.11: Goals Overview from iteration 1.

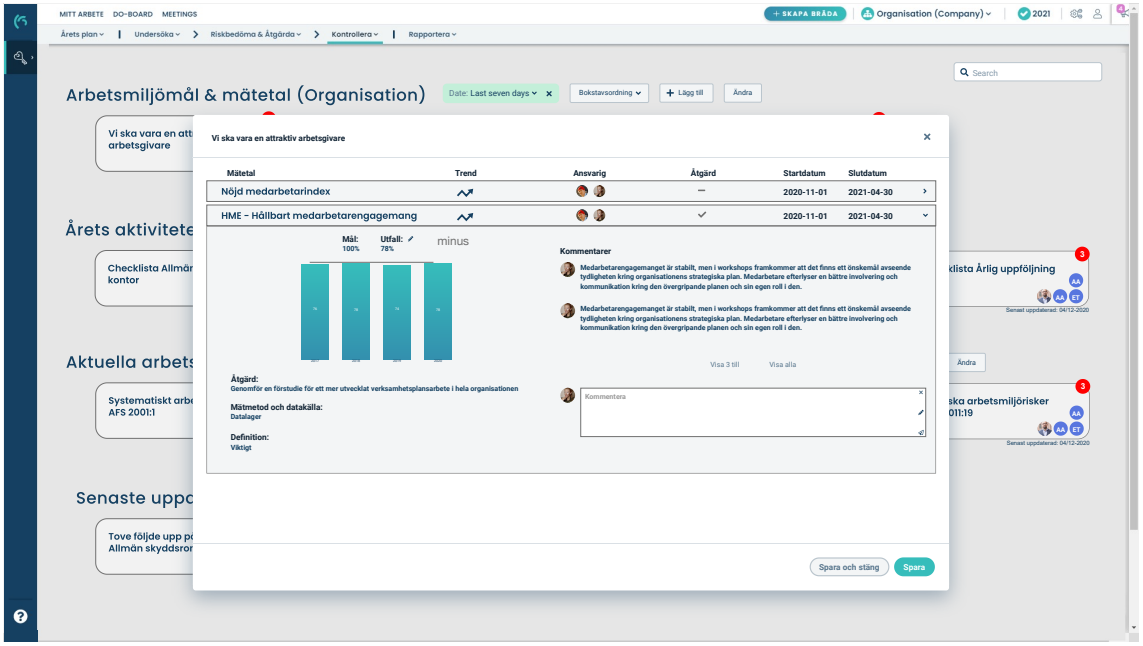

Figure G.12: Goals Overview - Details represents how to access details in the Goals Overview from iteration 1.

G.3 Expandable Cards

Expandable Cards is a concept that focuses on providing overview of the information that commonly occurs in check lists and regulations as well as measurements. The default layout of Expandable Cards is shown in figure G.13. Three alternatives for how to accommodate the screen space while expanding a card were developed. Option A is illustrated in figure G.14. In option A, the cards that are furthest away from the expanded card are reduced in size. Option B is illustrated in figure G.15. In option B, the juxtapose cards are reduced in size to make room for the expanded card. Option C is illustrated in figure G.16. In option C, the juxtapose cards are covered by the expanded card and therefore hidden from the users.

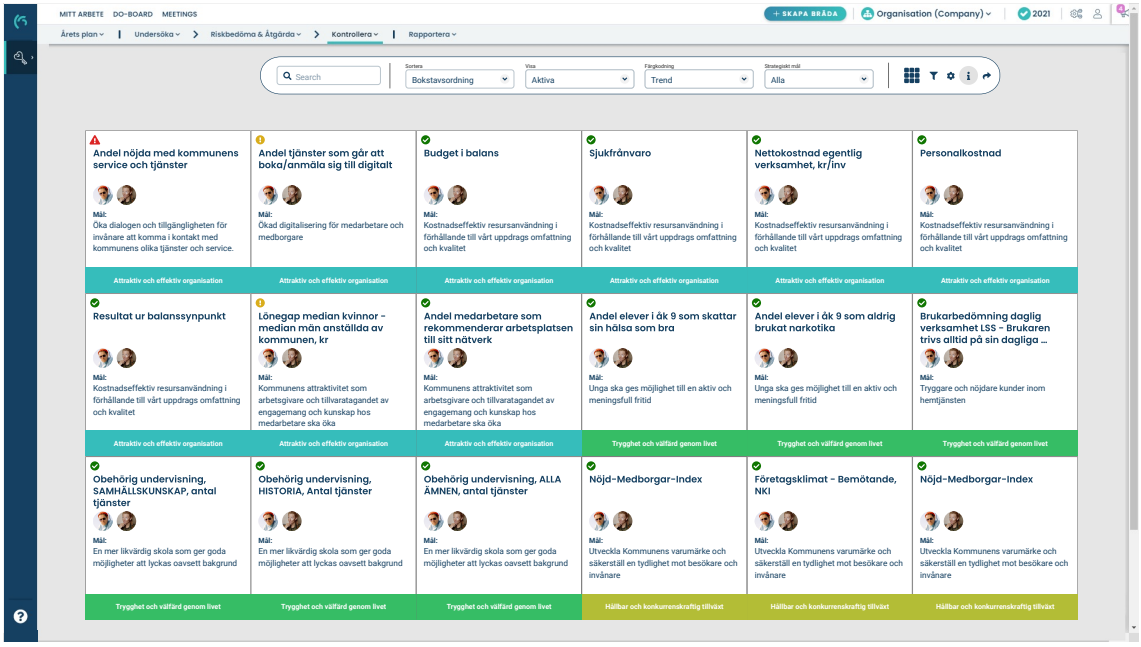

Figure G.13: Expandable Cards provides an overview of measurements.

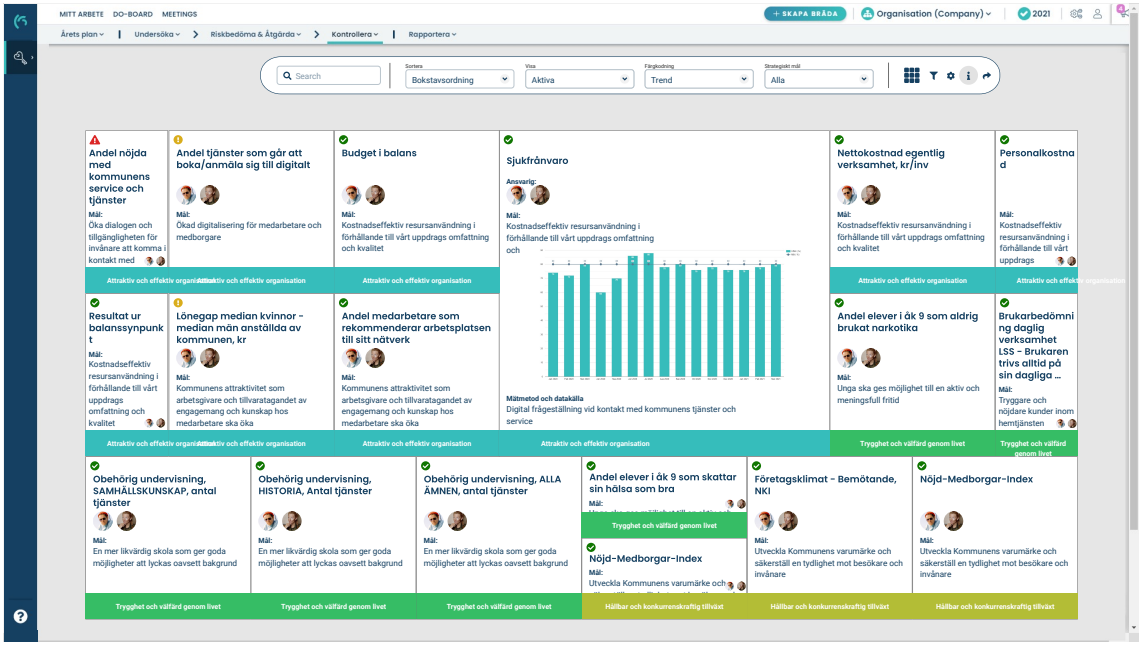

Figure G.14: Expandable Cards - Details A shows an alternative for expanding cards, where the outermost cards gets smaller to provide space.

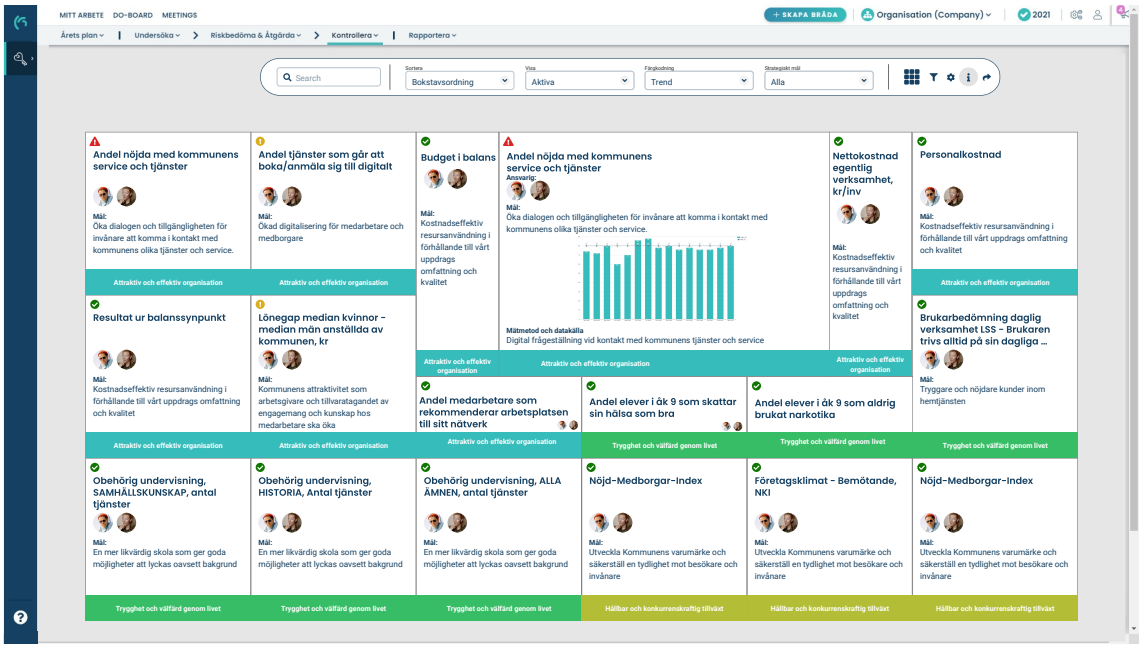

Figure G.15: Expandable Cards - Details B shows an alternative for expanding cards, where the closest cards gets smaller to provide space.

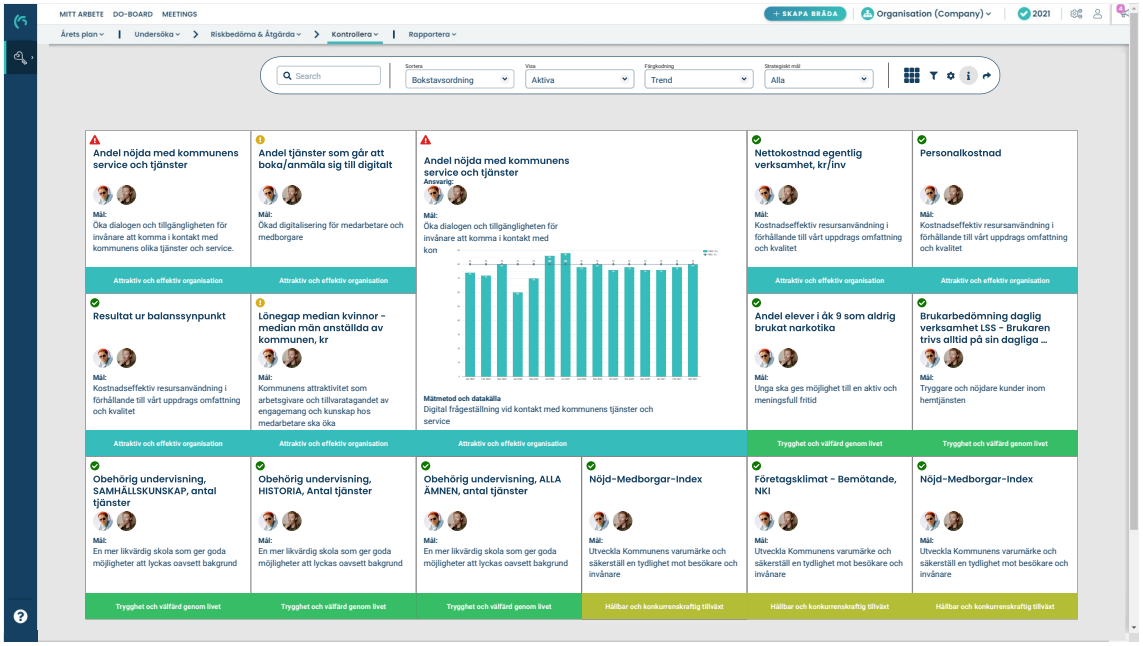

Figure G.16: Expandable Cards - Details C shows an alternative for expanding cards, where the juxtapose cards get covered by the larger card.

G.4 Enclosure

Enclosure is a type of Tree Map that makes use of enclosure to visualise hierarchies. Every node is enclosed by the node that is its parent, and this is done recursively. In this iteration, three different styles of the concept have been evaluated.

In concept A, as seen in figure G.17, the shape of the enclosing nodes are adapted to their content. This is done in an attempt to make the Enclosure idea more space efficient, which was one of the issues that were raised in the evaluation of Iteration 1 6.3.5.

In concept B, as seen in figure G.18, the node on the top level is drawn out horizontally to form a rectangle. On the second level, the nodes are placed next to each other. On the third and final level, the nodes are placed on top of each other.

In concept C, as seen in figure G.19, the nodes are placed next to each other on the top level. On all lower levels, the nodes are placed on top of each other.

On all of the three concepts, a menu was added to allow for searching, sorting, filtering and adjusting the visibility of nodes at different levels.
The sorting should allow the user to choose between sorting the nodes alphabetically, on latest updated or latest added.
The filtering could be made on for instance goals that have been met, or goals that have not been met.
To the right in the menu, choices can be made regarding the different node levels. Next to the name of the level, there is a colour indicator showing the current colour of that level. Clicking on the indicator should open a small panel where the user can change the colour if needed. This functionality should be made visible by a tool tip. Each node level also has three icon buttons, that are used to select how much of the level you want to see. The first button is for expanded view, where all available information of the nodes on the level will be displayed. The second button is for limited view, where only the headers of all nodes on the level are displayed. The third button is for hidden view, which makes all nodes on the level invisible. These buttons should also have tool tips explaining their meaning.

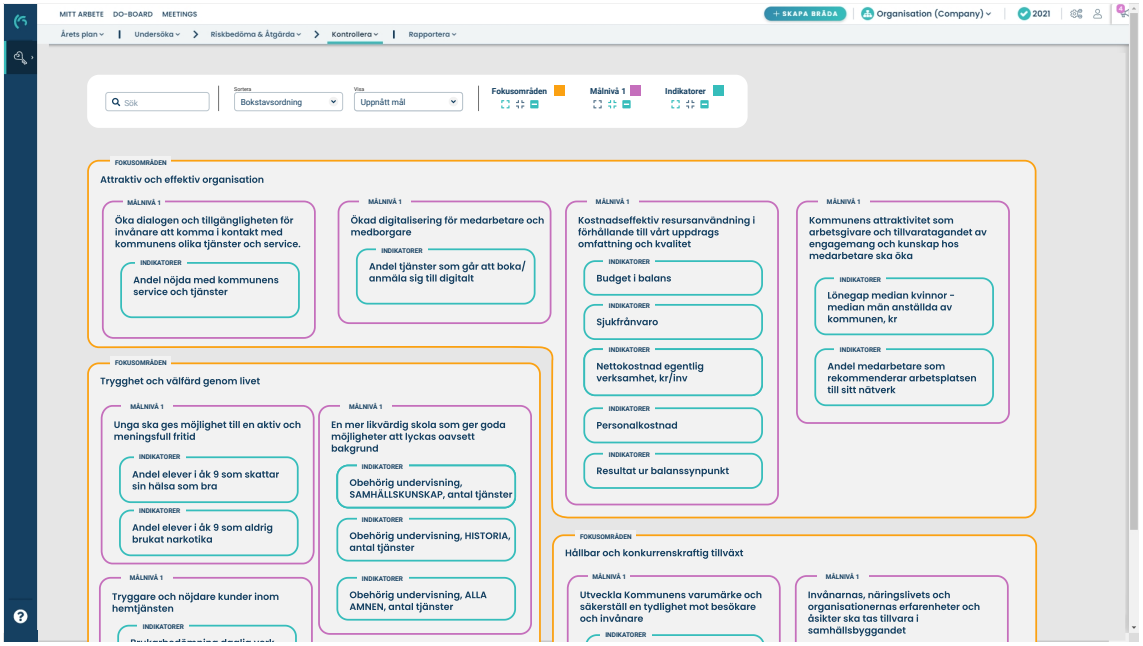

Figure G.17: Enclosure A with containers that adapts to their size and adjacent containers size.

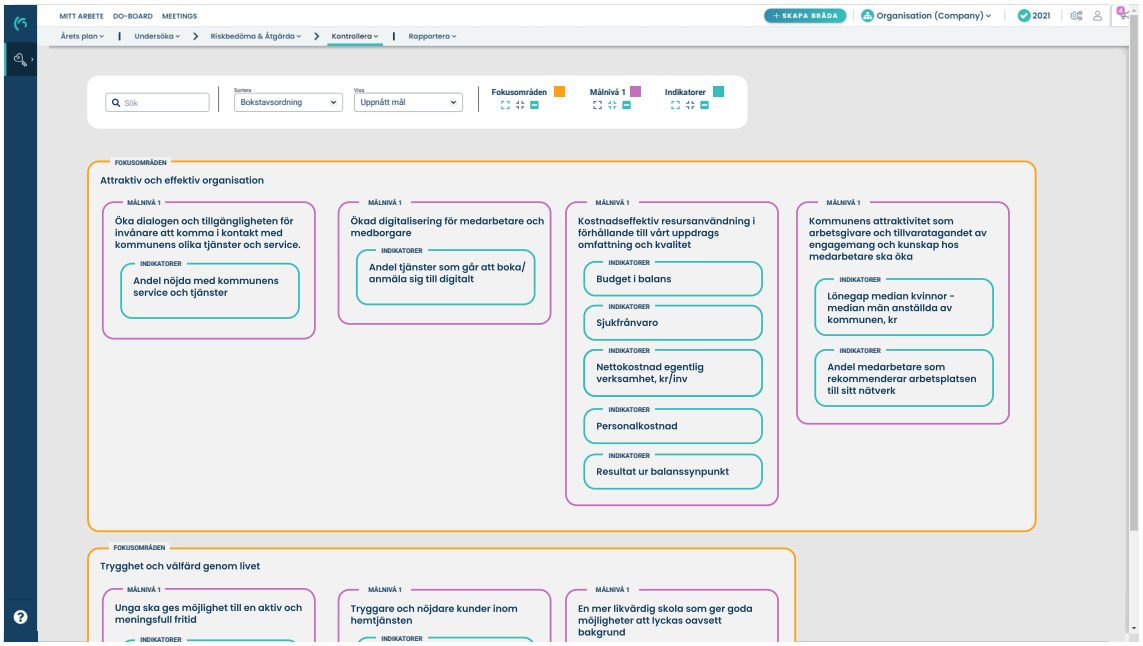

Figure G.18: Enclosure B - the highest node level is stacked vertically, the second is stacked horizontally, and the third is stacked vertically.

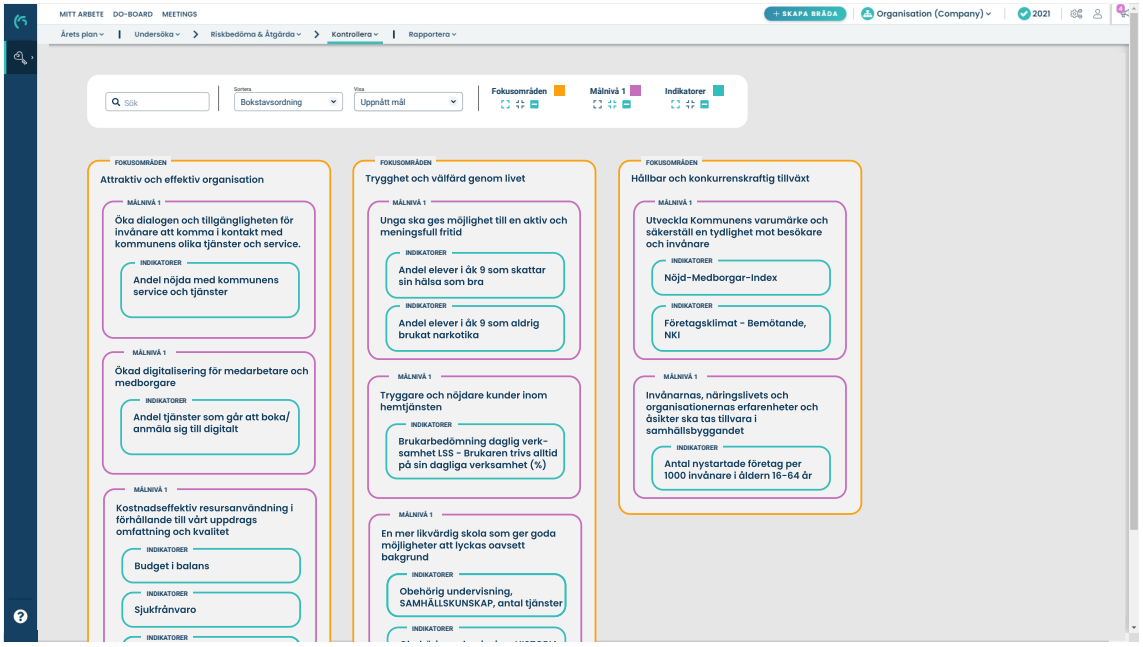

Figure G.19: Enclosure C with its content stacked horizontally. Additional nodes are put adjacent vertically. The view can be scrolled vertically.

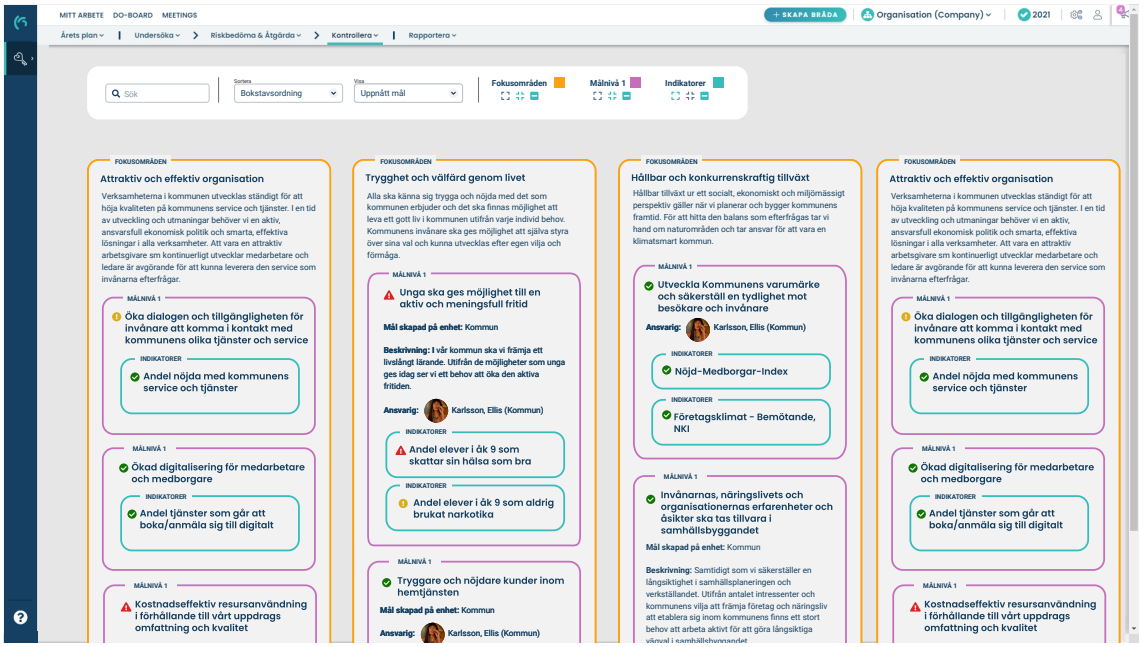

Figure G.20: Enclosure - Vertical - Scroll uses the same principle as Enclosure - Vertical. This prototype uses horizontal scrolling when there is more nodes than can fit on screen.

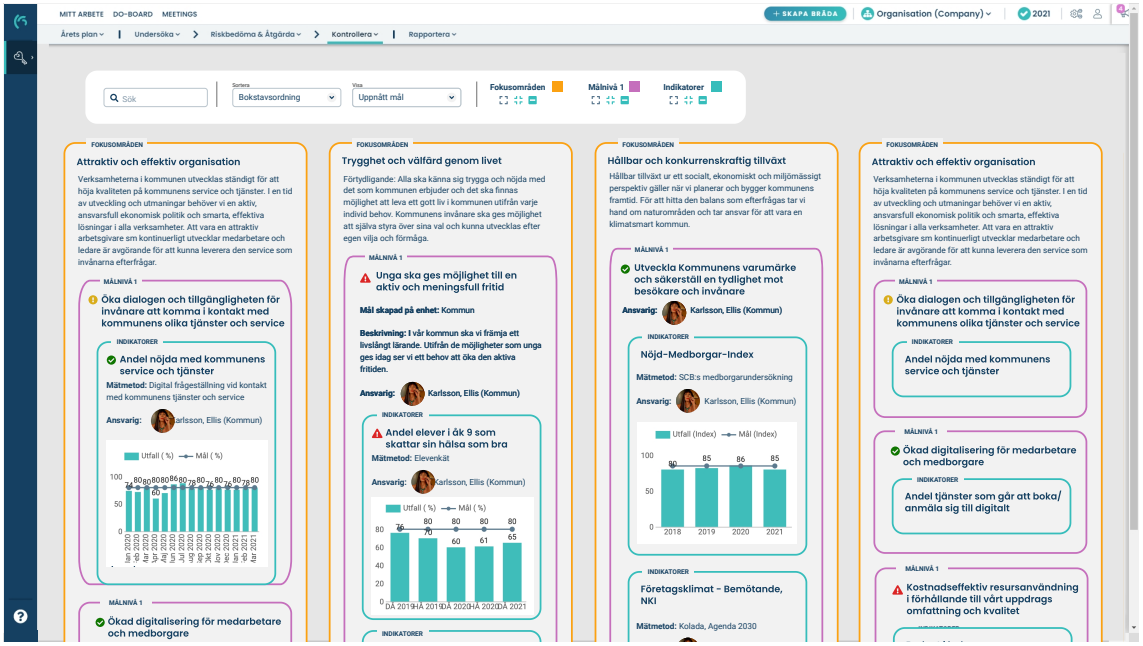

Figure G.21: Enclosure - Vertical - Scroll - Details shows how nodes can be expanded to show more detailed data.

G.5 Tree Structure

Tree Structure is a concept that has been evolved into two different directions. In concept A, as seen in figure G.22, the top level nodes are placed together in the centre of the tree visualization, with their underlying nodes surrounding them. This makes all nodes on the same level create a somewhat circular shape, that can be colour coded to make the understanding of the structure more direct.

In concept B, as seen in figure G.23, each top level node is placed individually from the other top level nodes. Each top node is placed in the horizontal centre of the screen, with its child nodes surrounding it to the sides and beneath, making each tree take the form of a half circle. For every top level node, there will be a similar tree. All trees are stacked on top of each other, and can be accessed by vertical scrolling.

Both concepts can be combined with a details view, as seen in figure G.24.

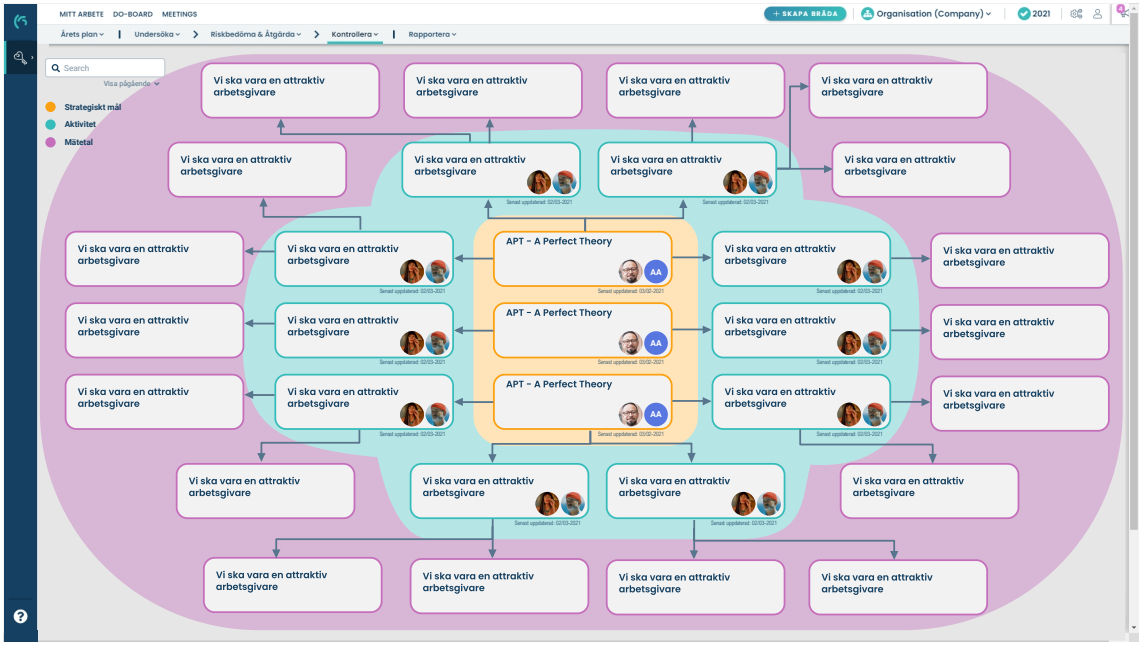

Figure G.22: Tree Structure - Colour

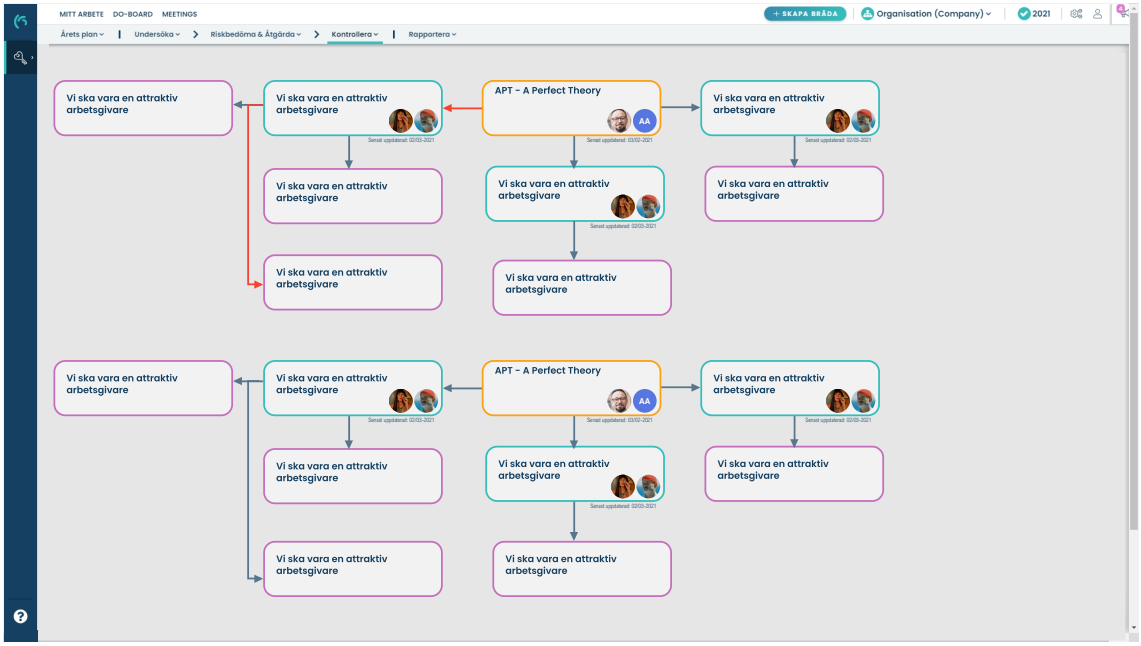

Figure G.23: Tree Structure - Half Circles

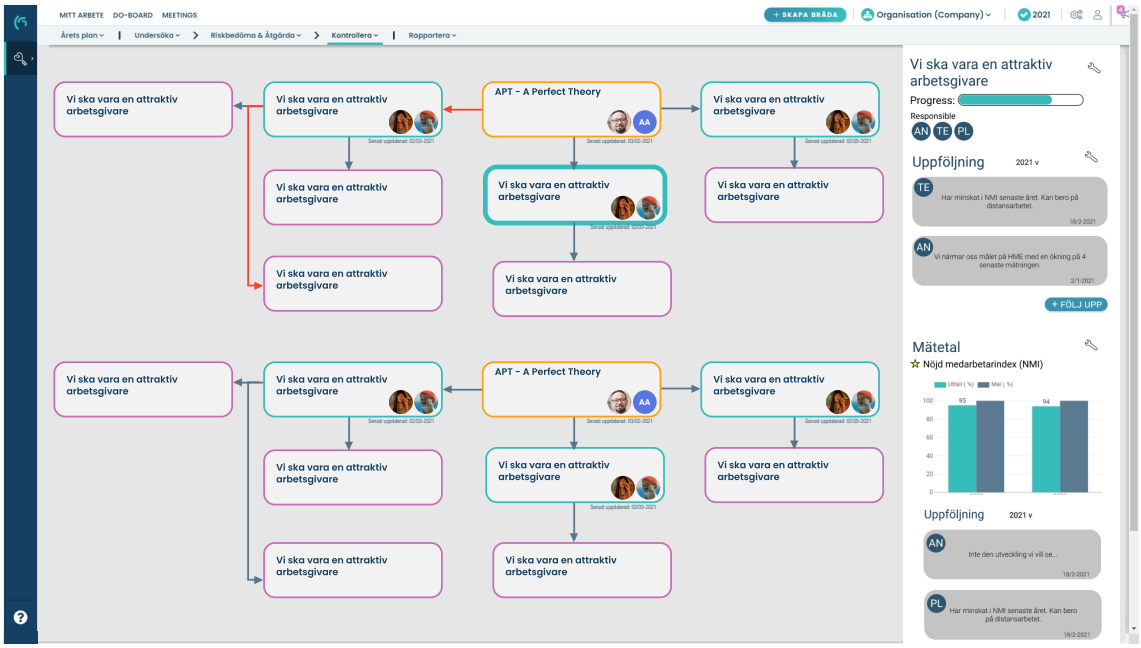

Figure G.24: Tree Structure - Details

Appendix H

Prototypes - Iteration3

H.1 Expandable Cards

Expandable Cards is a continuation of the concept from Iteration 2 with the same name, described in appendix G, section G.3. Changes made in this iteration include:

- Cards are grouped depending on which goal they belong to.
- Cards keep their initial size and visibility when another card is being expanded, they only move aside.
- Cards can be marked as favourites, which puts them as a duplicate in a separate section.
- Entire sections of cards can now be hidden.
- The user can now choose what to be displayed on each card in the minimized state.
- The ability to add new cards to a section is now added.

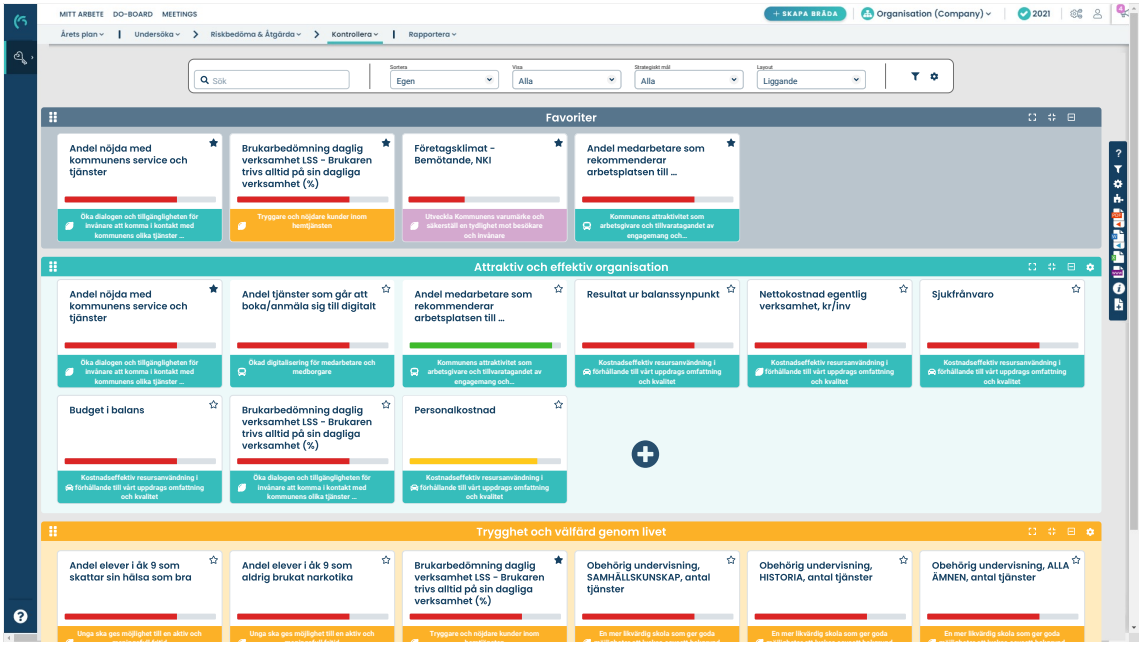

Figure H.1: Expandable Cards as the initial view presented to the user.

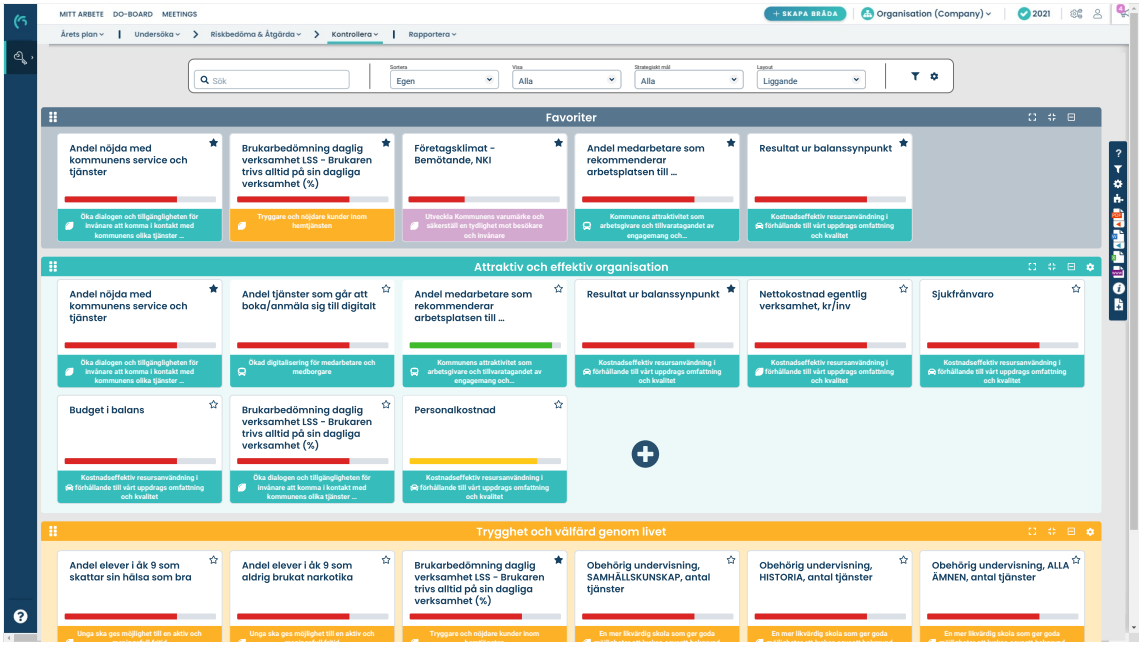

Figure H.2: Expandable Cards after marking "Resultat ur Balanssynpunkt" as a favourite.

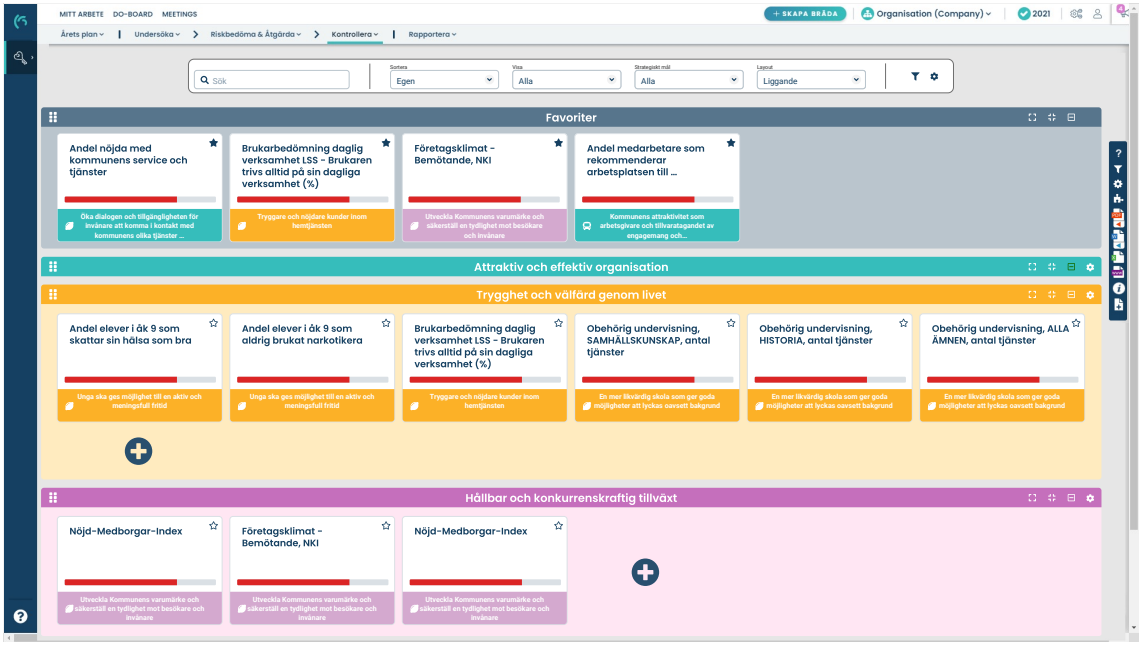

Figure H.3: Expandable Cards with the blue section minimized.

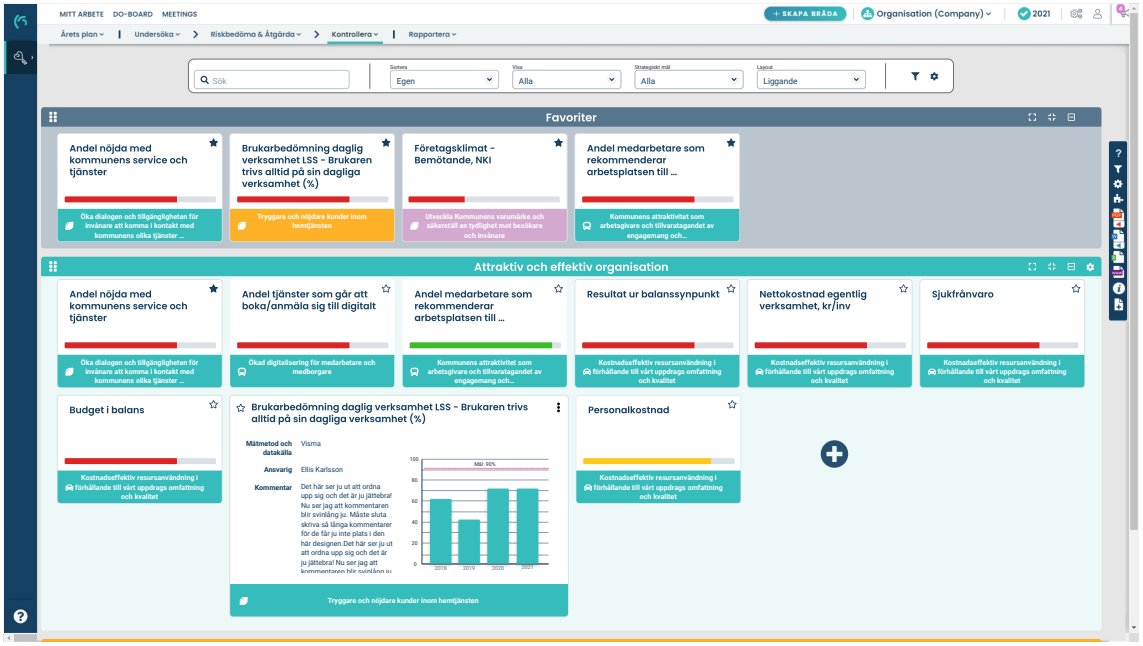

Figure H.4: Expandable Cards with one card expanded.

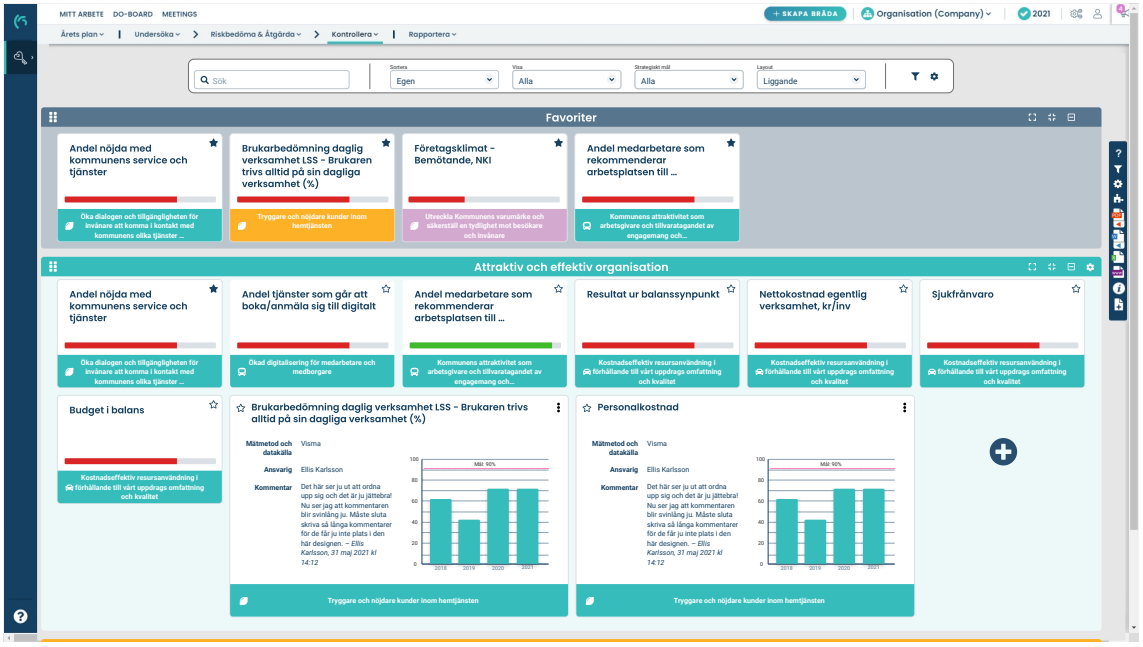

Figure H.5: Expandable Cards with two cards expanded.

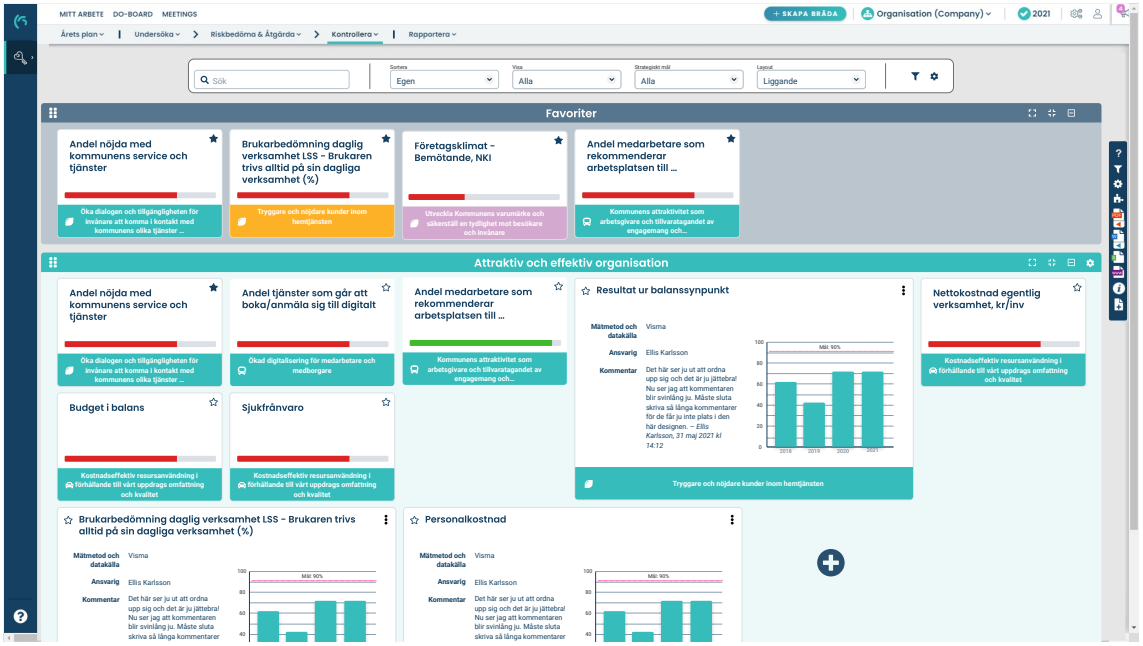

Figure H.6: Expandable Cards with three cards expanded.

H.2 Scorecards

Scorecards is a continuation of the concept from Iteration 2 with the same name described in appendix G, section G.1. Changes made during this iteration include:

- The background colour of each card is consistent and not used to signal the card's status.
- Information can now be visualized as icons, as a means to fit more information on the screen.
- The ability to change size of the cards to display a certain amount of cards has been removed.
- The users can now select what they want to be displayed on the cards.
- The users can now select if they want their information in the form of an icon or in text.
- The goal that the measurement belongs to is not placed at the top instead of the bottom of the cards.
- The cards can no longer be turned over. Instead, all information that is not available on the card is accessible from the side pane.
- The layout of the cards can be changed by the users, depending on what they prefer.

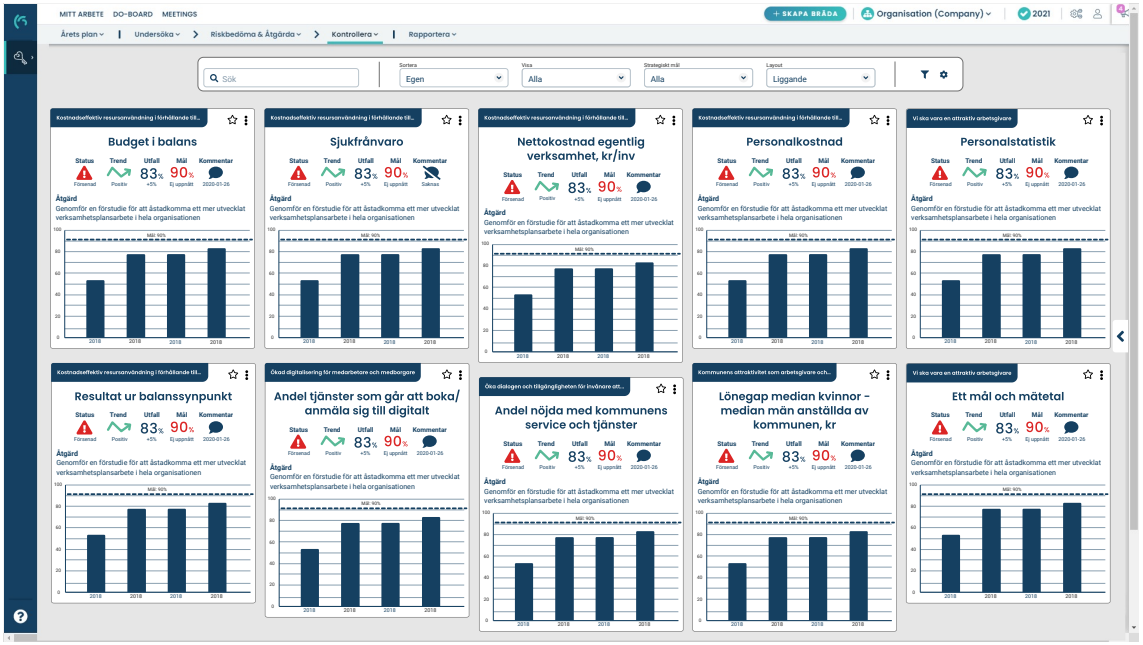

Figure H.7: SCORECARDS start screen with the side panel hidden.

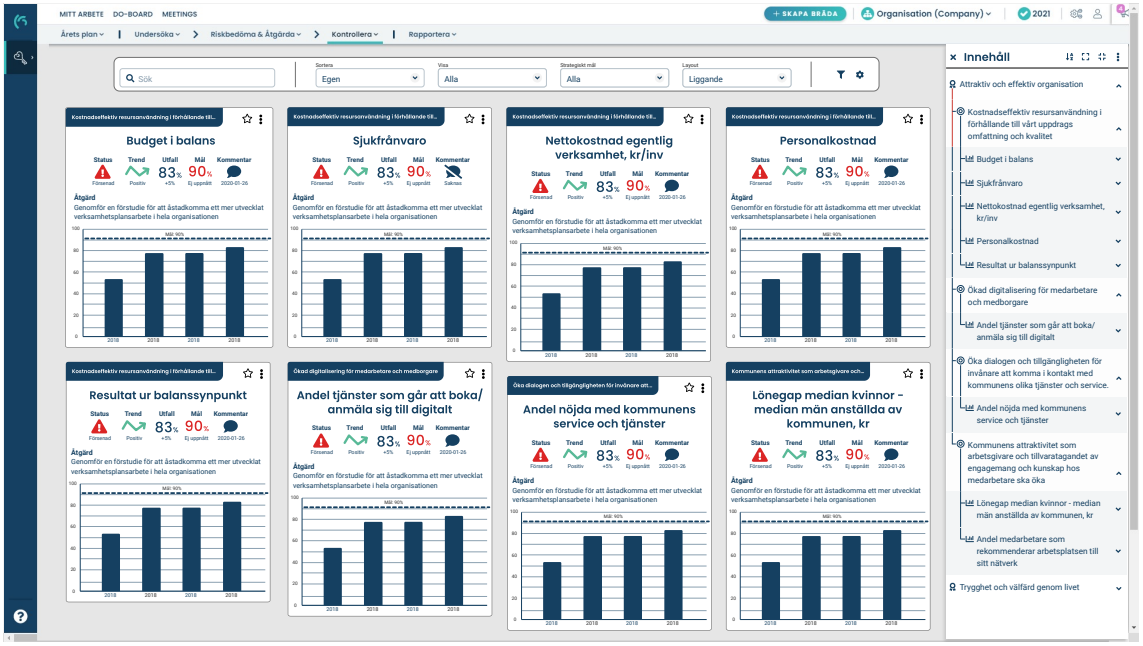

Figure H.8: SCORECARDS with the side panel visible, without selecting a card.

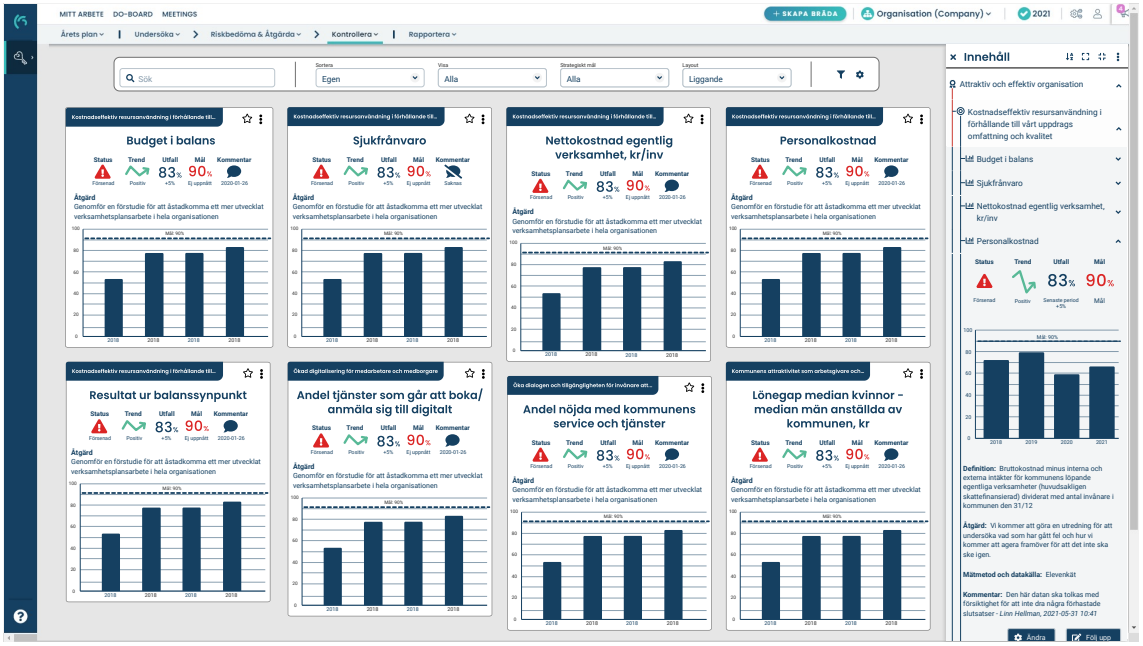

Figure H.9: Scorecards with the detailed view in the side panel visible when a card have been selected.

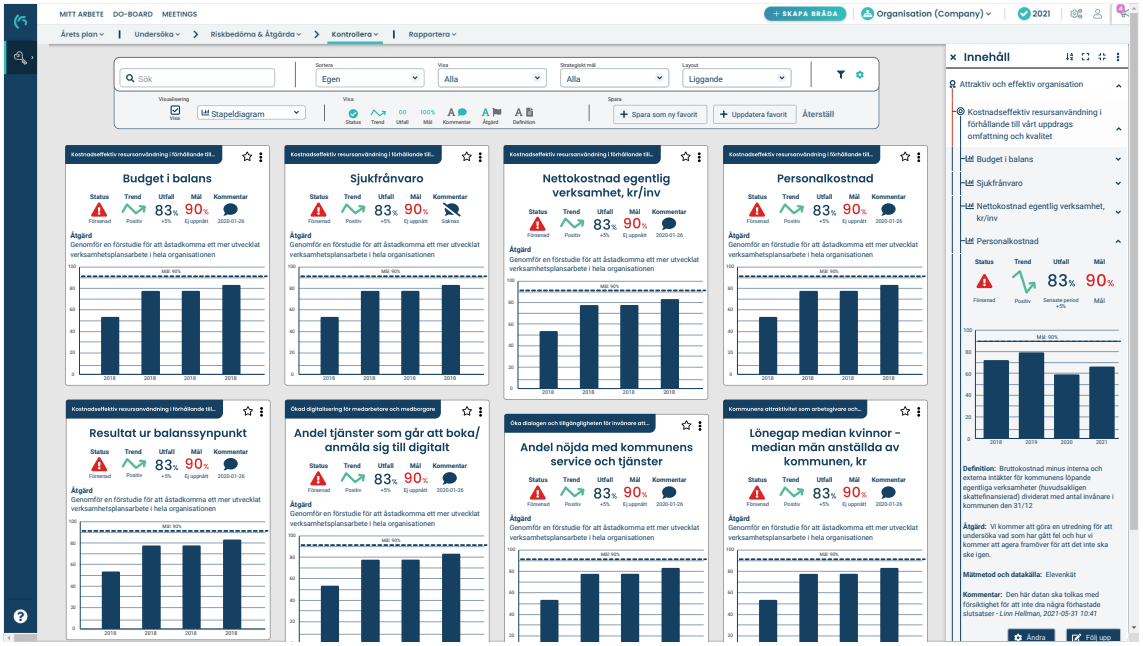

Figure H.10: Scorecards with the settings menu visible.

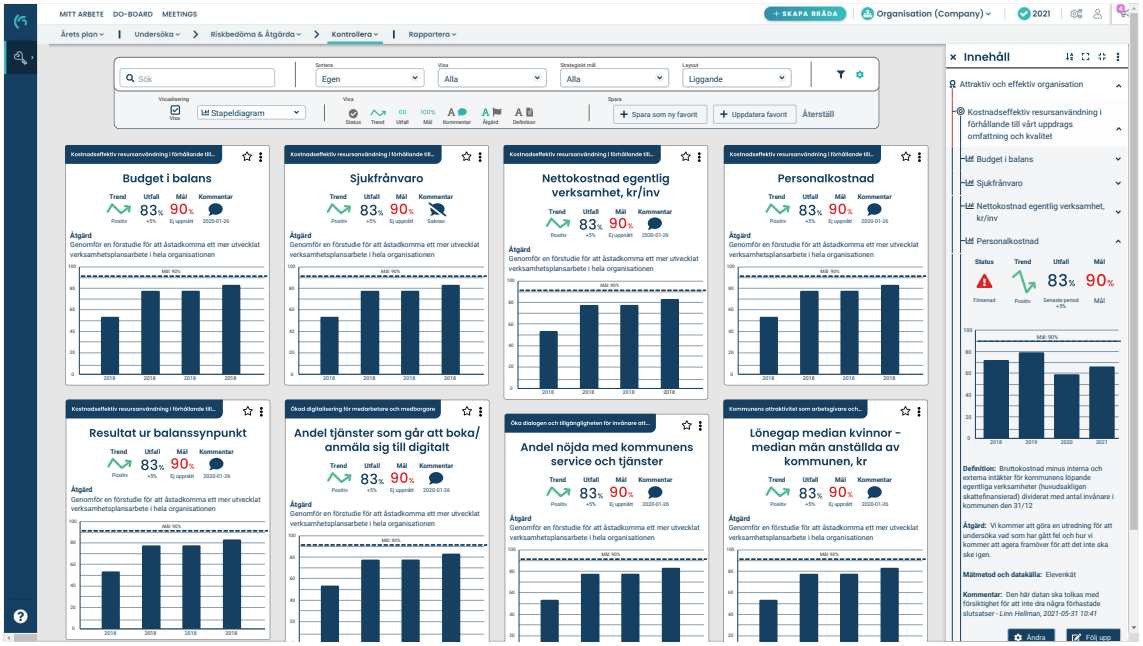

Figure H.11: SCORECARDS with the "status" icon hidden.

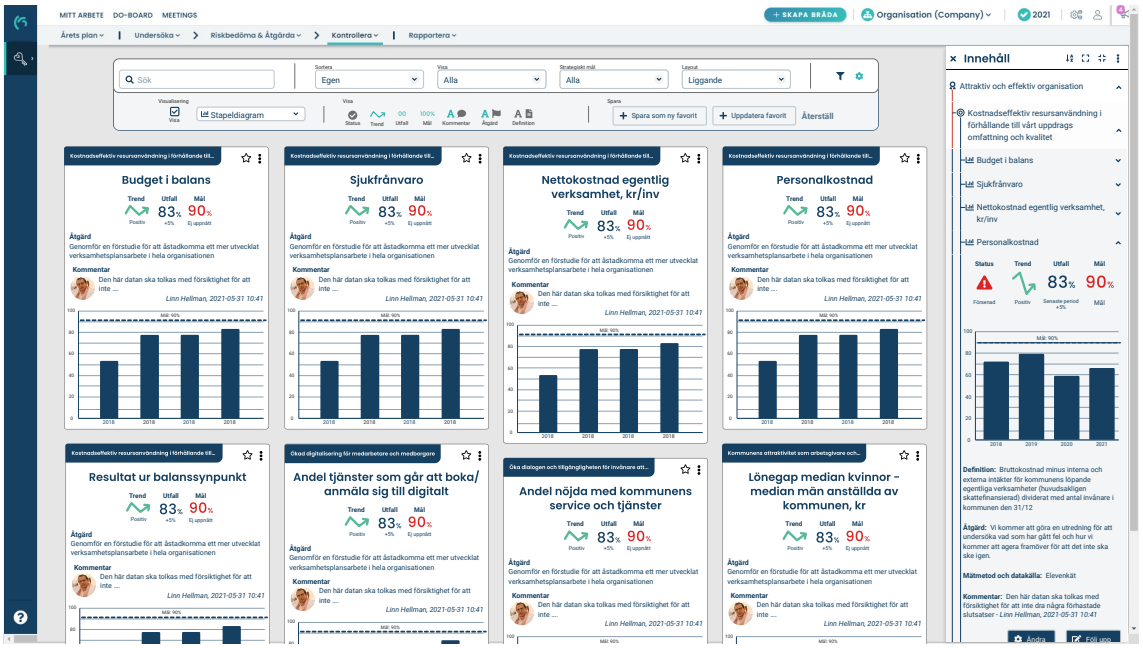

Figure H.12: SCORECARDS with the "status" icon hidden and "comments" shown as text.

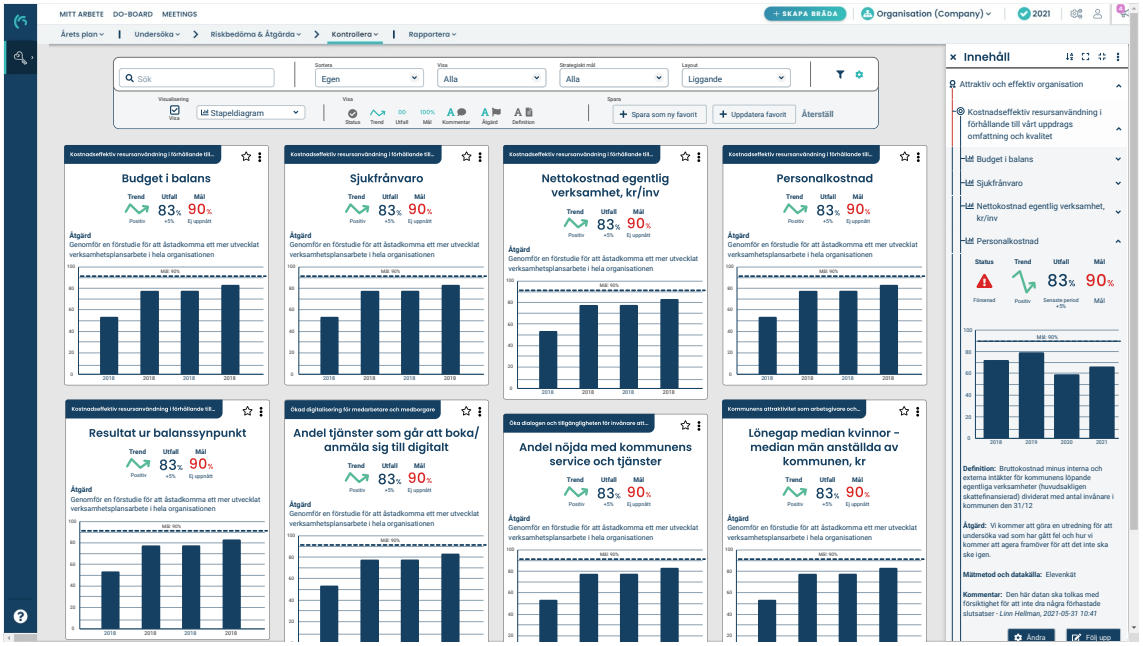

Figure H.13: SCORECARDS with the "status" and "comments" icons hidden.

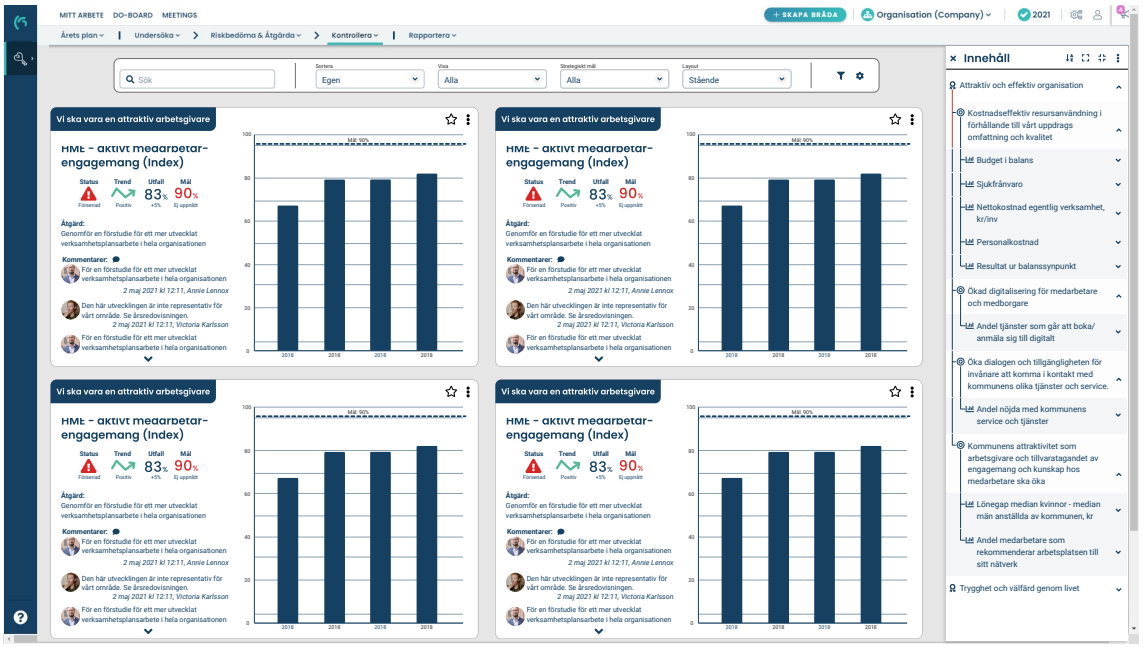

Figure H.14: SCORECARDS in the different layout called "standing cards".

H.3 Tree Structure

TREE STRUCTURE, shown in figure 6.46 is a continuation of the concept from Iteration 2 with the same name, described in appendix G, section G.5. Changes made during this iteration include:

- The nodes are now organized in half circles with the root node in the center of the screen.
- The ability to add nodes has been added.
- The colour coding is made more clear.
- When a node is selected to be shown in the side pane, other nodes are now faded out.
- Each node is labeled to make it easier for the users to see what kind of data they are visualizing.
- The parent node is made bigger and more distinct, to provide a more preattentive starting point for the users.
- Filtering options and a search function have been added.
- The colour scheme has been updated to be less distracting for the user.

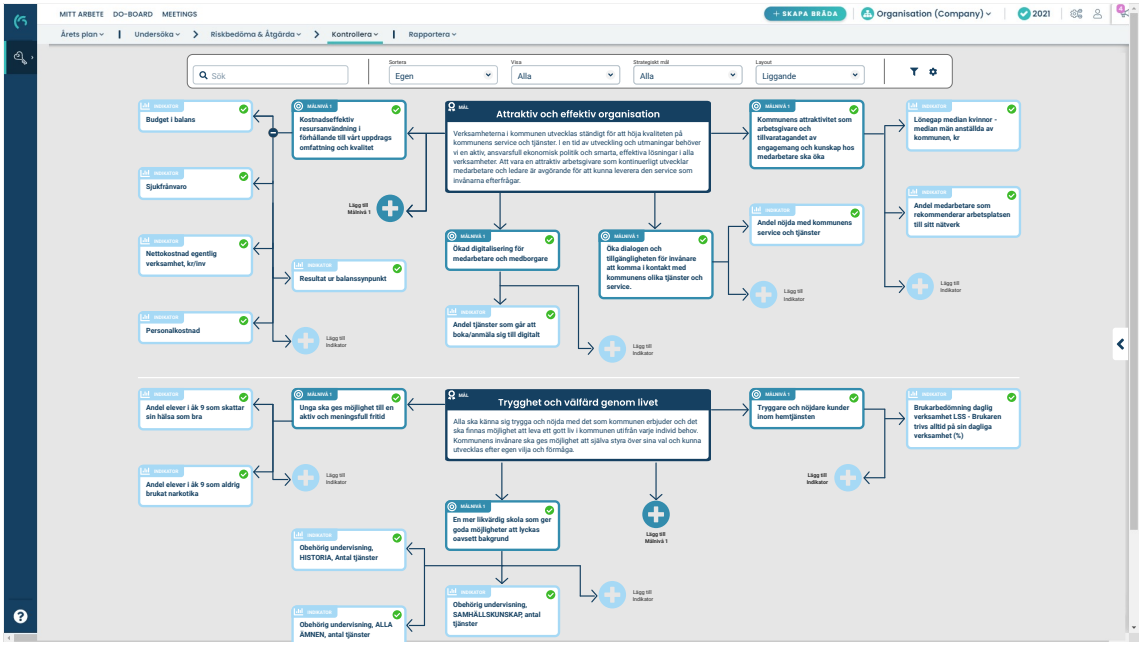

Figure H.15: Tree Structure with the side panel hidden.

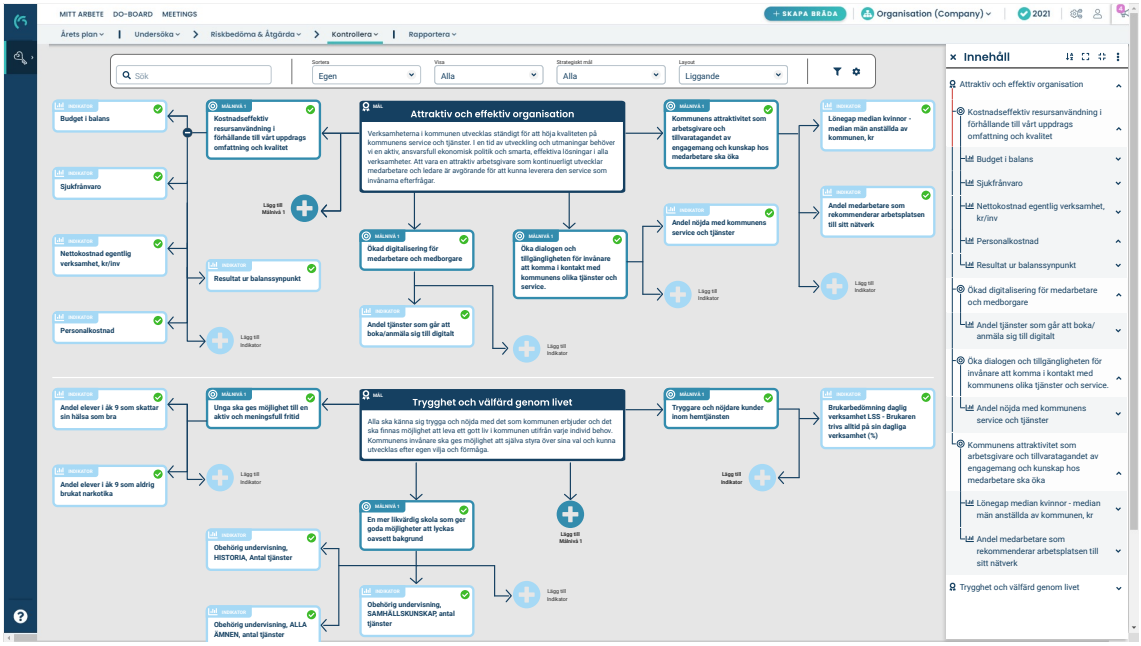

Figure H.16: Tree Structure with the side panel visible, without selecting a node.

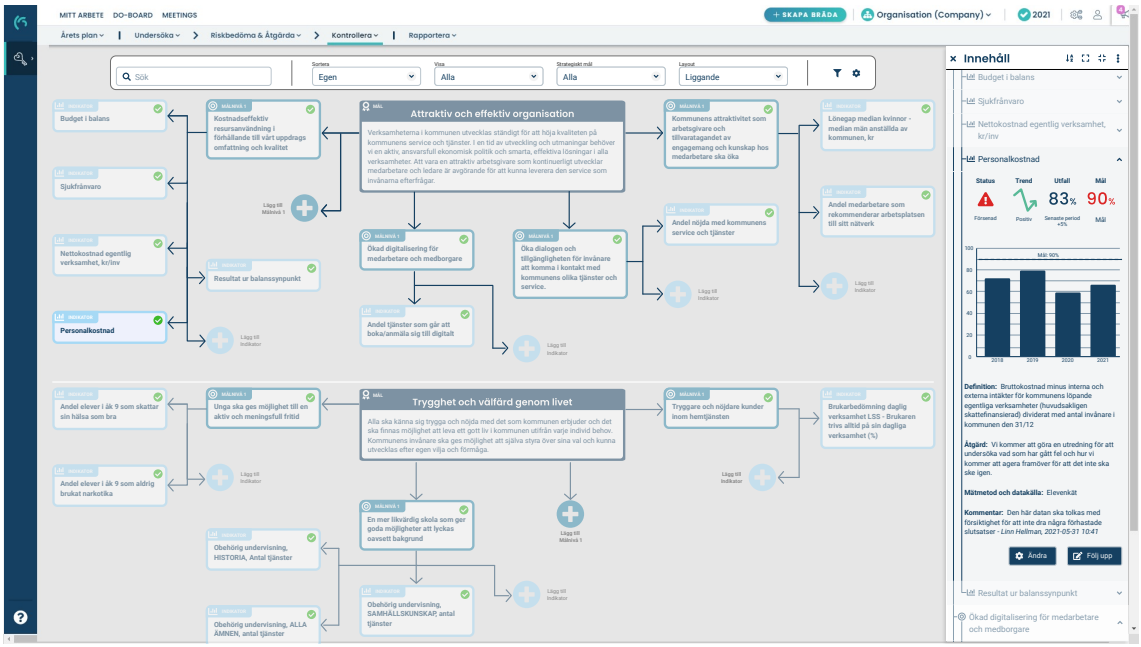

Figure H.17: Tree Structure when one node has been selected. Other nodes are faded out and the details are visible in the side panel.

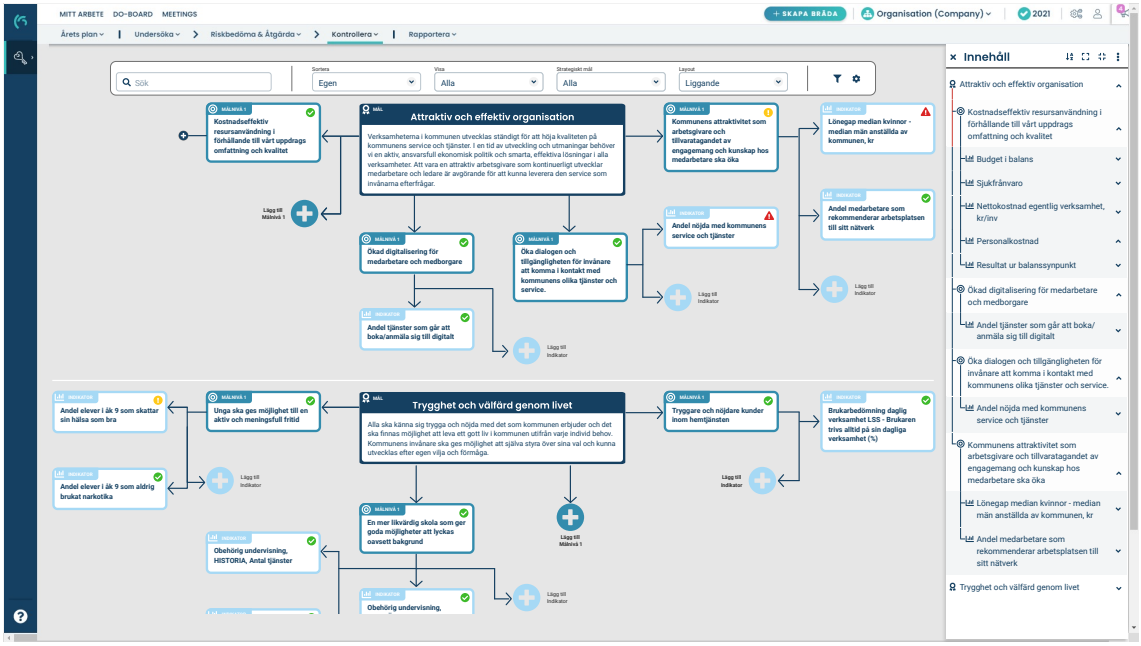

Figure H.18: Tree Structure with some nodes hidden in the top left.