UNIVERSIDADE ABERTA INSTITUTO SUPERIOR TÉCNICO

ENTERPRISE DASHBOARDS FOR WATERPROOFING SYSTEMS IN WOOD CONSTRUCTION

André da Silva Maximino

MASTER'S DEGREE IN INFORMATION AND ENTERPRISE SYSTEMS

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Thesis supervised by

Professor (PhD) Elizabeth Simão Carvalho

2020

Abstract

The act of decision-making in the management field can be complex. All the several industries have their own actors and very specific fields of intervention. For that reason, visual information can be a powerful ally when correctly adapted to its focused point.

Dashboards in particular, gather all the amount of data that's been generated every day and translate that into visual information that helps the user to monitor the project in a more dynamic and with much more control of the processes it is supposed to make decisions on.

Within the construction industry exist many sub-industries that contribute for the thousands of components that comprises a structure, a building, a final product. The wood construction is very common in Scandinavian countries and specially in residential buildings, in which it is necessary to install waterproofing systems for the so called "wet rooms", in constant contact with moist or water.

This study aims to develop a visual model that make possible the analysis, creation and the evaluation of dashboards that will support the decision-making process of the project manager, focusing on the management side of the product rather than the production. This is comprised by several stages of development which results in a high-definition prototype.

The user played an important role in this work throughout surveys and direct observation of testing, so it could evaluate the potential of the system to be used frequently. For the focus group, 6 participants were part of the testing sessions for the first version of the prototype. The score average was 74,6 in the System Usability Scale, with the prototype being considered as Good.

Keywords: waterproofing systems dashboards, information visualization, decision-making

Abstract

O ato de tomar decisões em gestão pode ser complexo. Todas as indústrias têm os seus próprios atores e campos de intervenção muito específicos. Por esse motivo, as informações visuais podem ser um aliado poderoso quando adaptadas corretamente ao seu ponto de foco.

Os *dashboards*, em particular, reúnem toda a quantidade de dados gerados todos os dias e convertem em informação visual que ajudam o usuário a monitorar o projeto de uma forma mais dinâmica e com muito mais controle dos processos nos quais ele deve tomar decisões.

A construção em madeira é muito comum nos países escandinavos e especialmente em edifícios residenciais, nos quais é necessário instalar sistemas de impermeabilização para as chamadas “divisões húmidas”, em constante contato com água ou humidade.

Este estudo tem como objetivo desenvolver um modelo visual que possibilite a análise, criação e avaliação de *dashboards* que darão suporte ao processo de tomada de decisão do *project manager*, com foco no lado gerencial do produto e não na produção. Isso é composto por vários estágios de desenvolvimento que resultam em um protótipo de alta definição.

O usuário desempenhou um papel importante neste trabalho ao longo de pesquisas e observação direta de testes, para avaliar o potencial do sistema a ser usado com frequência. Seis participantes fizeram parte das sessões de teste da primeira versão do protótipo que teve média de 74,6 no *System Usability Scale*, com o protótipo sendo considerado Bom.

Palavras-chave: *dashboards* de sistemas de impermeabilização, visualização de informação, tomada de decisão

Abstract

Beslutsfattandet inom förvaltningsområdet kan vara komplicerat. Alla de olika branscherna har sina egna aktörer och mycket specifika insatsområden. Av den anledningen kan visuell information vara en kraftfull allierad när den är korrekt anpassad till sin fokuserade punkt.

Speciellt *dashborderna* samlar in all mängd data som genereras varje dag och översätter den till visuell information som hjälper användaren att övervaka projektet i en mer dynamisk och med mycket mer kontroll över de processer som den ska ta beslut om.

Inom byggbranschen finns många underindustrier som bidrar till de tusentals komponenter som består av en struktur, en byggnad, en slutprodukt. Träkonstruktionen är mycket vanligt i skandinaviska länder och speciellt i bostadshus där det är nödvändigt att installera vattentätningssystem för våtrummen, i ständig kontakt med fukt eller vatten.

Denna studie syftar till att utveckla en visuell modell som möjliggör analys, skapande och utvärdering av *dashboard* som kommer att stödja beslutsprocessen för projektledaren, med fokus på produktens ledningssida snarare än produktionen. Detta består av flera utvecklingsstadier som resulterar i en högdefinitionsprototyp.

Användaren spelade en viktig roll i detta arbete genom undersökningar och direkt observation av tester, så att den kunde utvärdera potentialen för systemet som används ofta. För fokusgruppen var 6 deltagare en del av testsessionerna för den första versionen av prototypen. Poänggenomsnittet var 74,6 i System Usability Scale, där prototypen betraktades som bra.

Nyckelord: *dashboards* för vattentäthetssystem, informationsvisualisering, beslutsfattande

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To Renato Maldonado, for being the person that was crucial for the change on my academic goals and for being an inspiration to aim for more. Thank you.

André Maximino

Linköping, May 2020

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List of abbreviations

KPI	Key Performance Indicator
SLR	Systematic literature review
DSR	Design Science Research
CFO	Chief marketing officer
CEO	Chief executive officer
SME	Small-to-medium enterprise
BI	Business intelligence
VI	Visual Information
IT	Information Technology
IND	Indicator
NBC	Nordic Barrier Coating AB
NTC	Nordic Textile Converting AB
R&D	Research and Development
CPI	Cost performance index
SPI	Schedule performance index
SUS	System Usability Scale
ME	Metric of evaluation
SD	Standard Deviation
TAT	Time to act in a task
TCT	Time of conclusion of a task

1. Introduction

The growing amount of generated data has a direct connection to the increasing role of information systems in daily processes around all industries.

It´s not surprising the fact that with all this data, comes a need to organize it properly and connect the diversity of subjects in order to potentiate the information that the user will have access to. According to the definition of data, “Data are entities that, of themselves, lack any meaning. They constitute the “bricks” with which we build information and our communicative processes.” [1, p. 8]

One way to facilitate the output of that information is through visualization. Relying in the definition of the word, it is “an activity in which humans beings are engaged as an internal construction in the mind”[1, p. 7][2].

These two definitions make more sense when connected with a third: decision-making. Before, this type of interaction was limited to the management layer of the company. Nowadays, thanks to the access to information systems, it is possible to extend it to the lower levels of the business.[3, p. 500]

One of the expected contributions from this work is to improve the management experience of the end user through the use of information visualization techniques, namely, dashboards.

1.1. Objectives and expected results

The main objective of this work is the proposal of a visual model oriented to dashboards, so it will help the interpretation of Key Performance Indicators (KPI) within the construction industry[4], more specifically within waterproofing systems and extended to lamination and processing of non-woven products, plastics and products that sustains the isolation of housing.

For that reason, it is expected to divide this process into four main stages:

- KPIs identification, selection and analysis;

- Identification of the visual model of the end-users, tasks and selection of more appropriate visual techniques to be used by the dashboard;
- Proposal of a visual model;
- Dashboard prototype implementation and testing.

In order to evaluate the model, it is expected to develop a high-fidelity prototype, built taking into account the results from the users' enquiry. In that stage, the evaluation metrics will be noted and analyzed, as well as the several testing scenarios and these will be used as a basis for the further development of the prototype.

1.2. Research Methodology

1.2.1. Systematic literature review

A systematic literature review (SLR) is "a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest" [5, p. 1]. The goal is to have a rigorous result which gives a strong literary background and a good first step for the work to be developed later.

The research will then follow three main steps: Planning, Conducting and Reporting the Review, which are available in posterior sections of this document.

Planning phase comprises of the identification of the need for review, specifying the research questions and developing the review protocol. Conducting phase is the selection of the studies and data extraction. This is based in the review protocol stated in the previous item. Finally, the reporting the review phase is the summary of the extracted data and the report of the results.[6]

The phase of review protocol consists in a search of literature, using several search strings and connections between at the designated data sources them that establishes a link to retrieve the most relevant articles to be considered in the SLR.

1.2.2. Design Science Research

The methodology adopted in this study is the Design Science Research (DSR).This method involves creating artifacts or design theories as a basis for improving existing practice of research methods and focuses on two fundamental principles, related to information systems: the creation of knowledge from artifacts and the analysis of them for analysis of performance and results. Being a method that requires the generation of knowledge, it can be summarized in a process composed of cycles, and the outputs may arise from new models, to frameworks, architectures, methods or new design theories.[7][8]

According to Hevner [9], there are three fundamental cycles in this process: the cycle of relevance, design and rigor. The relevance cycle between the present environment (application domain, technical systems, problems and opportunities) and the DSR consists of the collection of requirements and the field test.

The design cycle comprises the construction of the design, the artifacts and the processes, as well as their evaluation. The rigor cycle between DSR and the knowledge base, comprises basic knowledge and subsequent additions (scientific theories and methods, meta-architectures)[10]. It is important to mention the cognitive processes inherent to this method, which include abduction, circumscription, deduction, reflection and abstraction [11].

Assuming that one of the objectives of this research is to propose a visual model and implement an artifact for evaluation purposes, the Design Science Research is potentially one of the most appropriate method to be used. It is also expected that there is already an existing practice for the design and creation of visual dashboards, and in order to adapt it to the existing data requirements and potential end-users needs, it is intended, through this method, to achieve this goal.[8]

1.3. Thesis organization

This Thesis is developed under six main chapters. In Chapter 2, a literary review is done in order to serve as a basis for the construction of the visual model to be suggested. Chapter 3 describes the relevant phases of analysis and selection of indicators and visual techniques to be used in the prototype. Chapter 4 is mainly focused in the model implementation as well as the main results from the tests. In Chapter 5 the results of the evaluation methods are presented according to the suggested visual model and this document ends with a critic of the model implementation and which are the main conclusions and suggestions for future work in Chapter 6.

2. Related Work

The goal for this chapter is the reviewing and mentioning of the most relevant definitions that will serve as a background for the development of the conceptual model, which is an interactive dashboard within the waterproofing systems and sub-industries of construction for decision-making in the management of the aforementioned industries.[12]

2.1. Information Visualization

By exploring the definitions of what is a visual technique and the elaboration of dashboards, it is possible to describe five stages of a dashboard development [13]. Also, it is possible to bridge a gap between this phase and the discussion about the several relationships between these tools, from demand until the implementation process and the adoption of these systems. They mention the four factors for the need for dashboards (LaPointe, 2005): poor organization of decision-relevant data, managerial biases, increasing demands for marketing accountability and the need for cross-departmental integration in performance reporting practices.

The findings on this article show that the main attention to dashboards are drawn by CMOs (Chief marketing officer) and CEOs (Chief executive officer) of larger corporations. It shows that these tools represent a way to integrate the firm level elevating it to trade market. The display of key metrics facilitates the communication between departments and business units. Also, it helps to diminish the inconsistencies across the organization as well as a main tool for decision making as it was expected.

When considering the potential of learning abilities from these tools, dashboards can work as a tool for capturing and visualizing traces of learning activities [14]. By using learning analytics, it is possible to define more accurate goals for learners. They used their own work data to present the several solutions. The findings of this paper show that besides showing different possibilities of dashboard solutions, the authors also found several research issues when concerns the development and evaluation of learning based dashboards, mainly based on the low amount of available data for this subject which limits the investigation, which can relate to the study as it has limited amount of data to establish a future proper solution.

The potential of dashboards extends to other sectors. In the medical sector, this can also be a powerful means to improve decision-making and lower medical error. Moniz [15] developed a dashboard to facilitate the analysis and evaluation of the health care data by professionals in the clinic and assist them in decision-making. The study was carried out involving several phases of interview, prototyping and evaluation of the suggested visual model. This study is particularly useful, since it structurally illustrates the process of creating dashboard models.[16]

Moore [17] conducted a study which has the goal to elucidate the main principles that should be adopted when developing visualizations that help effective strategic decision making. The research questions were focused in main themes as value, use, consumption, speed, meaning, trust and confidence. The findings include the realization about the value of the generated data and for the desired visualized effect, as well as the accuracy of the data. This study is relevant as it describes the challenge of dealing with great amount of data, the importance of that information and how to make a suitable selection in order to improve the decision-making process more effective.

Also, the organizations can use data visualization to improve decision making and operational execution [18]. There are three main activities: display reporting, operational alerting and visual discovery and analysis for different functions in an organization. Visualizations enable new forms of collaboration on data, as well as the main user profile for dashboards. The organizations face a lack of connection in dashboards between mobile and desktop platforms, where there is a great space for improvement, as well as the purpose of the dashboard itself for the organization. This report is highly relevant for this research as it has a broad approach to the visualization techniques and focusing in the main issues for a visual dashboard when it has the purpose for business decisions.[19]

2.2. Dashboards and Visual Techniques

A successful dashboard design translates the right metrics into several charts and gauges on a single page. This means that the author of the dashboard has to consider the right story to tell the readers, in this case, the end-users.[20] The way that story is told can influence the understanding of the entire narrative, and the misuse of the data can lead to a completely different route of the storyline, which means a complete distinct ending.[21][22]

This can be translated into the decision-making process. It is crucial to be aware of the right information to the right audience.[23][24] When compared to traditional dashboards, today's dashboards have the ability to increase the interaction between the user and the key metric (between the reader and the storyline), and from this involvement, it increases the interest value and a better end decision.[25]

For every design, the author must ask himself first three main questions[26]:

1. "Who is my audience?"
2. "What value will the dashboard add?"
3. "What type of dashboard am I creating?"

Audience

The author must know what motivates the audience and figure out how to adapt similar messages to distinct users. This is possible by structuring the information, decode the workflow and how does that translate in the daily tasks, the level of knowledge of the audience regarding the level of detail, analytical capabilities and the users comfort zone and the data expertise.

Value

The dashboard author needs to define what is the importance of the information, the goals and expectations for specific groups, the actions to be included and the time it will take to be executed, possible exceptions and alerts, the communication of progress and success, and a common interface so it will generate familiarization and recognition.

Creation

Traditionally, the creation of a dashboard is defined by some visual techniques that will fit in just one page, showing real-time information and general knowledge of a business. For the current times, that kind of approach can be very limiting. Each situation is different, makes what makes a good dashboard is how fluid is the data translated into visual graphics, the level of interactivity, timeless of data and analytical capabilities.[27] Before even considering the technique, the metrics to be considered have to be chosen and that's a challenge (according to Figure 2.1)

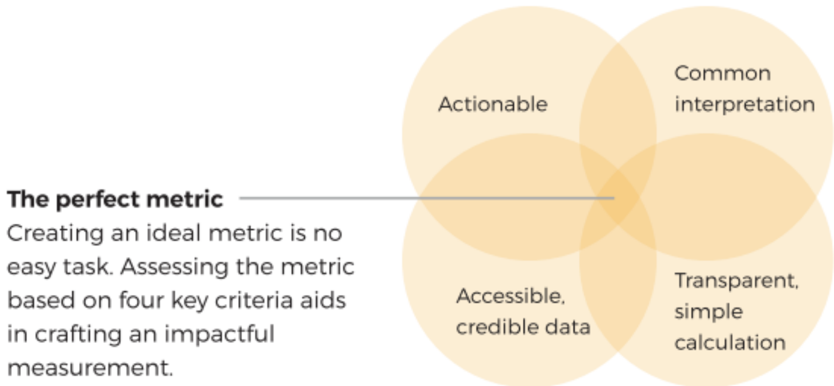


Figure 2.1:Consideration of the best metric

The conception of a dashboard and the way it looks depends mainly in four categories: Form, Structure, Design principles and Functionality.[28]

The Form of a dashboard comprises how it will look: if it's a one page, if it's an animated screen, for example. There are a few factors that influence the form of the dashboard: timelessness, aesthetic value, mobility, connectivity, data detail, data density, interactivity and collaboration.[29] These are illustrated in Figure 2.2:

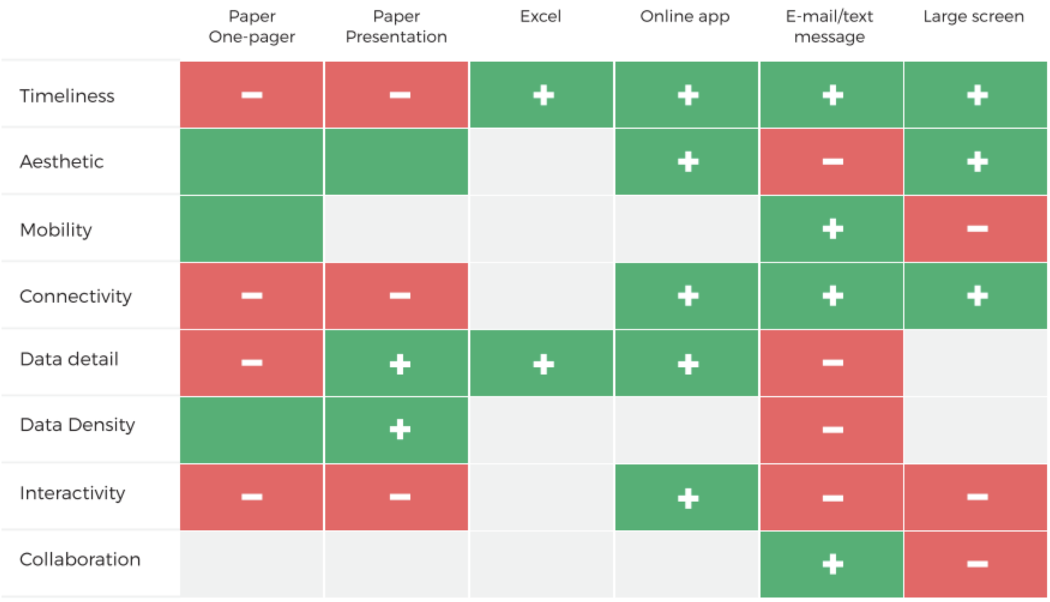


Figure 2.2:Influence of form when it comes to platform

The structure of a dashboard influences the way the dashboard looks at the problem. Going from a Question, through the data parameters and chart category and finally to the mapping of data to chart elements determines the way that the message is delivered and is different from department to department. The right model is more specific and when it comes to structure, it falls into three different categories: flow, relationships and grouping.[26][30]

A flowed structure is more suitable for a sequence of events along time. When the data to focus involves the relationships between entities or measures, the most suitable type of structure is maybe a mathematical, organizational or functional relationship. If the author wants to emphasize a hierarchy of categories, then should choose a grouping structure.

After the definition of the structure, some principles of design should be considered, such as Compactness and modularity, the gradual reveal of the information (growing from the key metric, to the context around it and finally the breakout), the guide attention, lead to action and explanation before information.[31]

2.3. Technique Design

When considering the interface design of a dashboard, it should be considered how clear and easy to the eye it should look. This being said, it is relevant to organize the visuals properly, leaving some room for the user to "breathe", with a suitable and homogeneous color palette and with harmonious typography.[32]

When considering data, there are two types of data: categorical and quantitative. Categorical data is the type of data that can be grouped by type or category. Quantitative data is all the information that can be measured.[33] An example of categorical data is the departments within a company, such as Human Resources, Production, Sales or Research and Development. Quantitative data can be the number of employees, the marker share, etc.[34]

When considering the process of dashboard elaboration, the first step is the idea of the solution (or problem formulation), the second step the prototype (or building, intervention and evaluation) and the last step the test phase (or reflection and learning). Phases one and two occur parallelly and all comes with a result of a last stage that is the formalization of learning (or writing the document).[8] Figure 2.3 illustrates the process.

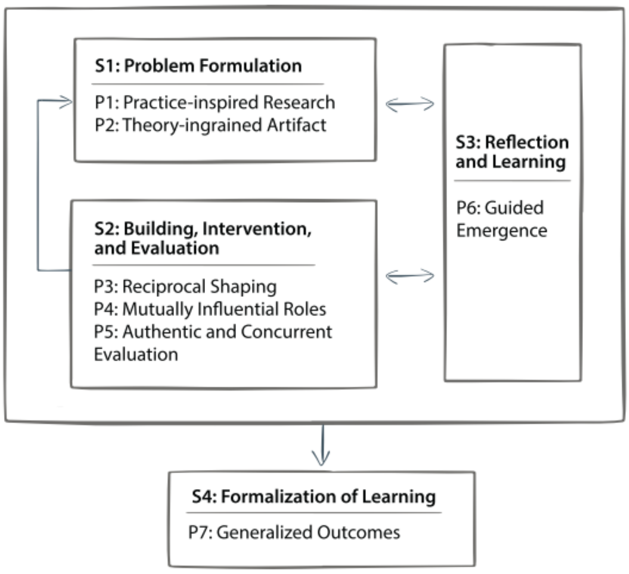


Figure 2.3: Method for the construction of the dashboard

When selecting the right type of charts or tables, we have to consider what was said prior regarding the type of data.[35] Considering nominal or ordinal data, a bar chart or a line chart can be the most suitable.[36] The most decisive factor in the type of visual technique to be shown is the chart category which can be divided into four different sub-types: Distribution, Composition, Relationship or Comparison and Trend.[31]

If it is important to understand how the elements spread across one or more axis, it is better to use a distribution type of chart, such as a Bar chart or scatterplot.

On another hand, if the division of the data into different pieces is what it matters, then the composition is the most suitable such as a pie chart, a bar chart or a tree map.[34] When considering the evolution of an element across, or trend, a line chart and area chart are more suitable[37].

Figure 2.4 [38] of the right charts to be used depending on the category the data fits in.

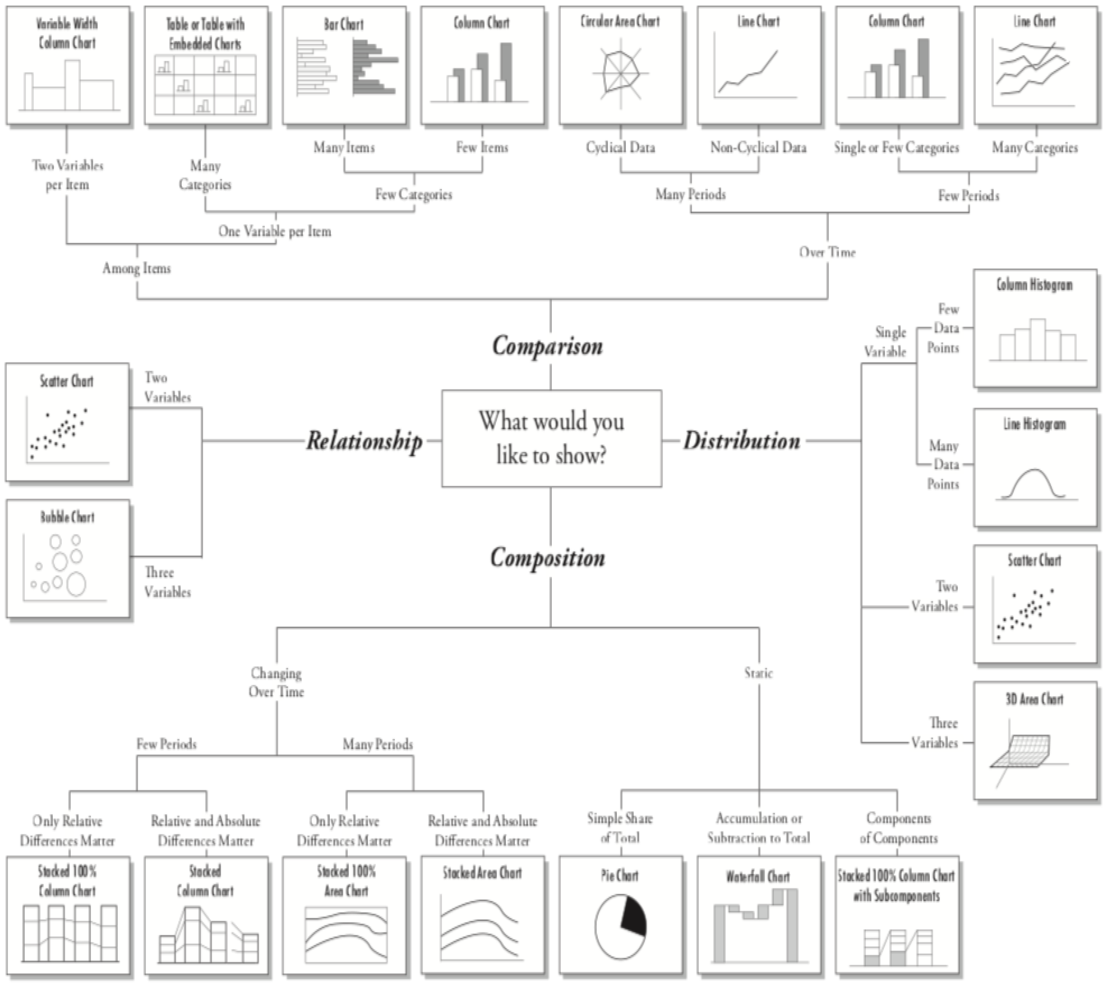


Figure 2.4: Types of charts to be used in a dashboard, depending on the category

There are other visual techniques besides the traditional bar charts, line and point charts.

Other visualization techniques can represent the relationships between multiple variables. One example is parallel coordinates, which plots the data on parallel axes connecting the corresponding points with lines (Figure 2.5).

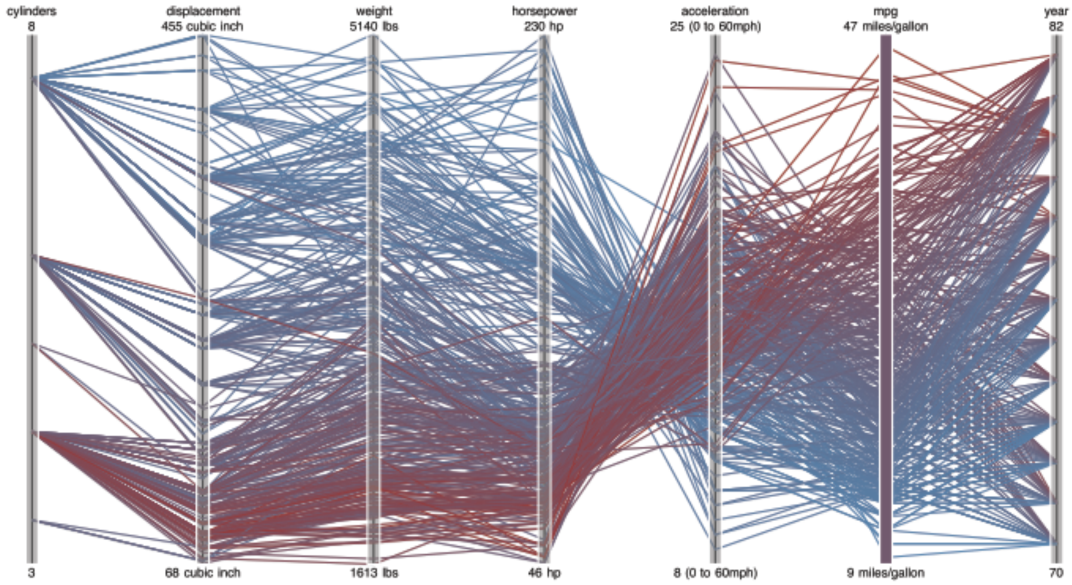


Figure 2.5: Example of parallel coordinates for automotive data

Source: [37, p. 8]

Maps can be used to do a cartographic projection and use the data to cross with the map information and generate a visual output.[39] For example, when tracking the variation of position in time, it generates a movement line, which can be set in a Flow Map. When focusing in geographical areas, the choropleth maps are a great tool to emphasize the data using a color scheme connected to a map (Figure 2.6).[40]

The Maps can also be complemented with pie charts instead of colors for example or other types of charts, to add more data information, being called graduated symbol maps.

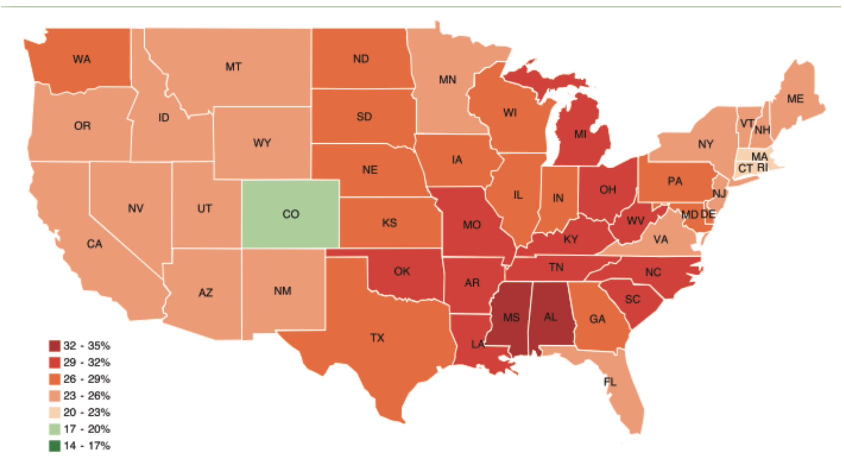


Figure 2.6: Choropleth map for obesity in the USA in 2008

When connecting several layers of hierarchies, the solution can be intricate and complex to understand. Usually is similar type of data that can be related with some visual link, as for example a node-link diagram, which appears to look like a tree with several branches representing the layers (Figure 2.7).

This type of technique can have several alternative schemes such as a dendrogram with leaves the nodes of the tree at the same level, or setting them in a color scheme for distinction.

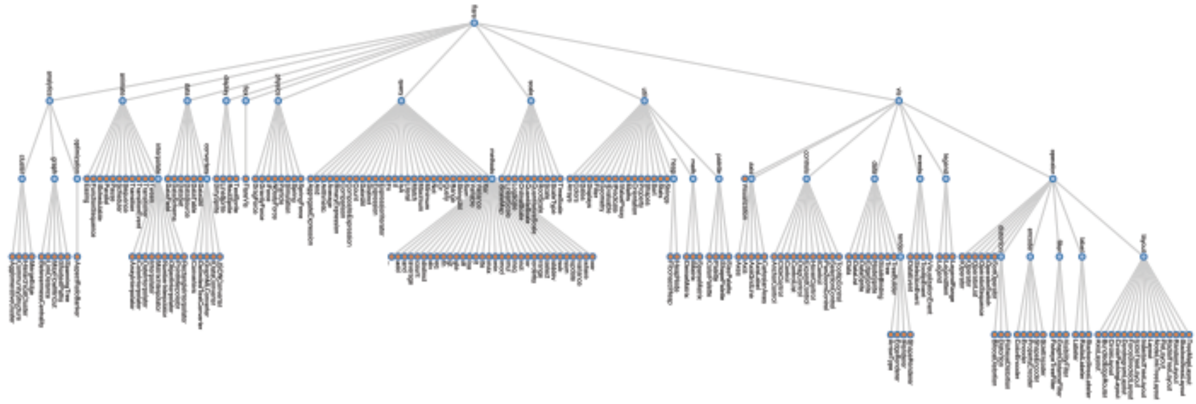


Figure 2.7: Radial Node-link diagram for a package hierarchy

Other techniques that can be used to illustrate hierarchy can be tree maps, radial space-filling or icicle tree layouts.

As said prior, when exploring the visualization through relationship, then it is interesting to consider how networks can be related. This can be done visually by creating a series of lines that cross the area and connecting the nodes that comprise the network layout (see Figure 2.8), with the alternative of an arc diagram or a matrix view.

Figure 2.8: Example of a force-directed layout

2.4. Using KPIs in Dashboards

In order to lower the uncertainty of decision making, it is important to analyze a certain number of key indicators. For this reason, management executives, from top layer positions to middle managing sectors, all rely in visual tools to help them evaluate and strategize the direction of the department.[41] They base their evaluation in KPIs.[42]

Vilarinho and Sousa suggest on how to develop dashboards for small-to-medium enterprises (SMEs) in order to improve the performance of productive equipment and processes[43]. This follows the processes of product development until the dashboard layout, considering visual management and continuous improvement approaches as well relevant data selection and the maturity of the information.

At the same time the dashboards were being developed, the company´s information system was also being improved so it could show three sides of the dashboard: operational, tactical and strategic.[44] This is relevant for this research as it focuses in the development of a visual technique for a smaller company, as it happens in this case as well.

Bititci focus on developing the visual strategy and performance management techniques and how these tools impact of the management decision-making of organizations[45]. To be able to perform this study, the author relied on qualitative case studies of seven manufacturing SMEs across Europe. Other elements to be considered for this purpose are the influence of people engagement and communication.

This research also shows that for long-term influence, it could be necessary to undergo an organizational culture adjustment. This paper is relevant for this research as it analyses the impact of visual strategy tools in organizations and how it influences the inner dynamics as well as the effects in different sizes of the company.

Dita researched the implementation of a business intelligence (BI) solution in a manufacturing company, with main focus on predictive analysis[46]. This has the objective of improving the process of decision-making on the operational level. The interesting fact of this master thesis is the focus on the project managing process and the way that a BI tool can help with optimizing the later phases of this. The generated dashboards are more focused in predictive analysis.

Gonçalves Teixeira[47] argued that success in a BI project "can be measured through three levels: reports output level (enables the consult of information); cooperation level with other areas; and support level to the short time."

The need to identify the main features, uses and benefits of performance dashboards, due to the low adoption of these tools by sales managers in Finland was a topic of research also[48]. There were four distinct purposes for the dashboards: monitoring, problem solving, rationalizing and communication and consistency. It was seen a correlation between the utilization of dashboards and user productivity.

The research conducted by Shi focus on propose an automatic approach to extracting KPIs from engineering projects related data[49]. The reason for this is connected with the amount of generated data from complex operational processes. There is also the objective of demonstrating how the domain knowledge can make the process of KPIs identification and visualization easier. The findings of this research proposed a conceptual model for a KPIs identification approach, and then evaluated by applying industrial data.

Zander and Hedin focus in which KPIs are most interesting for organizations in the construction industry and the most relevant for a BI application[50]. The data collected for this research was gathered by interviews and literature studies, ending in the most common KPIs for this industry. Finally, from that list, the most relevant indicators are selected to be visually represented. The findings of this paper show that there are a few key indicators that are desired to be shown from different perspectives, as pretax profit margin.

Also, it is important to mention that, although this is a research paper for the construction industry, there are many subsections within it, so for each sub-industry, the importance of the KPIs differ. It is also important to think about color scheme when developing a dashboard, as well as the choice of the correct chart and color changes the purpose of the visualization.[51] Most important is to consider that the user should not be flooded with information, as it has a limited amount of capacity to absorb the data and can prejudice de effectiveness of the dashboard. This is relevant for this research, as the wood sector is a sub-sector of the construction industry, and within it lays the water-tight systems, a very unique sector that will define the design of the visual technique.

2.5. Conclusion

In this chapter, were analyzed several relevant papers to this thesis. It´s possible to see in Figure 2.9 that the majority of the papers were released after 2010, peaking at 2016 with five papers. In fact, 84% of the total documents were written in this decade, proving that the most relevant information is relatively recent.

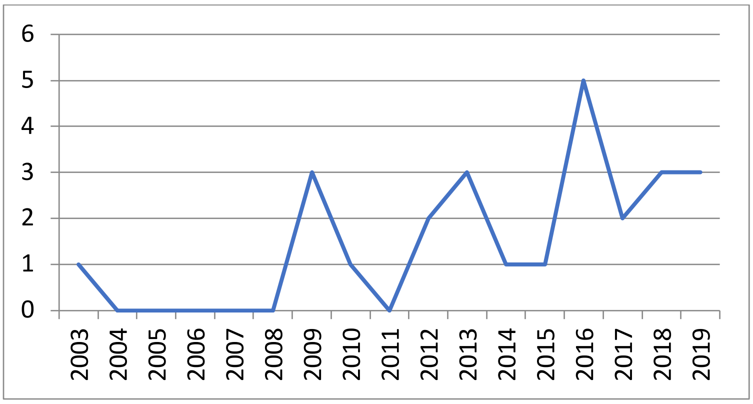


Figure 2.9: Distribution of the selected papers throughout the years (number x years)

Considering the type of publication for the research, the large majority of documents are reports (with 14 papers) followed by articles (with 9 papers). The considered reports also include thesis and thesis proposals.

It´s also relevant to understand the main theme for every selected paper and its relevancy to the research. The majority of papers are related to dashboards and visual information in construction, followed by the more enterprise related documents and general approach to the visual information theme.

Considering the relevant information to be included in the literary review, Figure 2.10 illustrates the number of papers that answered to each research question. The matrix of Publication Type and Selected Documents can be seen in Annex A.

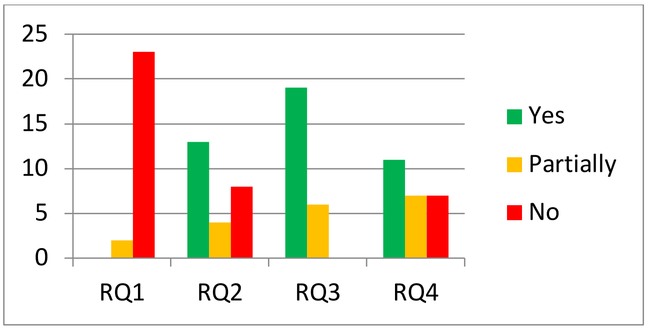


Figure 2.10: Number of papers that answered to the research questions

Figure 2.11 shows a summary of the main research areas that contribute for the development of the visual model.

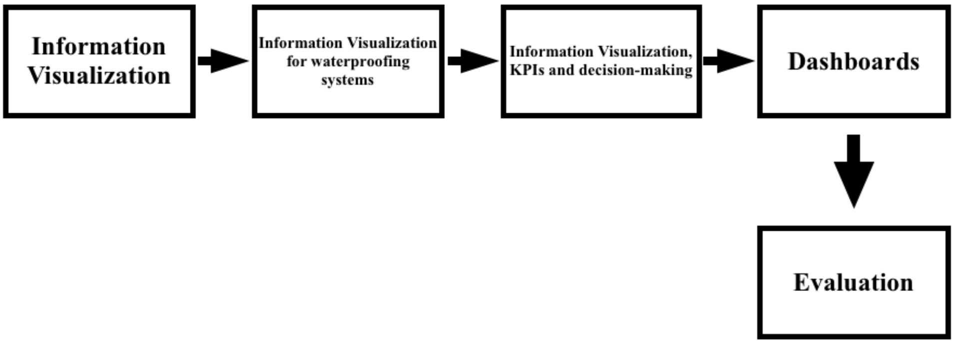


Figure 2.11: Main areas of research

It's relevant to mention how transversal is Visual Information (VI). During the process of development, it will gather several distinct knowledge fields that combine the transformation of data, to the interpretation of the end-user movements and wishes. It's a highly subjective chain of events as the design choice needs to be as universal to understand as possible, without being bland or monotonous.

It's been shown that there's a complexity of techniques that improve (or potentially ruins) the user experience and what is the main goal of the dashboard.

As said prior, the visual information and dashboards in particular are a non-stagnant field, so it was important to do research to recent articles and not relying in outdated information, that can happen quite fast in this sector.

In terms of preferable visual techniques to be applied to dashboards, table 2.1 illustrates the summary that relation with different KPIs, based on the articles discussed prior in this chapter and considering the relevancy for the construction industry. The matrix of Research Questions and Selected Documents can be seen in Annex B.

Table 2.1: Summary of indicators and preferable visual techniques

Indicator	Visual technique
Pretax profit margin per project	Bar chart
Pretax profit margin per customer	Bar chart
Chargeability	Line chart
Purchases	Bar chart
Tenders to be approved	Table
Time tracking	Line charts
Costs tracking	Pie Charts; Bar charts
Resources	Bar charts; tables

The next chapter will introduce the suggested visual model for this Thesis.

3. Conceptual Model

In this chapter will be discussed the conceptual model for the development of a dashboard towards the interpretation of specific KPIs within the sub-industry of construction in order to track projects and to be a tool to allow the improvement of decision-making, applicable for the case study and extended to the sector of waterproofing systems and construction industry in general.

3.1. Framework

For the relevance of this study, the main focus will be within a sub-sector of construction industry. In Sweden, the majority of residential and office buildings are built in wood. This comes with a complex chain of processes until it ends in the components that comply the structural elements[52].

Within it, the company that the study is focused, acts in the isolation of the rooms that may be exposed to continuous or temporary events of moist or to water. That is a highly regulated sector in Sweden, with strict rules and directives[53]. Also, every two years, it is conducted a major test that gathers the most sold brands of these types of products for the Swedish / Scandinavian market and it evaluates the quality in terms of local infiltrations, emulating real life situations[54].

It is a current problem the fact that many decisions are made without the optimal information to be used as a background and that can lead to poor decisions.[55]

In order to gather the user requirements and elaborate a conceptual model for the dashboard valid for the companies that can act within the waterproofing sub-industries, a case study will be conducted. It will focus on a company that acts in this branch of market (approximately 66% of the total Swedish market). Although it would be desirable to involve other similar companies due to time and managerial limitations only this one will be considered. Because its significance within the Swedish market is high, it is assumed that the conceptual model can be easily applied to other similar companies.

The company to be studied has its headquarters in Linköping, in southern Sweden, and develops technical products based on paper, nonwoven and several types of plastic materials. Further details are given in chapter 4, to explain the framework.

In terms of the quality tests that motivated the case study, there was an evolution of results from the first to the second test [56], but the brands represented by the company, showed a decrease in success results [57].

This was the beginning for the tracking of the main variables that form a project. With almost three years of gathered data, the main issue was to re-organize all this information in a way that could improve the management of the projects, optimize time and resources management as well as find out which are the main weaknesses so it could trigger a optimization action towards it.[58]

Also, it is a motivation the integration of KPI already in use for some projects, but not a tool commonly in use in the company. Having the access to the raw data and the possibility to calculate the indicators via middle calculations, it can be a powerful tool to “make or break” a project.

In order to begin this process, it was conducted a systematic review of literature[5] (resulted in chapter 2), in which was first performed an extended research of documents and articles to understand the universe of the information visualization and in what way it can help to interpret the KPIs results of the construction industry, and to lead to a suggestion of a cognitive model.

This model will focus in the analysis of the information that the user pretends to see. For this reason, it is a model focused in the user. The first goal is to define which visual technique is more suitable for the user’s needs and that means that is crucial that the user is also part of the idea and development of the dashboard and in the process of design of it.

The process of dashboard development follows a flow illustrated in Figure 3.1. It is important to mention that, for each distinct phase, the iterative process means that it can always go back to the idea point.

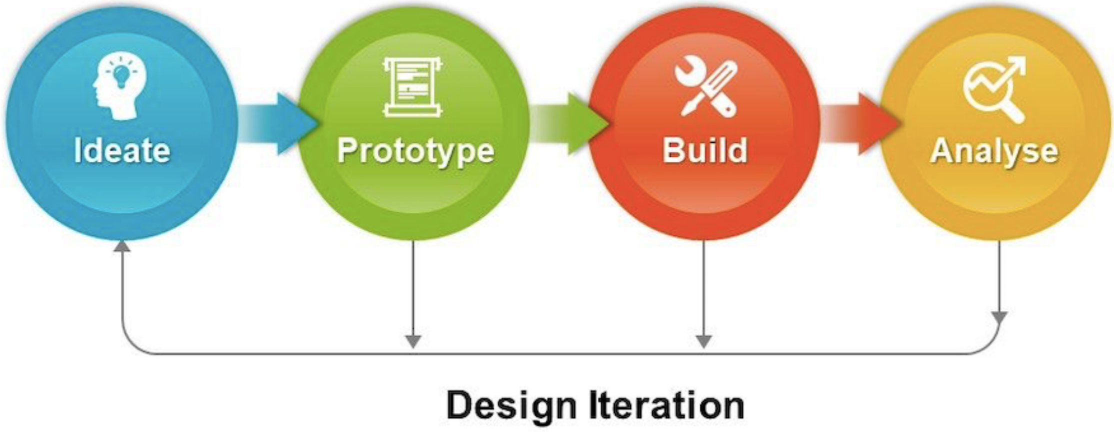


Figure 3.1: Phases of model development

The Idea phase comprises the analysis and selection of Indicators that will be displayed in the dashboard. Part of the Prototype and Build phase will be the low definition version of the dashboard and later the high definition version, compiling the several chosen visual techniques that, then will be tested in a usability evaluation (in the "Analyse" phase), and finally making sure that the model follows the initial requirements.

The phases of Prototyping and Analysis (or Usability evaluation) will be executed and explained in Chapter 4.

The next sub-section will present the method for analysis and selection of the indicators to be feature in the functional prototype to be later developed.

3.2. Analysis and selection of the Key Performance Indicators

To be able to choose the right indicators to be displayed, it is necessary to know the user and understand which are the main problems, the pattern of usage and which style of user we are dealing with.[59][60] This is important so, in further stages of the process, to be able to establish distinct scenarios of usage to be tested.[61]

For that reason, the process was divided in sub-sections: analysis of the user, selection of the indicators, evaluation techniques and evaluation.

According to Gonçalves et al [62], a way to identify and characterize the group of users could be through a pre-test enquiry, in which it is possible to know the target group and gather the necessary information to later, elaborate a series of tasks scenarios to be tested.

3.3. Users' analysis

As said in the section above, an enquiry is an important tool to know the users. Although this type of survey should have a great amount of answers, due to the specificity of the study and the lack of people to test properly, the enquiry and further tests were focused in the target group, which consists in six users, all having some kind of familiarity with the data and the visual techniques. The enquiry can be consulted in Annex C.

The focus group has ages from 25 to 44 years old and with the following job titles: 1 intern in product development, 1 product development engineer, 2 managers of production, 1 economist and the company CEO. Table 3.1 summarizes the group characteristics.

Table 3.1 Focus group characterization

Variable	Group	Result (number & Percentage)
Gender	Male	4 (67%)
	Female	2 (33%)
Age	18 – 24	0 (0%)
	25 – 34	3 (50%)
	35 – 44	3 (50%)
	45 – 54	0 (0%)
	+55	0 (0%)
Experience in the company	Less than 1 year	0 (0%)
	1 – 2 years	2 (33%)

	3 – 5 years	1 (17%)
	More than 5 years	3 (50%)
Company sector	Product Development	2 (33%)
	Production	2 (33%)
	Top Management	1 (17%)
	Economy	1 (17%)
Information Technologies (IT) experience	Beginner	0 (0%)
	Advanced Beginner	1 (17%)
	Competent	5 (83%)
	Expert	0 (0%)

One of the first questions had the intention to understand the familiarity of the user with several visual techniques, and which of them are used more often (see Figure 3.2).

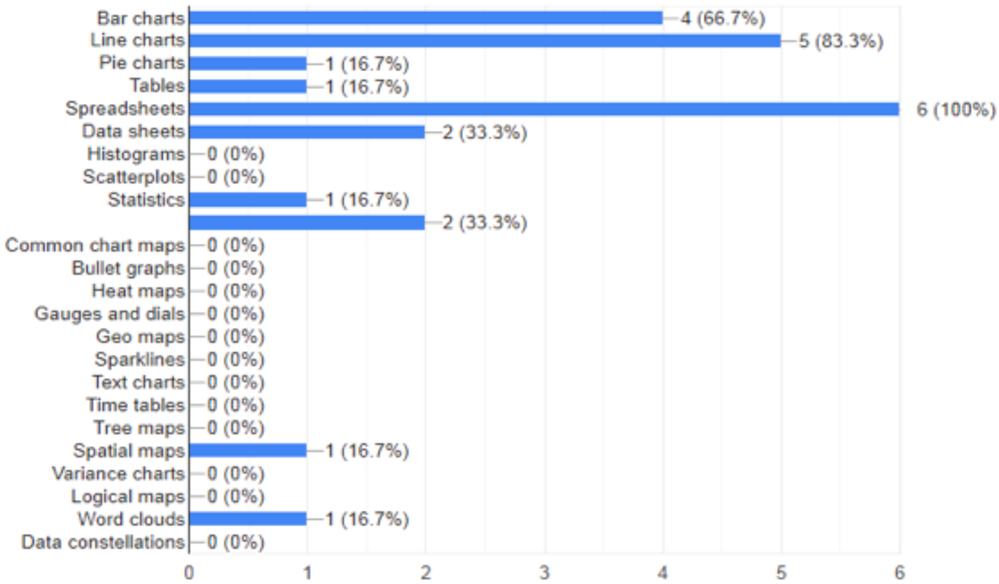


Figure 3.2: Visual techniques used more often

Interesting to notice that all enquiries use spreadsheets and most of them line charts, followed by bar charts. Also, data sheets, summary and reports are somewhat popular amongst the users. This means that the six users, on a daily basis, tend to rely on three main visual techniques.

When considering the most appealing KPIS to follow the progress in a project, there was no answer that collected the unanimity of responses, but three KPIS gathered 66,7% of responses, these being “Logged in Time in Main Project Categories”, “Ratio of Cost / Budget” and “Cost Performance Index”. With 50% of preference comes “Logged in Time in Specific Projects”, “Ratio of Completed / Estimated Tasks”, “Estimated Time per Task” and “Schedule Performance Index” (see Figure 3.3).

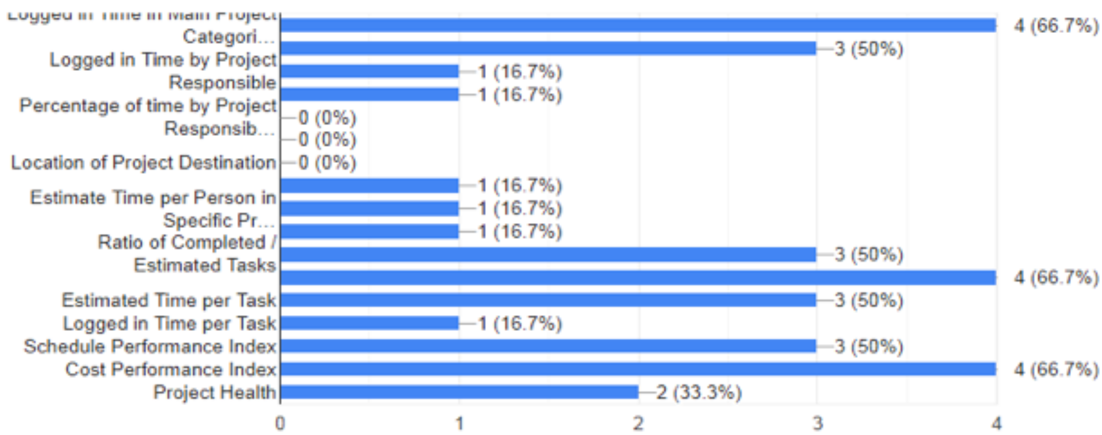


Figure 3.3: Most interesting KPIs

There is a main concern regarding the costs of a project rather than Time or Resources, with even no interest at all of having more information about a project location.

Three main fields of project monitoring were then tracked, with three separated questions focusing to ask users which visual techniques would be more appealing to track the “Time”, “Resources” and “Costs” of a Project.

When considering the “Time” tracking in a project, the answers were mainly focusing in three different type of charts: Line (50%), Bar and Pie charts (33% both), according to Figure 3.4.

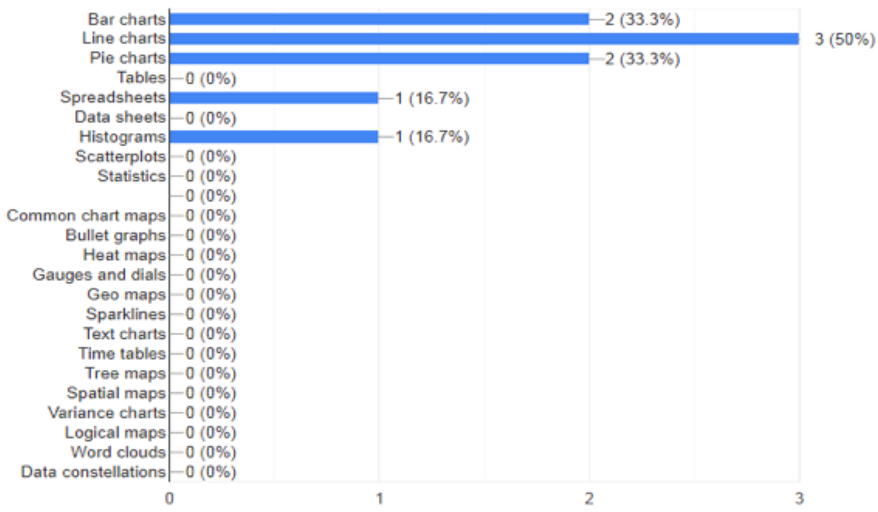


Figure 3.4: Visual techniques to track the time in a project

Regarding the tracking of the resources, the answers mainly focused in spreadsheets (83,3%), followed by Line and Pie charts (50% both), according to Figure 3.5.

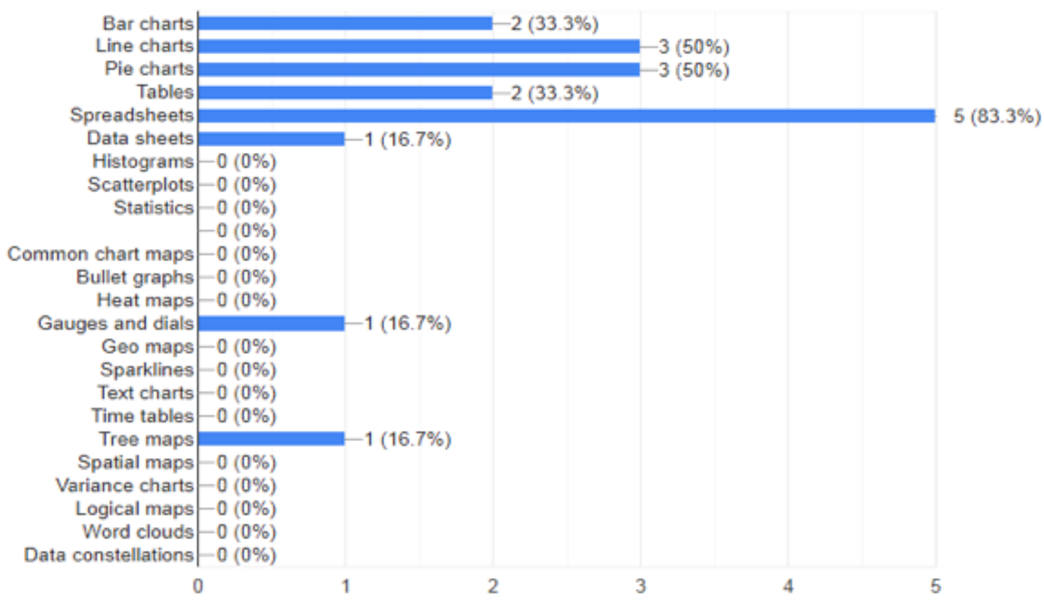


Figure 3.5: Visual techniques to track the resources of a project

Finally, regarding the costs of a project, the users were unanimous for a technique, with all of the six answers choosing Pie Charts as the best, followed by Bar charts (83,3%) and Line charts (50%), according to Figure 3.6.

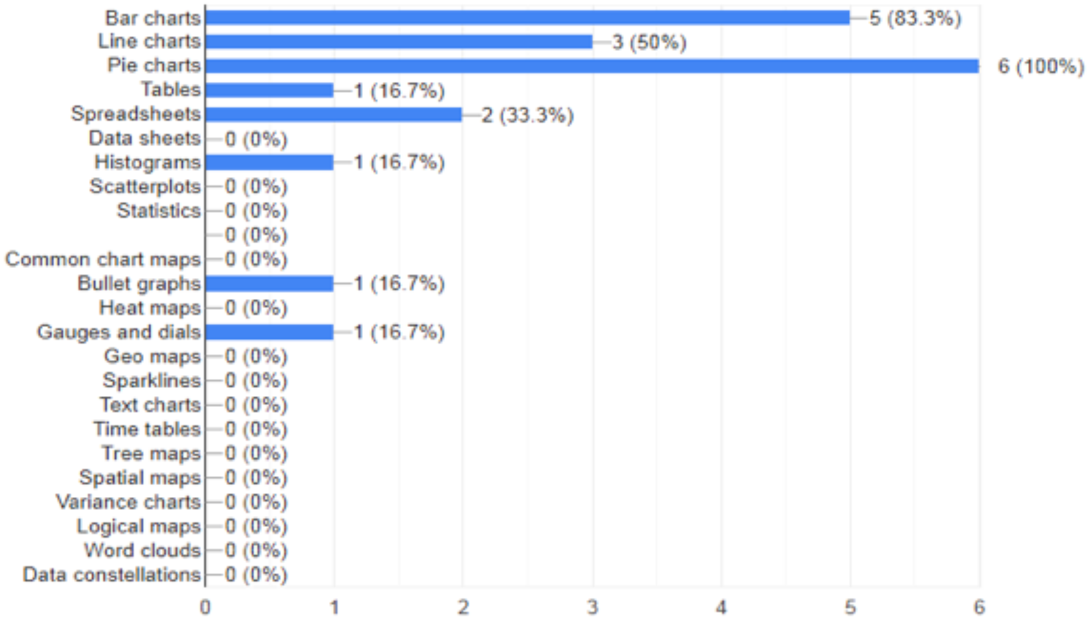


Figure 3.6: Visual techniques to track the costs of a project

After this first step of the enquiry, the questions were directed to a more specific theme, leading the enquired user to think about the visual aspect of a dashboard and evaluate specific examples of dashboards applying the data used by them. The first example asked the user to consider the main indicators featured in the dashboard, and for each of them, to enunciate which attributes were more important for a clearer understanding.

The answers varied for each indicator, but overall, it is possible to say that the user is more sensible to the color scheme and font choices, followed by the technique itself, more relevant for ratio interpretations and indexes. The results are displayed in Figure 3.7.

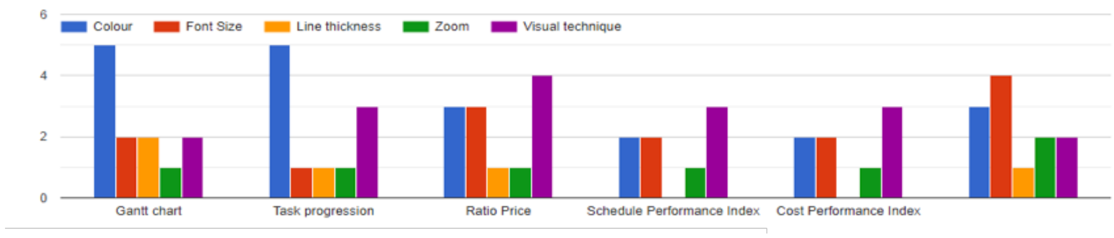


Figure 3.7: Results for the first dashboard, visual attributes more important

As a closing to the enquiry, it was shown an example of a dashboard with some of the asked KPIs and the visual techniques prior in the survey, but this time with the goal to capture the user's attention to the design and understand one more time what appeals to the enquired person in terms of sensibility to color scheme as well as variation of visual techniques. This was thought with two direct questions. The first so the user could locate the asked KPI in the dashboard and the second to the changes it would be necessary to each of the shown indicators.

The results for the last dashboard tended more towards the color scheme, font size or motion. Most of the attributes were satisfying to the user according to the amount of "no changes necessary" answers (see Figure 3.8).

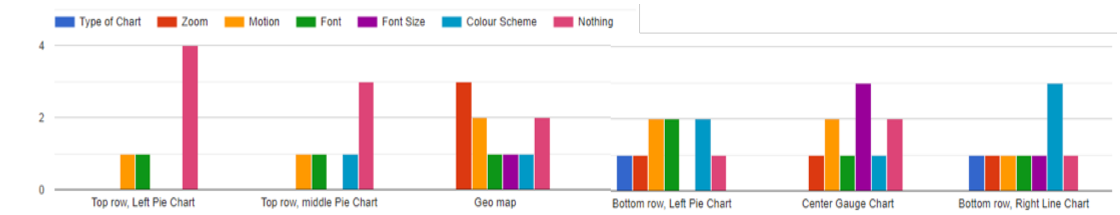


Figure 3.8: Results for the second dashboard, visual attributes to change

3.4. Selection of the Indicators

Considering the answers to the enquiry explained in the sub-section before and the results shown in Annex C, it was possible to select the more relevant indicators to be feature in the prototype and to be tested afterwards. These are:

IND1: Logged in time by every project responsible in main project categories. The projects are divided into four categories: "Customer Maintenance", "New business", "moisture sensors" and "consulting";

IND2: Logged in time by every project responsible in specific projects. In this indicator, every company which falls into a new or recurrent product, will have a new specific project opened and the time tracked;

IND3: Cost performance index. The measure of completed work for every unit of cost spent;

IND4: Schedule performance index. The measure of how close the project is to being completed when compared to the schedule;

IND5: Ratio of Completed tasks with the number of total estimated tasks;

IND6: Project health. An indicator that shows the present status of the project.

3.5. Selection of the Visual Techniques

In the previous section, six indicators were chosen and will be part of the dashboard. The next step is to analyze each one of them and select the most suitable visual technique to compose the dashboard to be tested in the prototype phase.

IND1: Logged in time by every project responsible in main project categories.

As stated prior, this indicator is the one that will lead as it will focus the logged in time in the four main categories "Customer Maintenance", "New Business", "Moisture Sensor" and "Consulting". It is a time tracking indicator, and considering the preferences of the users, the best technique to display that is through a chart.

One of the goals of this indicator is that, after being accessed, to be able to disclose more details on each of the projects. The amount of time logged through a timeline is interesting to analyze, considering that for each category, the lines and colors will make them distinct. The suggested chart for this indicator is a line chart.

IND2: Logged in time by every project responsible in specific projects.

The goal of this indicator is to provide more information when compared to IND1. For this one, each project (usually attributed to a customer), will be more detailed. The focus here is to have a percentage of time for each project that will be connected with IND1. For that reason, the most suitable chart is a pie chart, considering is also a time tracking indicator and is included in the user's preferences.

IND3: Cost performance index. The measure of completed work for every unit of cost spent

For this indicator, it is important to know the connection between the ratio between the completed work and every unit of cost spent. It is a measure of cost, and according to Figure 3.8, six out of six users chose pie charts as the best visual tool for this. Due to the fact that this is an index that varies from 0 to 1, it doesn't make sense to use a chart but instead a visual technique that is appealing and strong to the eye. For that reason, a Gauge display suits best.

IND4: Schedule performance index. The measure of how close the project is to being completed when compared to the schedule

Similar to IND3, this index also is the ratio between time to completion of the project when compared to the scheduled time. Due to the fact that it varies from 0 to 1, it should have a visual tool that is simple and appealing, so a Gauge display is also a suggestion for this indicator.

IND5: Ratio of Completed tasks with the number of total estimated tasks

This indicator is related to IND4, but in this case, is focused in the number of tasks that were set for each project, and by the time of analysis, should be measurable when compared to the total amount of tasks. A suitable technique for this indicator is the bar chart, as, for each project, different color bars, alongside with the percentage of completion makes it clear to track the project progress.

IND6: Project health.

This indicator is, perhaps, the most important of all six, as it works as an analysis summary. It is highly dependable on IND2, IND3 and IND4, and will establish a relationship between them in order to deliver to the user the information about the overall status of the enhanced project. It should show as text, highlighted with simple color code, green, yellow or red, representing the urgency of attention to the selected project.

3.6. Dashboard Construction

All the focus users work in an office environment with a fixed workstation and screen of approximately 21 inches. This means that in general, this is the physical space where the information may be displayed, and thus identifies the visual area that can be exploited by the dashboard to map the results.

Another relevant aspect is how should be the information organized visually. Which indicators to highlight and interactions between them. The size and color scheme are also important, as clearly stated by the users' preferences.

Table 3.2 shows the main techniques to be developed between indicators.

Table 3.2: Relationship between indicators' framing, highlight and links

Indicator	Theme	Framing	Highlight	Linking
IND1	Logged in time for main categories	Project responsible	Project category	IND2; IND5
IND2	Specific projects	Project responsible; project category	Project category	IND1; IND5
IND3	Cost performance index	Project name	Task name	IND4; IND6
IND4	Schedule performance index	Project name	Task name	IND3; IND6
IND5	Ratio of tasks	Project responsible; Project	Task name; Project responsible;	IND1; IND2

		Category; Project name	Project category	
IND6	Project health	Project responsible; Project Category; Project Name; Task name	Task name	IND3; IND4

3.7. Conclusion

This chapter focused on the design of the conceptual model for the dashboard as well as the first contact with the focus group to identify their requirements and perceive their current interaction with visual techniques to map the KPIs. Besides this, it also aimed to identify if these techniques should be considered in the dashboard or others ones are more suitable.

It was also possible to establish a workflow between the initial phase of enquiry and the process of choosing the indicators and visual techniques, as it is not always possible to follow exactly the user's preferences but giving focus to the most effective technique instead.

Six indicators were chosen and adjacent visual techniques (that are illustrated in Table 3.3), and the next chapter will describe the phases of prototype implementation, based on the defined conceptual model. Those phases are the dashboard construction and the usability evaluation.

Table 3.3: Indicators' summary and visual techniques

Indicator Code Number	Description	Visual Technique
IND1	Logged in time by every project responsible in main project categories	Line Chart
IND2	Logged in time by every project responsible in specific projects	Pie Chart
IND3	Cost performance index	Gauge display
IND4	Schedule performance index	Gauge display
IND5	Ratio of completed tasks and the number of total estimated tasks	Bar chart
IND6	Project health	Text

4. Prototype

The development of the dashboard comprises the considerations mentioned in prior chapters and the tasks of development of a prototype should respect some directives of good design.

It is important to perform the dimensioning with reliable metrics according to the user requirements and the distinct scenarios.[25]

The following sub-sections will show how this process developed, presenting the data source and the means to transform this into an operational prototype and respective evaluation.

4.1. Case Study

The company in which this study is focused is called Staga Sweden AB, a Linköpings-based company, in southern Sweden, that develops technical products based on paper, nonwoven and plastic. The company is part of a small group named Staga Group, consisting in Staga Sweden (Mother Company) and daughter companies Nordic Barrier Coating AB (NBC), Nordic Textile Converting AB (NTC) and Tabey AB. The entire group has a similar vision and work focus, as said prior, within the Nonwoven and technical paper industry.

Important clients are set in the automotive industry, graphic paper, medical and construction. A key segment for the company is the waterproofing system that is applied into the wet rooms, mostly in wood construction.

Staga's wet room items are produced to meet the latest industry regulations BBV 10: 1[53] and can thus be part of a certified wet room system. The produced system is made of foil type and is set up as a wallpaper on floors and walls of wood-based construction structures.

The existent items in the system are:

- Well Cuffs
- Fiber strip

• Adhesive tape
• Internal corner
• Pipe collars
• Wet rooms foil
• Wet rooms strip
• External corner

It is also within the company's business concept to be able to measure the moisture in which the products are used. Apart from this main sector, other components of the business include the trading and unwinding of technical paper, extrusion, lamination and plastic-based rolls for several end-uses as well as general development within the industry in the means of consulting work for other companies.

The typical cooperation synergy between departments when it comes to a new project, has some directives to follow, not in a strict policy, but an overall agreed strategy of work. This is valid for the present times, and because it is a company that is relatively new to the market (10 years), it's constantly growing in means and people, and one of the current challenges is the organic grow of the company and match it to the IT tools and organizational framework.

Figure 4.1 illustrates a typical cooperation map, when focused on the Research and Development department (R&D) and how it connects to the Production Department and Economy.

Another relevant point to raise is the fact that this company, as a group, is formed by approximately forty people. Twenty two people works now in the Mother Company and when considering the concepts of "Departments", this is taken into account that it is a growing company, in which, for example, for the R&D department, the main key actors are just two people, with four extra current collaborators.

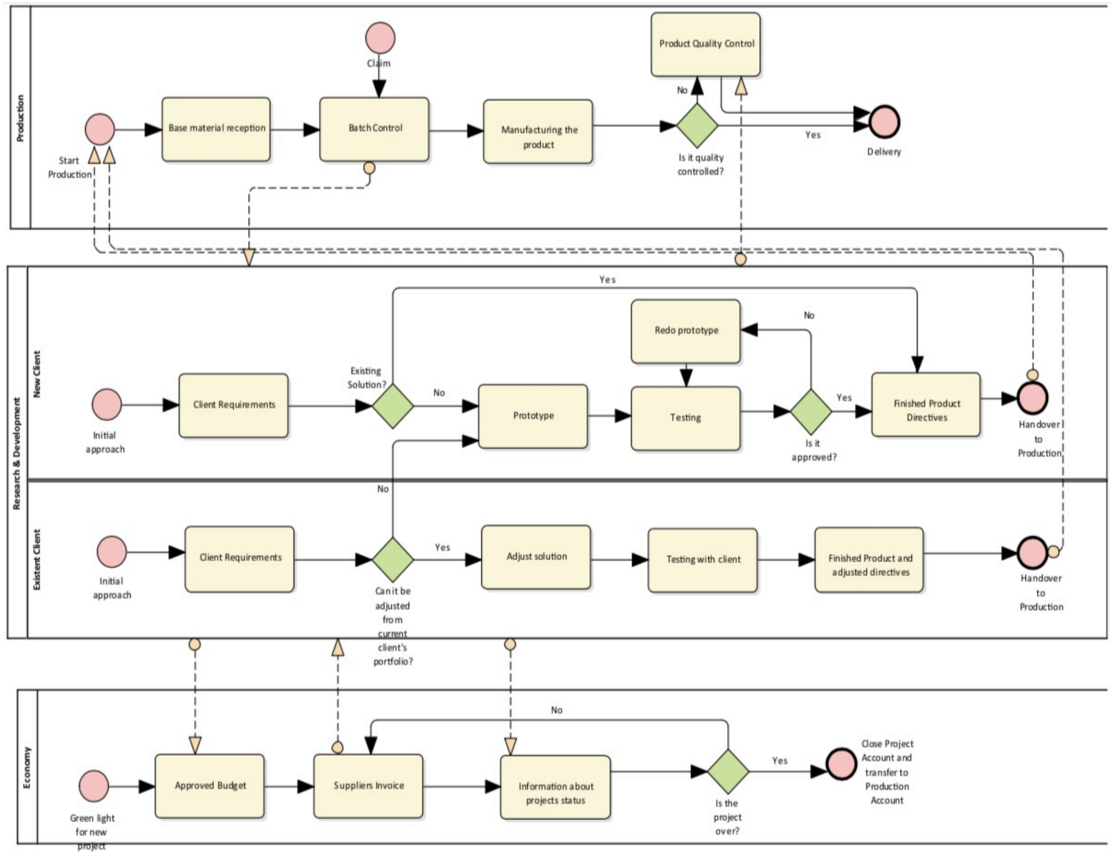


Figure 4.1: Collaboration map between the three main departments regarding a R&D Project

4.2. Data Gathering

The data used for this work was gathered from a Project Management online tool called "Teamwork Projects"[1], in which each Project collaborator can access when it's given permission and control each project.

All the companies within the Staga Group are present in this project management tool as well as the main customers. Once the user logs in, it is possible to get a full picture of the current active projects and from this point on can access the main tasks and deadlines for any of them (see Figure 4.2).

[1] www.teamwork.com

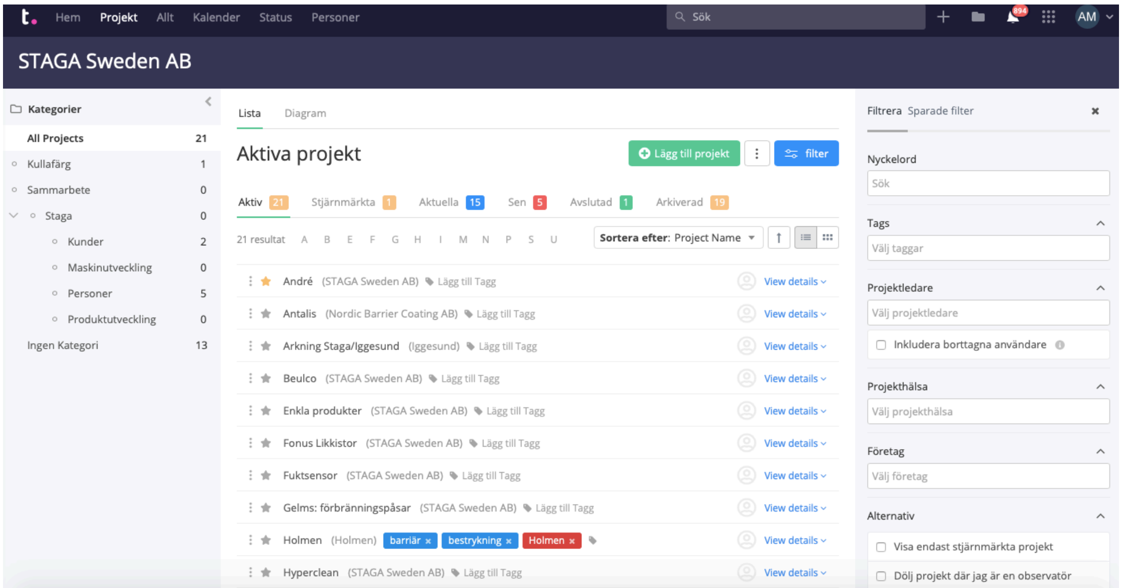


Figure 4.2: Teamworks Project layout

Each project has attached several tasks to it. These tasks are added when a new project is originated and the estimated time of completion for each task is also added at this point. With this action it is possible to generate a Gantt chart, also available by Teamworks.

The project collaborator (customer or employee) can add a task, log in time, cost or see the real-time status. This is a company policy to increase transparency between the customer and supplier, as it can be seen how each task is going until the project is completed and if it's necessary to perform changes.

Although there are many possibilities, Teamworks is mainly used for tracking the main collaborators project performance focusing on time / task ratio. It is possible to check the main characteristics of a collaborator for a specific period (see Figure 4.3).

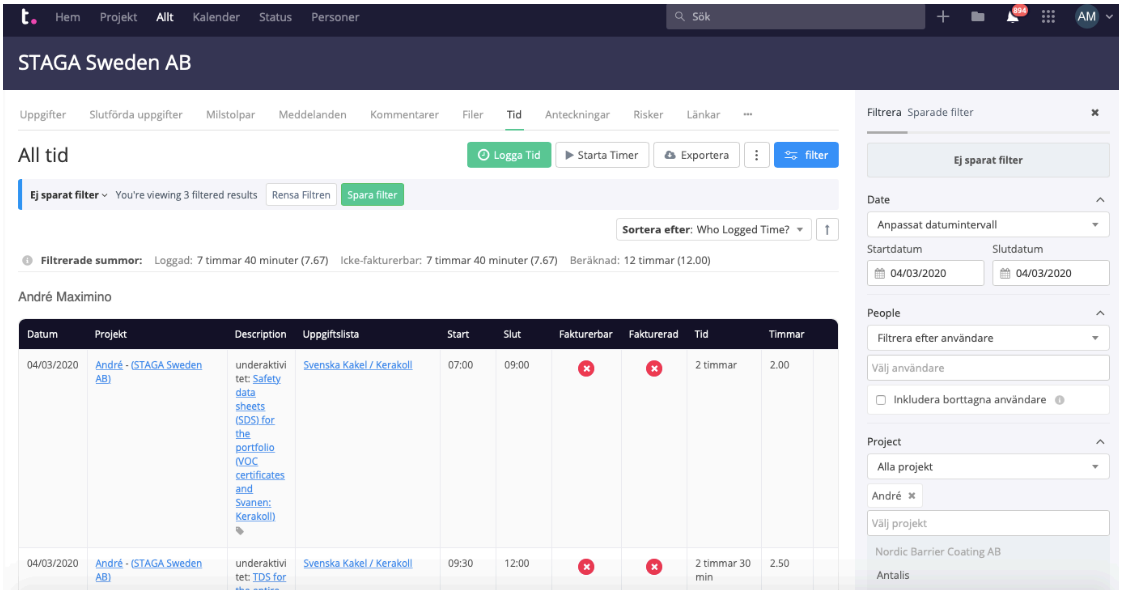


Figure 4.3: Teamwork's specific time, tasks description

From this stage it's possible to extract and export the main project's characteristics to an excel file, which generates the raw data.

To transform and process the raw data, it was used Power BI Desktop[2] which was a clear software to manage all the categories and with the advantage of allowing a student license to use, for the purpose of this work.[63][64]

The following process flow (Figure 4.4) illustrates the chain until the elaboration of the dashboard[3]:

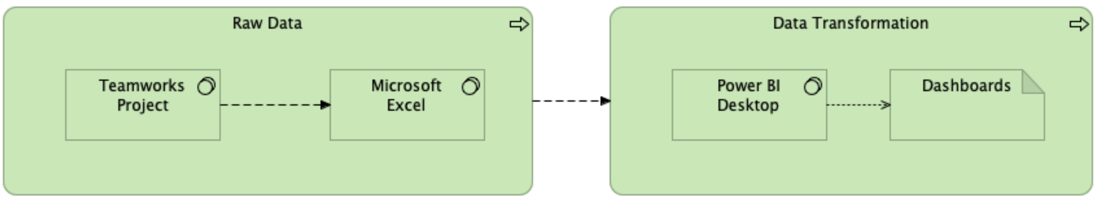


Figure 4.4: Data Process Flow

[2] https://powerbi.microsoft.com/sv-se/ (visit in March 21st, 2020)
[3] https://www.archimatetool.com (visit in March 21st, 2020)

4.3. Middle calculations for the KPIs

In order to represent the KPIs in the dashboard, some middle calculations will be necessary to be performed, as the raw data doesn't give this information directly. For that reason, the next sub-sections will identify the formulas to be considered.

4.3.1. Cost Performance Index

According to Roseke [65], the cost performance index (CPI), can be defined as Equation 1.

$$\text{Cost Performance Index} = \frac{\text{Earned Value}}{\text{Actual Cost}}$$

Equation 1: Cost Performance Index Calculation

It is important to mention that this indicator is possible to calculate considering the project as a sum of tasks, with each task being assigned both start and finish dates and budget. The Earned Value can be calculated by multiplying the percentage of completion of task and the task budget. On the other hand, the Actual Cost is calculated by the amount spent on the task.

If CPI is less than 1, the task is over budget.
If CPI is 1, the task in on budget.
If CPI is greater than 1, the task is under budget.

Considering the information above, the necessary data to perform the calculation is illustrated in Figure 4.5.

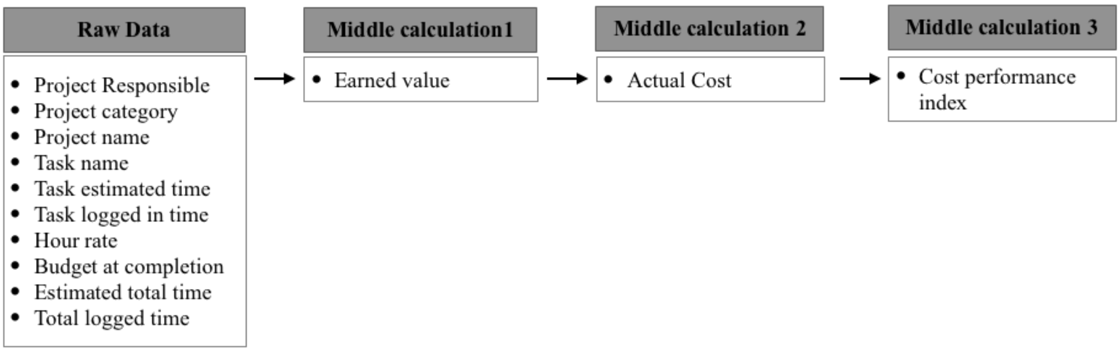


Figure 4.5: Phases and necessary data to calculate the CPI

4.3.2. Schedule Performance Index

The schedule performance index can be defined as [66] illustrated in Equation 2.

$$\text{Schedule Performance Index} = \frac{\text{Earned Value}}{\text{Planned Value}}$$

Equation 2: Schedule Performance Index Calculation

To interpret the values:
If SPI is less than 1, the task is behind schedule
If SPI is 1, the task in on schedule.
If SPI is greater than 1, the task is ahead of schedule.

Similarly to the cost performance index, this is also a ration between values, but in this case we have to consider the planned value, that can be calculated by the multiplication of the percentage of completed planned of the task by the task budget.

The necessary data to perform the calculation of this index is illustrated in Figure 4.6.

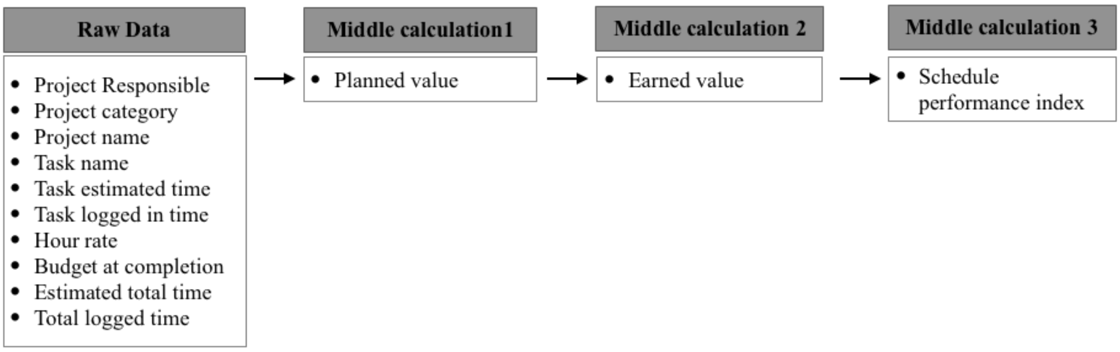


Figure 4.6: Phases and necessary data to calculate the SPI

4.3.3. Ratio of completed tasks with total estimated tasks

The calculation of the ratio between the completed tasks and the total number of estimated tasks is a direct division between these two numbers. The necessary data to perform that calculation is displayed in Figure 4.7.

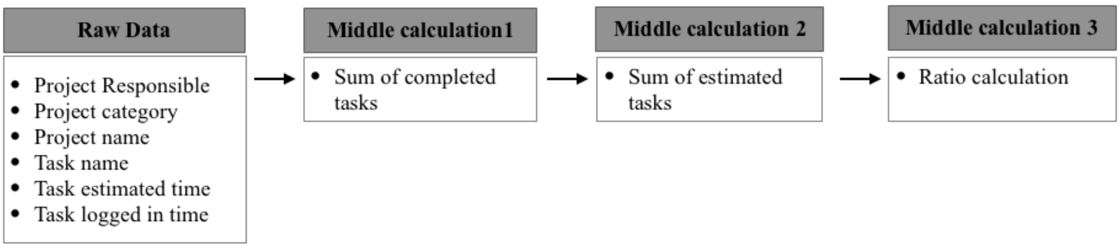


Figure 4.7: Phases and necessary data to calculate the ratio between completed and estimated tasks.

4.3.4. Project Health

As stated prior, the output of the project health is a text with a featured color that will express the general status of the project. This is highly dependable on two other indicators and the result will return the text and color schemes according to Table 4.1. It is important to mention the fact then, when the task is 100% done, the status will be displayed as “Complete”.

Table 4.1: Output of Project Health indicator

CPI	Text	Color
<1	Over budget	Red
>0.5 and <1	Over budget	Yellow
=1	On budget	Green
>1	Under budget	Green
SPI	**Text**	**Color**
<1	Behind schedule	Red
>0.5 and <1	Behind schedule	Yellow
=1	On schedule	Green
=1	Complete	Green
>1	Ahead of schedule	Green

4.4. Prototype implementation and KPIs mapping

During the stage of drawing the main goal is to transfer to a concrete visual tool, what was suggested from the enquiry results. With the indicators being chosen to be interpreted visually, the main concerns are the correct proportion of detail, as too much information (or too little) can lead to a bad result, as well as bad coding.[62]

In a first step, it was necessary to test the visual proposals of the model for the several indicators and possible interactions.[67] For that reason, the most effective way is through a low fidelity prototype, in paper, where the ideas can turn rapidly into something visual and immediately can be detected imperfections in the logic and corrected instantly. Figure 4.8 illustrates the results for that process (remaining images can be seen in Annex D).

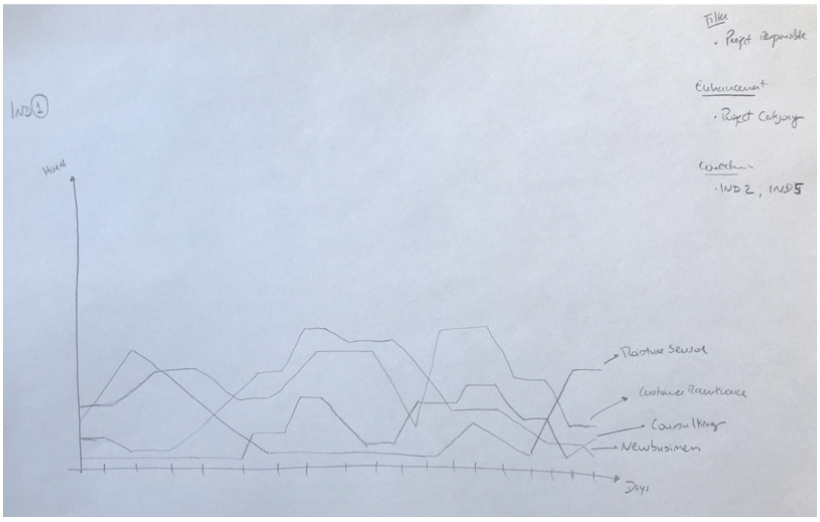


Figure 4.8: Low fidelity prototype for the indicator IND1

Every indicator was developed separately in Microsoft Power BI Desktop and after that, the entire dashboard was created, introducing all the indicators and evaluating the best position and dimensions for each.

For the first indicator, IND1, the main idea was to include the information that the users stated in the enquiry being the most relevant, so in a line chart and for a timeline, all the main categories of projects were included, as well as the time logged in for each of it, for all the users, according to Figure 4.9.

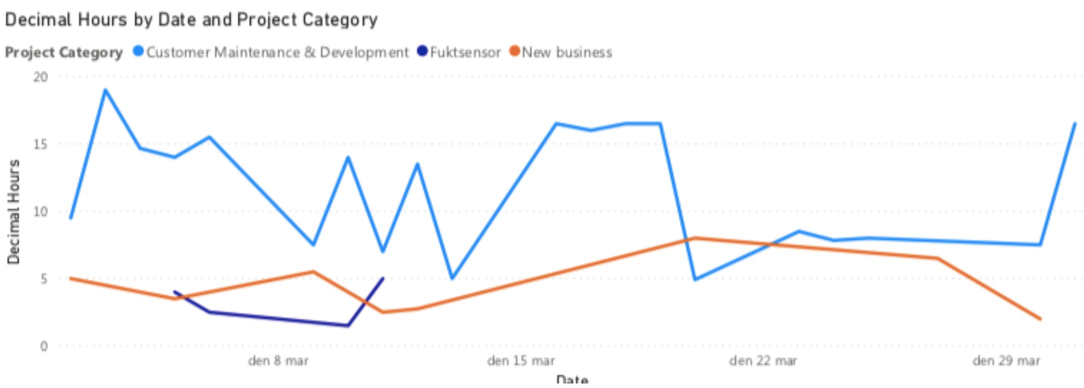


Figure 4.9: Functional prototype for IND1

One of the requirements was the ability to filter the information by responsible, project and project category, so with this function, the user can see the adjusted information. This is illustrated in Figure 4.10.

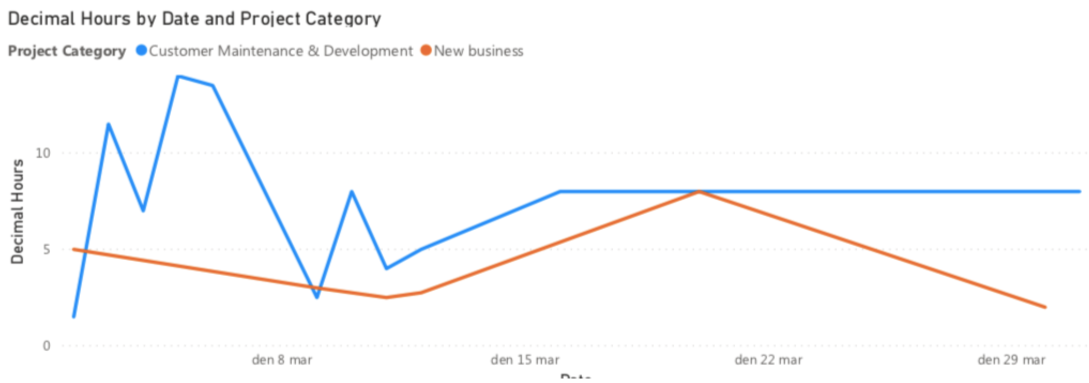


Figure 4.10: Project Category by user for IND1

The second indicator, as stated prior on this document, gathers the logged in time for the specific projects, and according to the enquiry results, the best visual tool should be a pie chart. Figure 4.11 illustrates the result of the indicator.

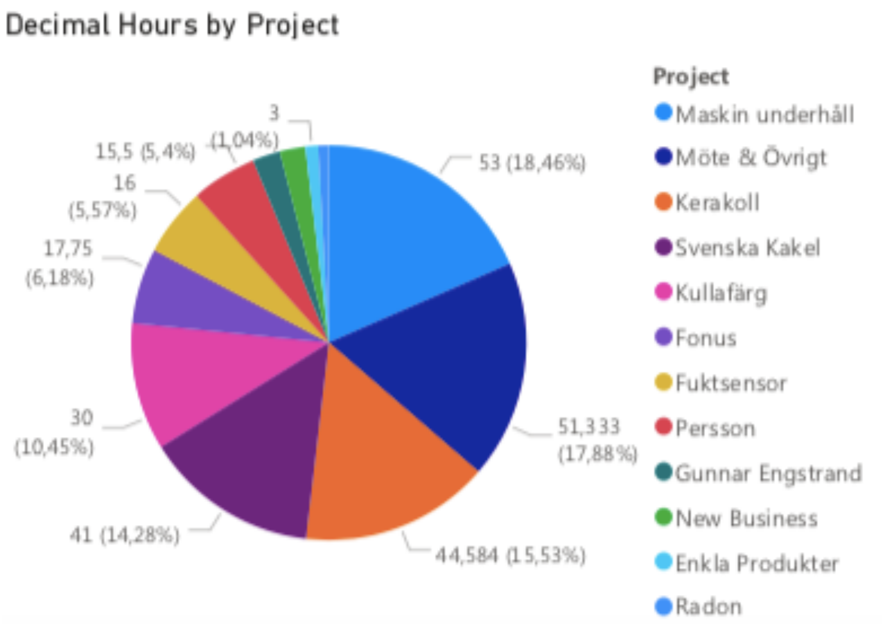


Figure 4.11: Functional prototype for IND2

Similarly to indicator IND1, this also has the ability of being filtered by project responsible, Project and Project Category, with the results adjusted if the user chooses to see a specific project responsible, for example, as illustrated in Figure 4.12.

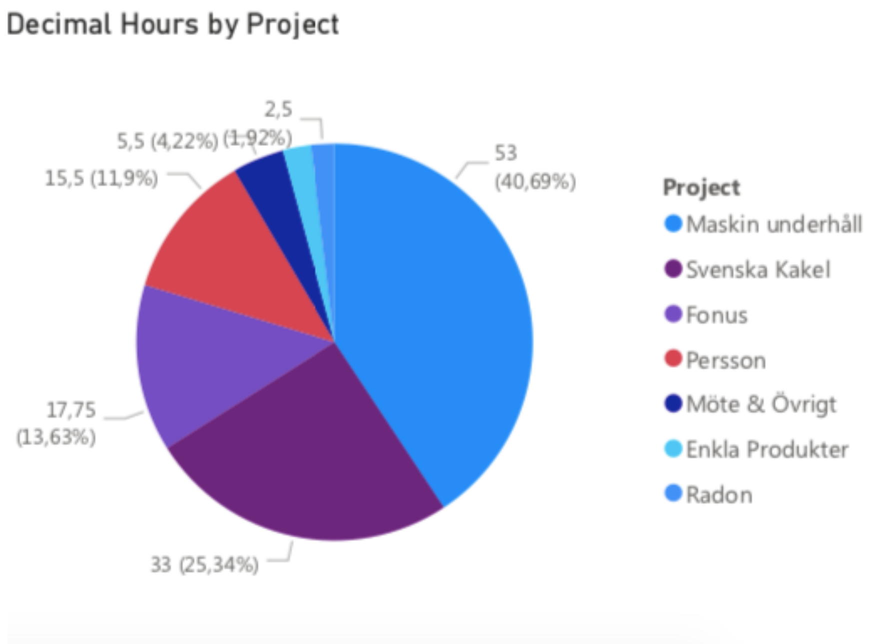


Figure 4.12: Filtered projects by user for IND2

Indicators 3 (IND3) and 4 (IND4) are somehow related to each other, so it would make sense to develop them side by side and locate them close by within the dashboard.

The gauge displays represent the indexes for the CPI and SPI when the user presses a specific task, project or project category, with this indicator adjusting the value automatically and showing the max value for the chosen category as a comparison element. Figure 4.13 illustrates this information.

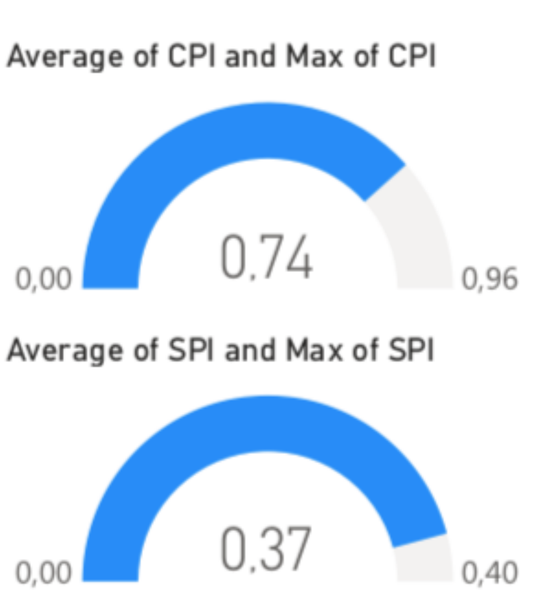


Figure 4.13: Functional prototype for IND3 and IND4

Indicator 5 (IND5), as stated prior, represents the percentage of completed tasks in a bar chart for a clear vision of the information and with the possibility of scrolling the graph if the information becomes too extent (see Figure 4.14).

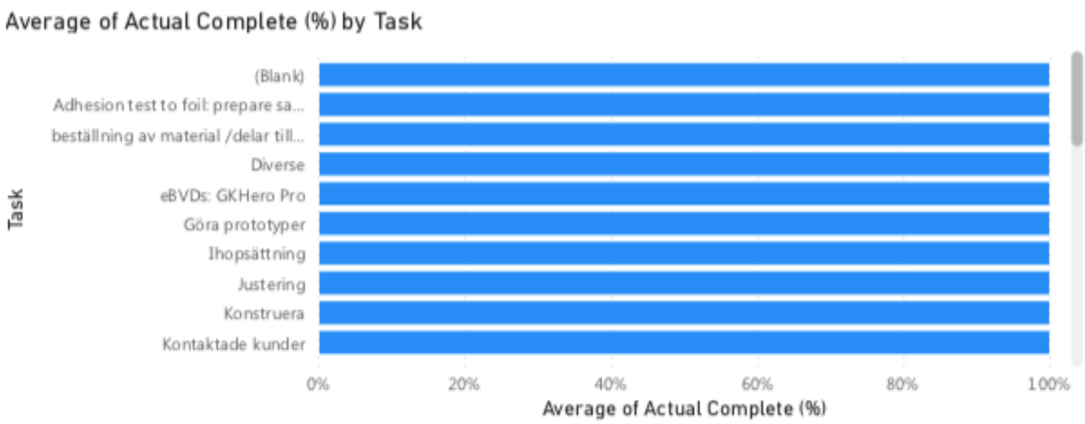


Figure 4.14: Functional prototype for IND5

For this indicator, there is also the possibility of filtering the information by project responsible, project and project category (see Figure 4.15).

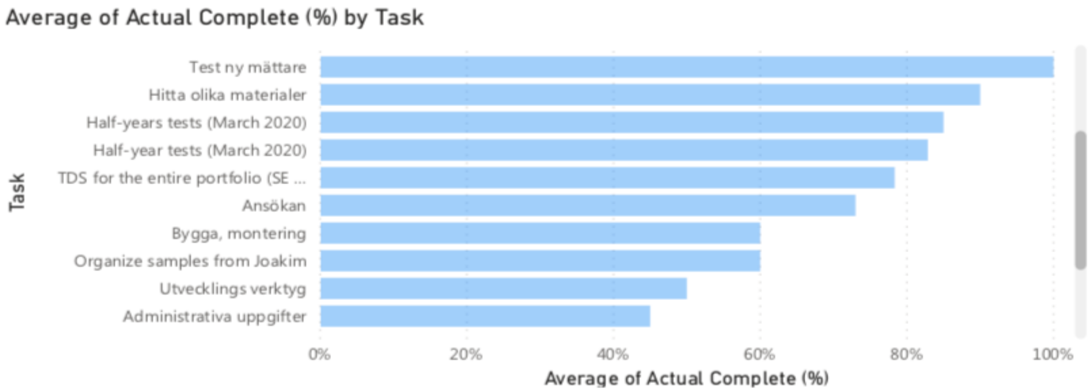


Figure 4.15: Specific project tasks by user for IND5

Lastly, indicator 6 (IND6) is the simplest one visually, but the one that required more adjustments during the development of the prototype.

The first idea was to generate a single text bar with the result of the analysis in one sentence, comprising information for both budget and schedule, followed by a colored background, ranging from red to green.

The main challenge was the effectiveness of this idea, as it was more difficult to generate a productive coding cycle in Excel to generate the correct text and visually, it was limited, because most of the results were a yellow background, due to one of the indexes not matching.

For that reason, the bar text was divided in two. One analyzing the cost performance index (on the left) and one analyzing the schedule performance index (on the right) with independent color schemes, although following the same strategy as the initial idea.

The result is a better visual output, as the message is simple to decipher and the juxtaposed colors are not aggressive to the eye. Figure 4.16 illustrates one example when the indexes don´t have the same result.

Figure 4.16: Functional prototype for IND6

4.5. Dashboard final presentation

Based on the results of the low fidelity prototype, the placement of the indicators should save the largest area for the most important information. For that reason, the dashboard was divided in two halves, with a larger area dominant by the most important indicator.

On the top half, it was clear that IND1 needed more area, as for a timeline chart, it´s necessary to have a clear perception of the four distinct categories and the logged hours, as well as enough space to understand trends. The remaining area was saved for the two indexes, CPI and SPI, on the right side, as they are important to analyze, but more important is the visual output of IND6.

The bottom half comprises the most important and decisive indicators, with a significant area being reserved for the more appealing pie chart and the display of the specific projects, on the right side. The left side was saved for the percentage of complete tasks. This indicator could have less area, but to maintain a good proportion and not exceed area to the top half of the dashboard, it was decided to maintain a good proportion and extended the text bar of IND6 and have highlighted texts.

In Figure 4.17, it is possible to see the placement and approximate dimensions of every indicator.

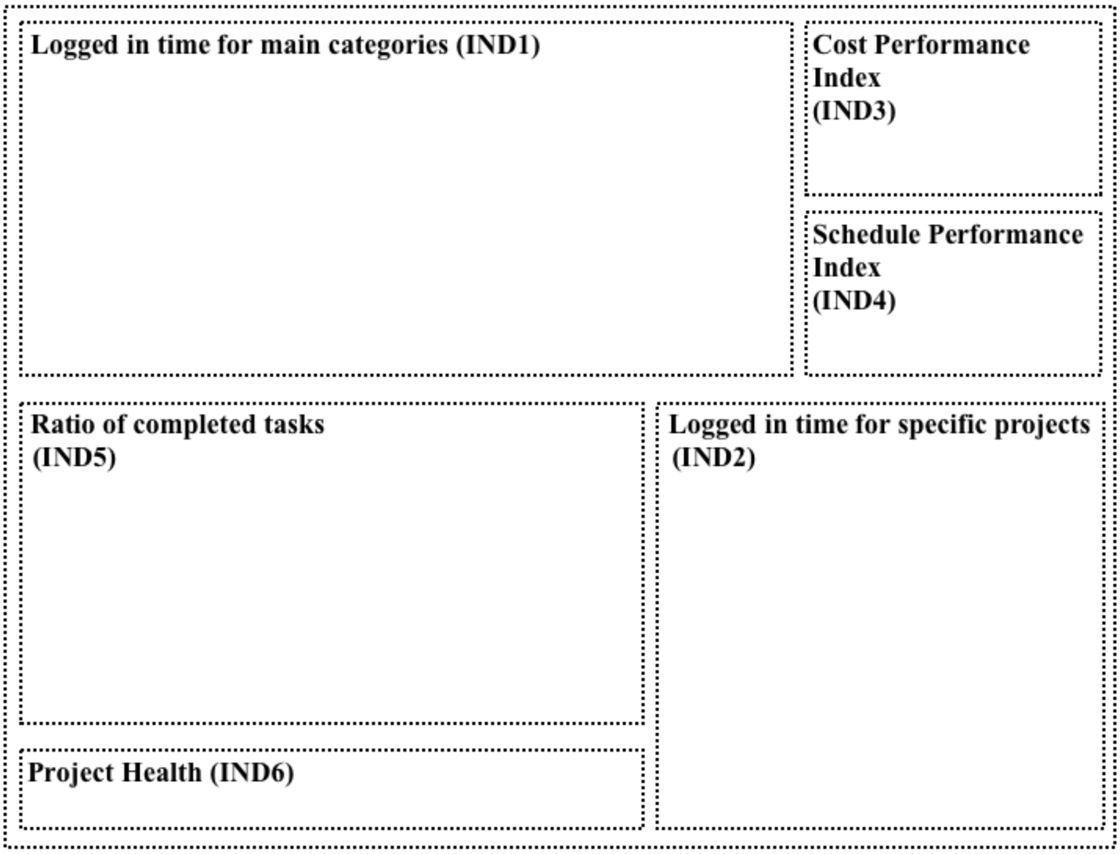


Figure 4.17: Indicators location in the dashboard

Considering the interactions between the indicators, some filters were created in order to adjust the information on the entire panel. The filter bar is located on the right side of the dashboard and easily accessible.

The most important filters to consider in this case are mainly the Project Responsible, as the information can become a bit too complex when more responsibles are added to the projects, especially on indicator IND1.

As said prior, when the information becomes too extent in IND5, it is available a scroll bar.

In terms of color schemes, it was important to maintain a neutral color throughout the dashboard, in order to highlight the IND6 and also the diversity of colors in IND2. Figure 4.18 illustrates the functional prototype after the placement of the indicators and filters.

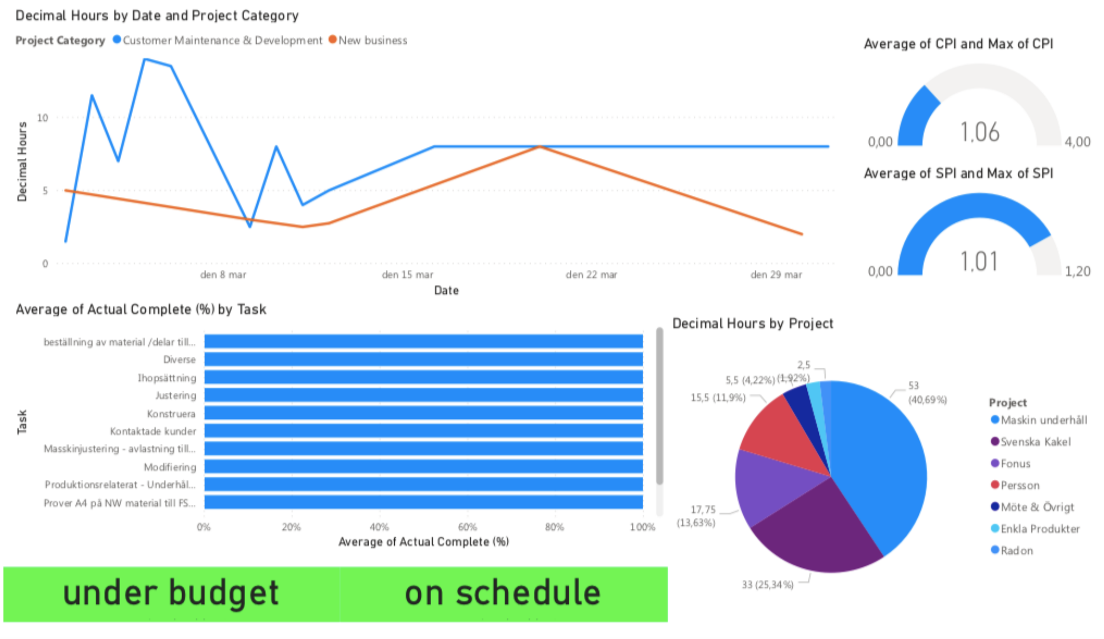


Figure 4.18: Functional prototype used during the test sessions

4.6. Conclusion

In this chapter it was possible to interpret the indicators generated in the concept model and, connecting that information with the results and preferences from the enquires, to suggest a visual prototype based in the case study company.

This was possible with the execution of a low-fidelity prototype and after this, to generate the middle calculations and visual techniques more suitable to fit in the indicators.

In the next chapter, the further steps of the dashboard evaluation will be described, as well as the results of the tests.

5. Evaluation

This chapter describes the stage of testing and evaluation of the prototype that was developed throughout the process. The focus group will be the same that answered the enquiry for the visual techniques.

According to the distinct test scenarios that will be elaborated in this chapter, the users will be exposed to a series of questions and tasks requirements within the dashboard and the results will be noted and interpreted further.[68]

This will be possible by stating four different stages of evaluation: definition of evaluation methods, planning the tests, usability tests and analysis of the results.

In order to be able to evaluate the usability and functionality of the dashboard developed in this document, it was decided to use tests with several distinct scenarios, observations (both quantitative and qualitative) as well as an enquiry of usability evaluation System Usability Scale (SUS).[62] These documents are illustrated in Annexes E and F.

The goal of these tests is to evaluate the capacity of learning of the participant, the time that the user spends when interacting with the dashboard as well as the efficiency of the tasks, the errors when fulfilling the tasks and comfort of usability, the interaction between the users and the visual techniques and if these interfere in the decision-making process and finally to identify specific problems regarding usability and design.

All these factors will be described in the following sub-chapters.

5.1. Definition of Scenarios

According to Nielsen, when evaluating usability, there is no need to have more than five users to obtain the best results [69]. This is not general though, as for every human factors issue, it can depend on the end goal, and when one wants to aim for statistics results, then it is optimal to rely on more users for the tests.[70]

For this case in particular, the tests were performed with six users, divided into four different scenarios. Table 3.1 in chapter 3 resumes the characteristics of the professionals involved in this study.

The test scenarios were elaborated, considering that all the questions covered the main indicators and the different points of view in order to make a decision regarding a determined project.

The evaluations must be done considering the most important indicators for usability, those being efficiency and satisfaction.[71][72]

Table 5.1 resumes the four different scenarios and the tasks to be performed under the test sessions.

Table 5.1: Scenarios to be considered during test sessions

Scenario 1 (S1) – Identify the several project categories focused during the analysis period
Can you identify the number of categories logged in by the team?
Which categories did Responsible 1 focus time in?
Which day has more logged in hours by Responsible 2?
For that day, which category has more hours?
Scenario 2 (S2) – It is important to know which projects were involved during the period of analysis
Can you identify which projects are under the category “Customer Maintenance”?
Which projects were focused by Responsible 2?
Scenario 3 (S3) – Within each project, before making any decision, it’s crucial to understand tasks were completed, undergoing and what is the status concerning time and cost.
Under project “X”, can you identify which tasks are completed?
For the same project, what is the Project Health status for 3 tasks that are undergoing?
Can you identify the CPI and SPI for each of those tasks?

Scenario 4 (S4) – The understanding of the Project Health indicator determines the ability of making a decision regarding a specific project
Which projects are "over budget"?
Which projects are in worst condition regarding the costs? Identify the CPI for each of them.
Which projects are "behind schedule"?
Which projects are in worst condition regarding the schedule? Identify the SPI for each of them.

Regarding the approach of testing, the users have no previous contact with the high-definition prototype as it is expected this to be evaluated as a first approach and depending on the user's IT knowledge.

It was created a guide for helping the participant to understand what is expected from him.[73]

This guide includes an introduction, the inclusion of demographic information, the scenarios, a closed answer enquiry to evaluate the efficiency of the dashboard and a SUS enquiry. This is available in Annex F.

5.2. Test Sessions

The test sessions were performed under closed doors, with just the presence of the user. The tools for the tests were a desktop computer with Windows 10 installed and the dashboard was tested in Microsoft Power BI. It was asked the users to speak while exploring the dashboard, and that was captured via audio recording, according to Thinking Aloud method.[74]

Table 5.2 summarizes the general duration and main statistics for the sessions.

Table 5.2 Results and main statistics during test sessions

	Results (minutes)
Shortest Time	18:00
Longest Time	45:02
Average	26:53
Median	21:48
Standard Deviation	10:51
+1 Standard Deviation	37:44
-1 Standard Deviation	16:02

Visually, it is possible to see the distribution of the average times per user in Figure 5.1.

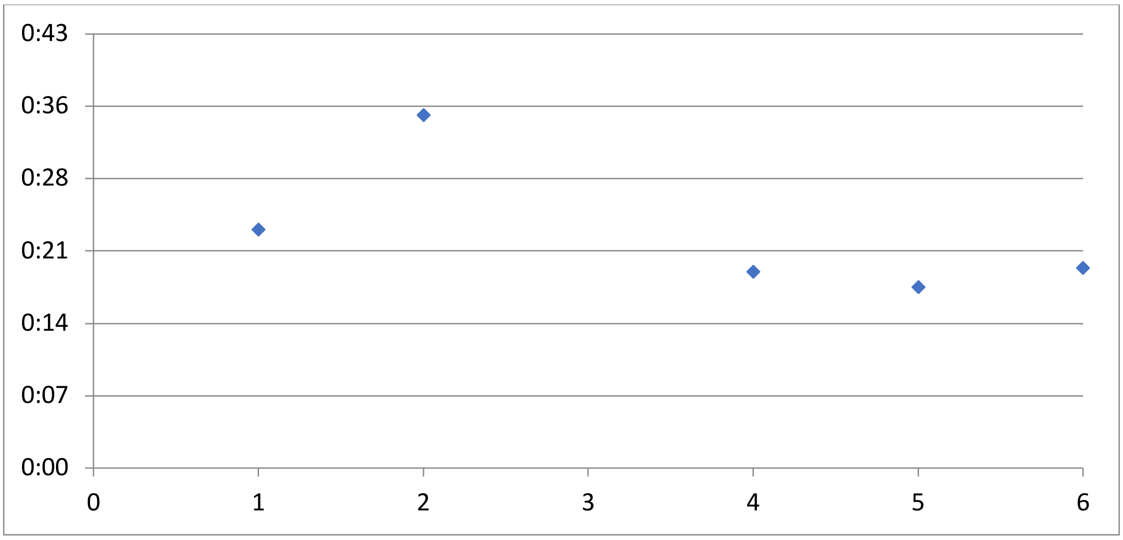


Figure 5.1: Distribution of average time per user

From Table 5.2 and Figure 5.1 it is possible to compare the six users, and all have results within the intervals of +1 SD and -1 SD. User 5 was the fastest and has the professional title of Production Planning responsible, which is used to KPIs daily, but was the user with least questions and feedback.

User 3 was the one that took more time to complete the scenarios, but on the other hand, was also the one that gave more feedback and pointed more fails in the system.

5.3. Quantitative and qualitative evaluation by observation

During the test sessions with the six users, these were followed by the evaluator whilst completing the scenarios and its tasks.[75] It was possible to take several notes during this process and elaborate the evaluation metrics, described in Table 5.3, and from these, two metrics were focused on IND2 (ME-1) and IND6 (ME-4). From the five metrics, three evaluate all indicators.

Table 5.3 Metrics of evaluation by observation and tools during testing

Metric of evaluation	Description	Tool of testing	Phase of testing
ME-1	Be able to identify the Projects in the dashboard (IND2)	Audio recording. Thinking aloud method.	While the user is completing each test scenario.
ME-2	Time of conclusion of a task (Efficiency when doing tasks)	Measured time whilst the user is completing the test scenario.	While the user is completing each test scenario.
ME-3	Time to act in a task (Efficiency when doing tasks)	Measured time whilst the user is completing the test scenario.	While the user is completing each test scenario.
ME-4	Identify Budget & Schedule Project Health (IND6)	Audio recording. Thinking aloud method.	While the user is completing each test scenario.
ME-5	Identify problems with interactions, visual techniques, design.	Audio recording. Thinking aloud method.	During the entire test session.

From metric ME-1, it was important to understand if the users could identify correctly all the projects that were displayed in the dashboard, and all six users were able to do that with considerable easiness.

The first scenario focus on IND1 and all users identified the logged in time graph, taking more time to identify the categories within it. The first contact with the filters was tested in task 2 from the first scenario, and all users took more time to think how to function with the filters, especially user 2, from the economy department.

Metric ME-4 was focused on IND6, project health, tested in scenario 4, and the highest difficulty was related with the relationship between the project status in IND6 and CPI and SPI indicators, and the filters to choose the different status of budget and schedule. User 2 was the one with the most difficulty to use the filters.

The summary of time per user in the four different scenarios, considering the time to act in a task (TAT) and the time for conclusion of a task (TCT) are displayed in Figure 5.2.

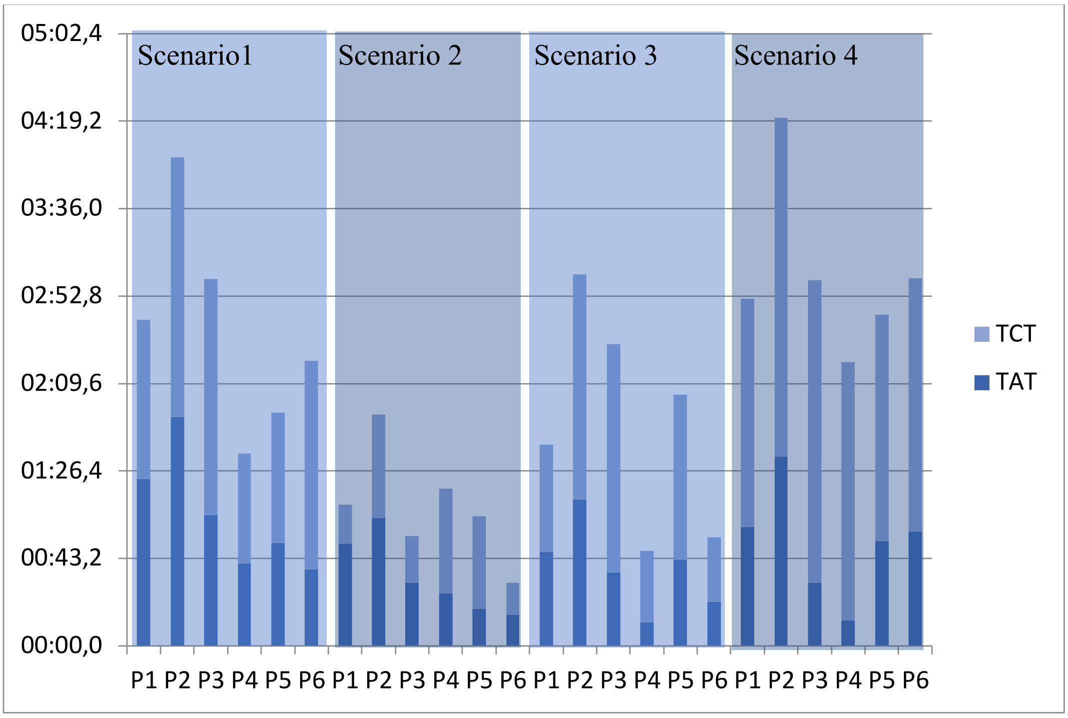


Figure 5.2: Duration of execution of a scenario per user (Px)

It was possible to see an increase of user familiarity with the dashboard as each participant acted faster, in average. This changed when the complexity of the task increased, especially in scenario 4. The summary of metrics ME-2 and ME-3 are displayed in Table 5.4.

Table 5.4 Results for metrics ME-2 and ME-3

	S1		S2		S3		S4	
	TAT	**TCT**	**TAT**	**TCT**	**TAT**	**TCT**	**TAT**	**TCT**
Shortest Time	00:38	00:54	00:15	00:16	00:12	00:32	00:13	01:52
Longest Time	01:53	02:08	01:03	00:52	01:12	01:53	01:33	02:47
Average	01:05	01:31	00:34	00:34	00:39	01:11	00:51	02:12
Median	00:58	01:31	00:29	00:34	00:40	01:07	00:54	02:06
Standard Deviation	00:29	00:30	00:19	00:17	00:21	00:36	00:27	00:22
+1 Standard Deviation	01:34	02:01	00:53	00:51	01:00	01:47	01:18	02:34
-1 Standard Deviation	00:36	01:01	00:15	00:18	00:17	00:35	00:23	01:51

Scenario 1was focused in indicator IND1 and it was the first approach of the user to the dashboard. That explains the higher average per user, as wasn't familiar with the visuals or the filters. The TAT has the highest average (1 minute and 5 seconds) for this scenario which explains that the user needs to spend more time thinking before acting. The second highest value for the TCT (1 minute and 31 seconds) also corroborates that fact.

Scenario 2 focused in indicator IND2 and all the users were faster to complete the two tasks, as possible to see in Figure 5.2. For this scenario, it was asked the user to apply two different filters to have the required information about IND2, and apart from user 2 who took the longest time, in general, all the users were faster.

Scenario 3 focused on the interpretation of indicators IND3, IND4 and IND5 and the interaction between these. After a simpler scenario, the goal was to increase the complexity of the tasks in the last two scenarios, asking the user to connect different indicators and using filters. User 4 was the fastest to complete the scenario (with TCT of just 32 seconds), but this is a user familiar with the cost and schedule indexes (plant manager), not having any difficulties to finish the tasks.

Although user 2 works in the economics department and most familiar with the indexes, it was the user with most difficulty exploring the dashboard for the most complex scenarios and didn't rely on the filters, taking more time to finish the tasks.

In Scenario 4 the users had most difficulties, mainly being able to correlate the indexes with the status and applying the correct filters. Almost 100% of the users had filters activated that they forgot to reset in order to proceed in the test, making them to doubt the answer and spending more time correcting the filters that were asked.

That fact allied to the higher number of tasks to be performed with larger amount of information to be extracted, contributed for higher averages of TAT (51 seconds) and TCT (2 minutes and 12 seconds).

IND3 and IND4 had most problems, with 5 out of 6 users not using them as expected, mainly being confused by the correlation of the average value and the max value. The titles being too small and the filters too discrete were also other problems raised by the participants.

The metric of evaluation ME-5 has the goal to identify all the problems regarding the usage of the dashboard when it comes to design, filters, color scheme, visual techniques, amongst others. Table 5.5 summarizes the main problems identified by the users and the evaluator.

Table 5.5 List of problems in evaluation metric ME-5

Identified Problem	Description
ME-5-01	Is not possible to reset filters.
ME-5-02	Filter boxes are too small.
ME-5-03	Indicators need to be highlighted.
ME-5-04	The titles should be bigger; it would be easier to identify the indicators.
ME-5-05	In indicator IND5, the filter should be fixed when a task is selected and not reset.
ME-5-06	In indicators IND3 and IND4, the gauge displays to max values are not clear.

ME-5-07	In indicator IND6, the project health should be more clear when alternating from projects to tasks.
ME-5-08	It lacks the inclusion of total cost for comprehension of CPI.
ME-5-09	In indicator IND5, it's not clear when all tasks are in fixed window or if there is a drop-down bar.
ME-5-10	It should be possible to filter projects by total cost and not just by CPI.
ME-5-11	In indicator IND1, the days axel should be more clear

5.4. Quantitative evaluation by enquiry

In Annex E, it is presented the guidelines that the user had to follow during the test and after the participant finished each scenario, had to answer two quick questions of satisfaction. After the last scenario was completed, then the user had to answer three questions of system satisfaction in a scale divided by 5 levels (Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree).

These questions connected the user's satisfaction with the easiness to complete the tasks and the time that he took to complete the scenario.

Figure 5.3 illustrates the answers for the first scenario.

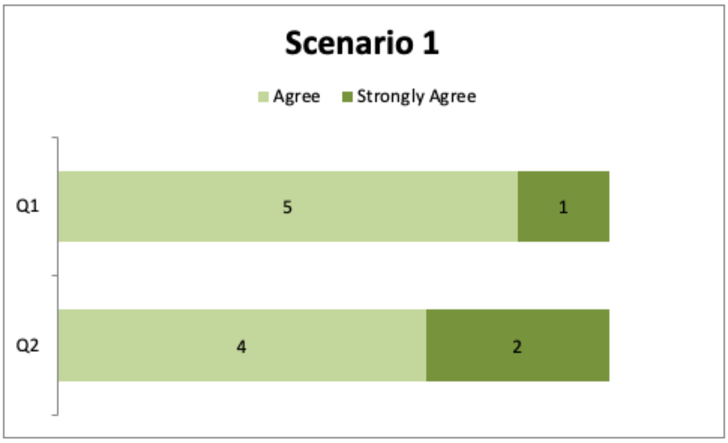


Figure 5.3: Enquiry results for Scenario 1

The users tended to be optimistic for the first contact with the dashboard, showing an overall satisfaction completing the tasks.

In Scenario 2, as said prior, the user was more familiar with the dashboard and considering the answers from Figure 5.4, the users were generally more satisfied when comparing to scenario 1, apart from user 4, which was more conservative in the answers to these enquiries.

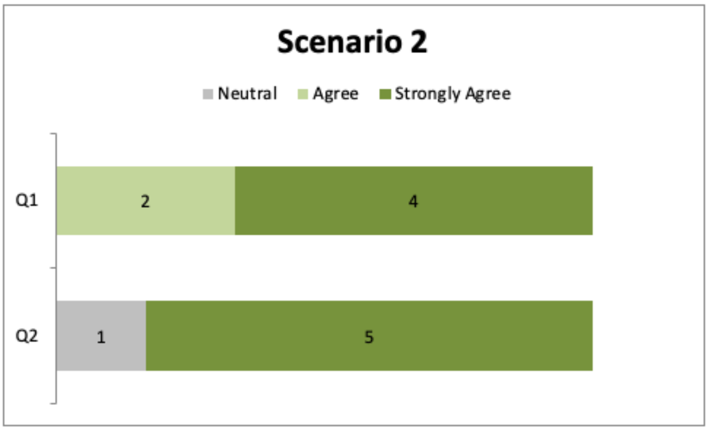


Figure 5.4: Enquiry results for Scenario 2

In scenario 3, it was possible to see a tendency of less satisfaction when the complexity of the scenario increased, with all users being satisfied but two being neutral when considering the time to finish the tasks. Figure 5.5 illustrates the results for this scenario.

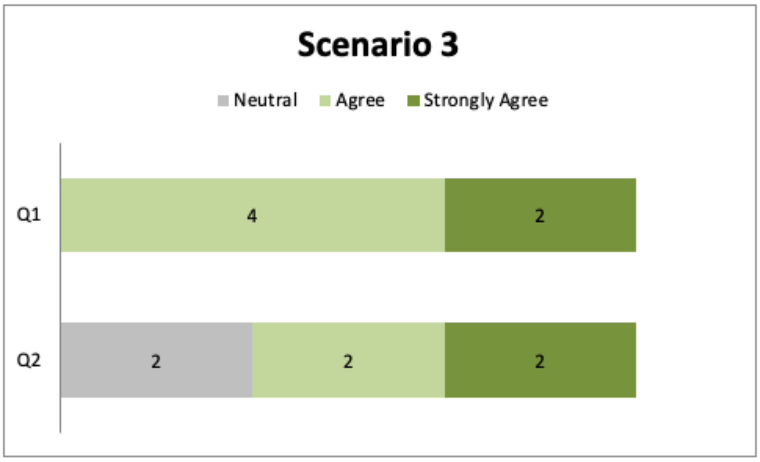


Figure 5.5: Enquiry results for Scenario 3

When comparing the results of Scenario 4 (Figure 5.6) with Scenario 3, it is possible to see that, this being the scenario with most tasks and more complex, it showed in the satisfaction results that the users had more distinct answers. User 3 had the most questions for this scenario and the results for his own performance were below the previous scenarios.

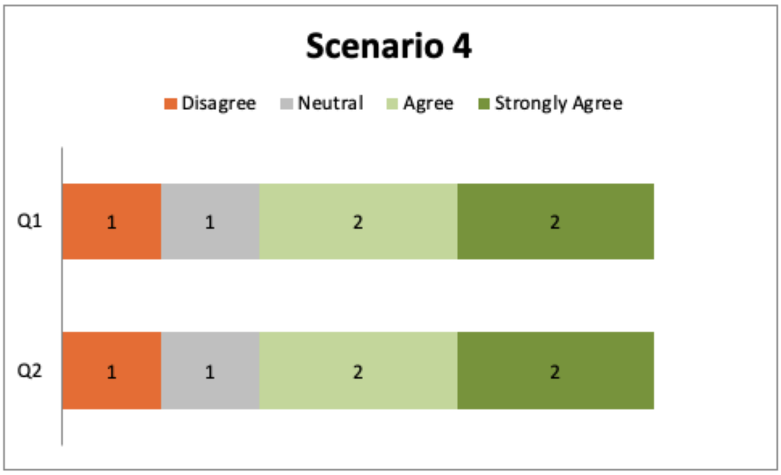


Figure 5.6: Enquiry results for Scenario 4

After the conclusion of the scenarios, the users filled in an enquiry with the following questions:

1. By using this system, I'll improve the project monitoring.
2. The interaction of these indicators are a good tool for feedback and cross information.
3. This system will be helpful to reduce project errors when considering time and costs.

The answers were generally positive, with only users 3 and 4 answering "Neutral" to the abilities of this system to reduce project errors, as these users had a considerable difficulty to correlate the indexes with the status of the project. This explains the more conservative approach. Figure 5.7 illustrates the results for the system enquiry.

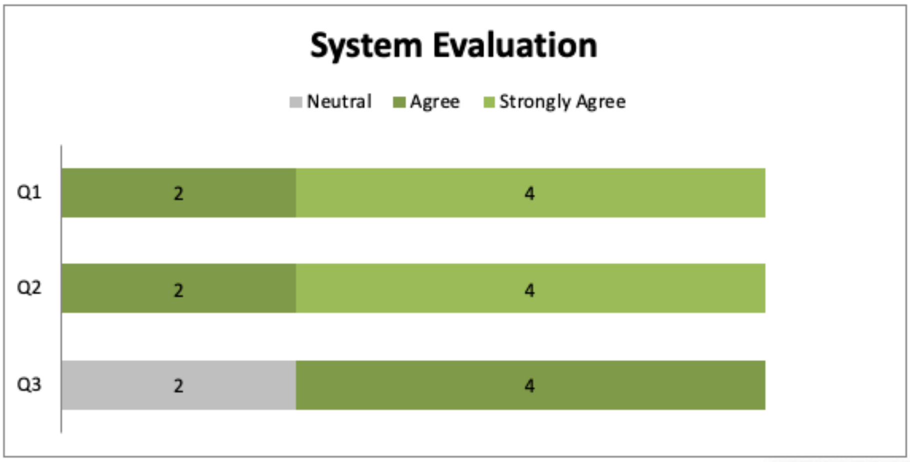


Figure 5.7: Enquiry results for System Evaluation

It is important to mention that answers were given taking into account that this was the first approach to a new visual tool by a small group of users. This explains the bigger impact of neutral answers in the overall result. A longer period of testing and the correction of errors of this first prototype would help to improve the satisfaction rates.

5.5. SUS enquiry evaluation

The System Usability Scale (SUS) enquiry is a quick evaluation which allows the evaluator to get a fast answer about the usability of a system.[76] This is a tool that retrieves the opinion of a test participant in 10 questions, after the testing of a system.[77]

The answers vary between 0 and 100, and each answer is graded in the Likert scale of 5 points. Table 5.6 summarizes the scoring system and the ratings.[78][79]

Table 5.6 SUS Score and ratings

SUS Score	Grade	Adjective Rating
> 80.3	A	Excellent
68 – 80.3	B	Good
68	C	Okay
51 – 68	D	Poor
< 51	F	Awful

The ten questions that the users had to answer are presented next[80]:

1. I would like to use this system frequently.
2. I believe this system is more complex than necessary.
3. I think the system is easy to use.
4. I think I would need someone experienced to help me using the system.
5. I think all the functionalities in this system are well integrated.
6. I think this system has too many inconsistencies.
7. I think the majority of people would be able to use this system quickly.
8. I think this system is too complicated to use.
9. I felt confident when using this system.
10. I had to learn a lot before being able to use this system.

Figure 5.8 shows the results for the enquiry (the full enquiry is available in Annex F). The average of the system is 74,6, which according to Table 5.6 it's "Good". The standard deviation is 8,9 and the median 75.

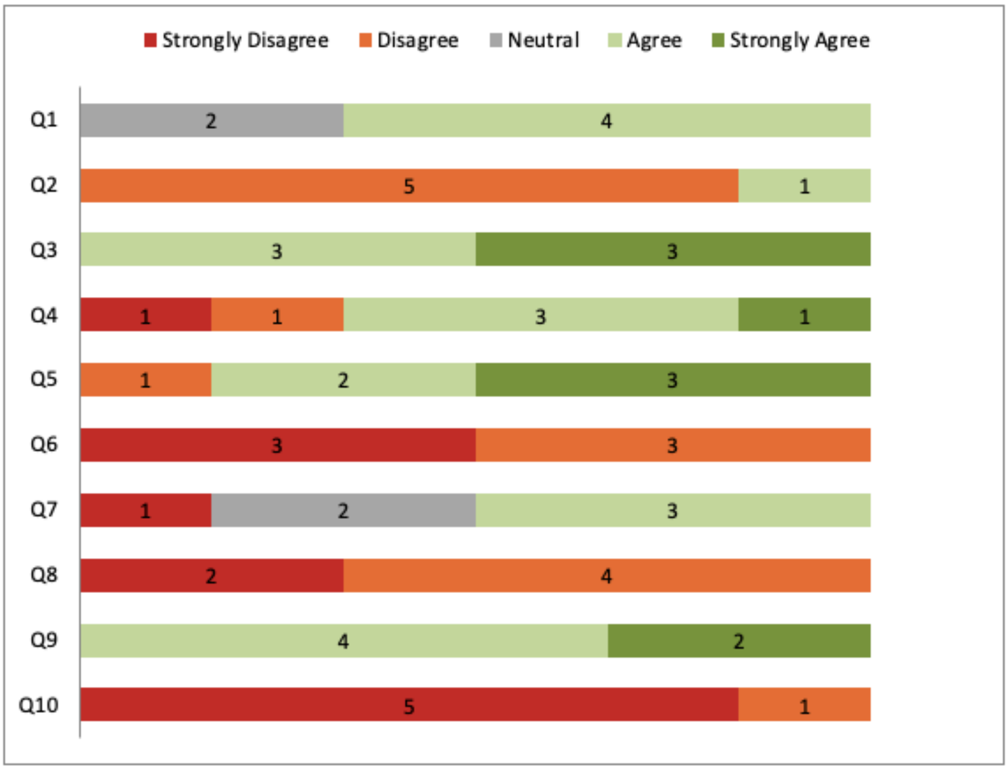


Figure 5.8: SUS Enquiry results

When considering the learning need for the user, question 4 shows an average 3,3 and question 10 an average of 1,2. In one hand 4 participants confirmed that they would need experienced help to use the system, but all users disagreed on learning a lot before being able to use the system, which is a strong lead that it was the experience of the first prototype and finding the first errors that had the consequence of more formal answers to the learning experience.

When considering the wish to use this system more often, 4 out of 6 users agreed, with just 2 being neutral whilst only 1 user believing that this system is more complex than necessary.

In terms of inconsistencies, all six users disagreed or strongly disagreed that there were too many inconsistencies.

5.6. Conclusion

In order to confirm that the design choices were the correct ones for the conceptual model, it is necessary to translate them into a prototype and test it. The first contact with a user that had no direct input in the modelling of the system and is not biased is crucial to understand if the dashboard is working properly.

In general, the prototype had a SUS score of 74,6, being considered as “Good”. There were no big incongruences found in the prototype, but some improvements to be done to the filtering and titles, as well as improve the appearance of indicators IND3 and IND4, so it is more obvious the information that is expected to be shown and to improve the interaction with IND6.

It was interesting to confirm that the higher the complexity of the scenario, that the user would take more time to think and to act within the task.

The next chapter will focus on the discussion of the evaluation methods of the conceptual model as well as the limitations, conclusions and suggestions for future work.

6. Conclusions and future work

The Visualization Information field has the great potential to improve the analysis of a project and minimize human errors when it comes to decision-making.

It is being highly used in the industrial world, with visual techniques being used to optimize the production lines and extended to management top layers to analyze sales and the company health in financial terms.

It can be extended to customer satisfaction, employee performance, project status, amongst others. The possibilities to apply a visual technique are almost endless, and all is necessary is the data that is constantly being produced and is even more valuable than oil nowadays.

This was one of the motivators to apply the visual information into the construction industry where this study was focused on. Although there are already studies in this field, for the particular case study no documents were found. The company is acting in such a niche market (from technical paper, to medical solutions, or waterproofing systems) that it was known from the beginning that this was going to be the biggest challenge.

The intention of this study was to focus in the waterproofing systems produced by this company but can be extended to the remaining products. It was found that when it comes to a project analysis, within this field, the enquiries and people working at the company were more interested in more general indicators, from a management point of view, in contrast with the possibility to focus on the waterproofing products and the production line itself.

The next step was to generate a conceptual model that could be applied to the management side of the waterproofing systems, which KPIs were more interesting to be calculated and indicators for this particular product.

The results from the prototype tests proved that the overall system had a “Good” rate within the users. On the other hand, it was also experienced that, with such small focus group, if one person has a different answer, it can influence the entire rate of the system. Ideally, the focus group should be extended to other companies that work with waterproofing systems for wood construction and get different points of view.

6.1. Objectives and expected results

The main objective of this testing phase was to generate a prototype that was easy to understand and intuitive not just for the Research and Development professionals, but also for the others involved in the monthly meetings where the projects are discussed and this tool will be used.

The evaluation methods proved to be satisfactory, as the six indicators were tested from four different test scenarios, with increase of complexity in scenarios 3 and 4.

The results showed that the users, after spending more time familiarizing with the dashboard and the filters, were generally faster in the second scenario (more simple), and took more time to solve more complex tasks, proving that they needed more time to think and act when interacting and connecting different types of information.

For a first contact with the prototype, the general satisfaction results were positive and from the testing sessions, eleven different errors were found, and will be important to improve the dashboard and increase the user experience in the future.

Of all indicators, IND3 and IND4, CPI and SPI indicators, respectively, were the ones with most questions and doubts. Not about the indicators itself, but the choice of the visual technique for it and the interpretation of the max value and average value. The usage of filters was another fact to be considered and to be improved.

Of all the evaluation metrics, it was possible to test successfully all of them.
For the usability evaluation, it was used the SUS enquiry and the goal was to reach rate "Excellent" (>80,3). That goal was not reached, as the system reached an average of 74,6 with standard deviation of 8,9 and median of 75,0 and being rated as "Good".

In general, it is possible to say that this conceptual model for the generation of visual dashboards was very useful to improve the focus group experience and already started a discussion to improve the prototype for future usage.

6.2. Limitations

There were several limitations to take into account when doing this study.

As said prior, the niche in which this industry is focused difficult the research process as there weren't many documents or references to rely on for the waterproofing systems. The closest industry was the construction industry in Sweden, but with very little information as well. The first challenge was to gather the more general information and start focusing in this sub-industry.

The evaluation of the model itself is based in the user, which plays a key role from the design stage to the prototype test.[81] For that reason it would be better to have a larger focus group, but due to the subject of the study being limited, it would be difficult to find more test users.

Related to the research and testing itself is the subject of the study. As said, the waterproofing systems for wood construction is such a focused industry that would be hard to find specific indicators just for this matter. For that reason, and also due to the user being part of the design process, more general indicators were chosen to be evaluated, which leads to a conceptual model and prototype that can be extended to niche industries with focus in project management and decision-making.

6.3. Future work

After the evaluation of the prototype and gathering the user opinions and errors found in the prototype, one of the future goals is to improve the dashboard and present an updated version to the users, as this is a tool that has the objective to be used in monthly meetings to help monitoring the waterproofing projects.

Another point to be focused is a simplified version of this prototype based on the indicators chosen from the conceptual model and with visual techniques that will allow the daily work with these types of products. This second prototype is already under development and started being discussed after the testing sessions.

Figure 6.1 illustrates the second screen to be added to the dashboard, in which the participants suggested to include the additional information regarding estimated costs and average costs, as well more detailed information about the time of the projects and the clearer information for the Schedule and Cost indicators in the form of bar charts.

This second dashboard serves as a complement to the more detailed one that was tested in this study.

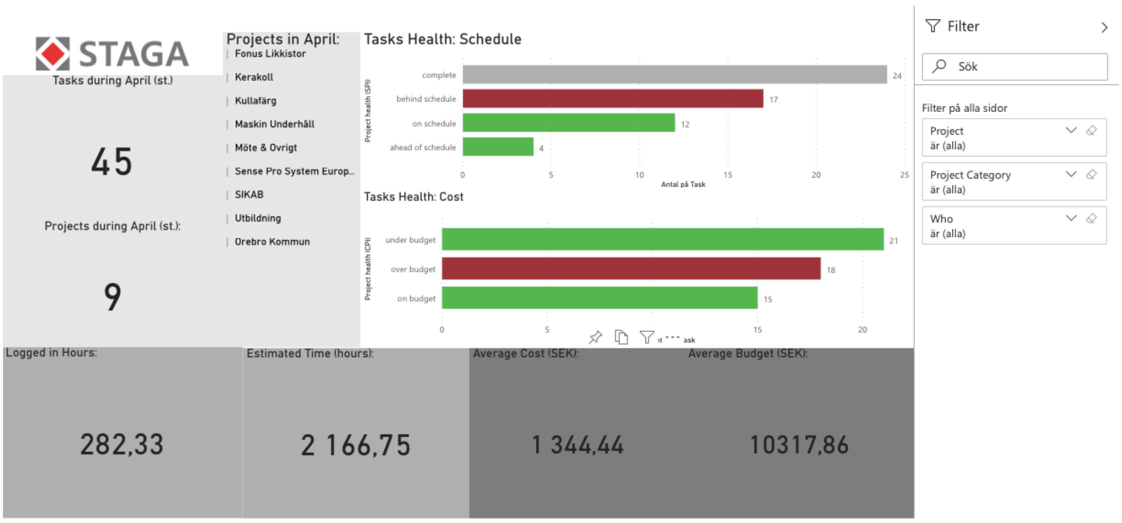


Figure 6.1: Prototype for the second dashboard screen under development

7. References

[1] R. Mazza, *Introduction to Information Visualization*. Springer-Verlag London Limited, 2009.

[2] S. AL-Haddad, “Visualization What does users consider to be a user-friendly dashboard?,” 2018.

[3] K. C. Laudon and J. P. Laudon, *Management information Systems: Managing the Digital Firm*. Pearson Education Limited, 2016.

[4] M. BI, “Vad är ett KPI / Nyckeltal och hur används det?” .

[5] B. Kitchenham, “Procedures for Performing Systematic Reviews,” 2004.

[6] A.-W. Harzing, “Harzing: Publish or Perish,” 2019. [Online]. Available: https://harzing.com/resources/publish-or-perish.

[7] B. Kuechler and S. Petter, “Design Science Research in Information Systems,” no. 1, pp. 1–66, 2012, doi: 1756-0500-5-79 [pii]\r10.1186/1756-0500-5-79.

[8] N. Mccurdy, J. Dykes, and M. Meyer, “Action Design Research and Visualization Design.”

[9] A. R. Hevner, “A Three Cycle View of Design Science Research,” *Scand. J. Inf. Syst.*, vol. 19, no. 2, pp. 87–92, 2007, doi: http://aisel.aisnet.org/sjis/vol19/iss2/4.

[10] T. Mettler, “A Design Science Research Perspective on Maturity Models in Information Systems,” vol. 41, no. 0, 2009.

[11] W. Kuechler and V. Vaishnavi, “The emergence of design research in information systems in North America,” *J. Des. Res.*, vol. 7, no. 1, pp. 1–16, 2008, doi: 10.1504/JDR.2008.019897.

[12] P. Lindell and D. Nilsson, “Providing visualisation of wood industry data with a user centred design,” 2016.

[13] K. Pauwels *et al.*, “Dashboards as a service: Why, what, how, and what research is needed?,” *J. Serv. Res.*, vol. 12, no. 2, pp. 175–189, 2009, doi: 10.1177/1094670509344213.

[14] K. Verbert *et al.*, “Learning dashboards: An overview and future research opportunities,” *Pers. Ubiquitous Comput.*, vol. 18, no. 6, pp. 1499–1514, 2014, doi: 10.1007/s00779-013-0751-2.

[15] B. Alexandre and P. Moniz, “Modelo de Criação de Dashboards Clínicos,”

Universidade Aberta, 2018.

[16] G. M. O'Brien, James A. and Marakas, *Management Information Systems*. McGraw-Hill/Irwin, 2011.

[17] J. Moore, "Visualisation of data to optimise strategic decision making," University of Cape Town, 2017.

[18] D. Stodder, "Data Visualization and discovery for better business decisions," 2013.

[19] Y. C. AvNils, H.; Rasmussen, Manish Bansal; Claire, *Business Dashboards: A Visual Catalog for Design and Deployment*. John Wiley & Sons, Inc., 2009.

[20] R. O. Valles and C. Norman, "Investigating the impact of data visualization based on real time construction project information," University of Oklahoma, 2016.

[21] H. Kerzner, "Project Management Metrics , KPIs and Dashboards," *Int. Inst. Learn.*, pp. 1–61, 2015.

[22] M. S. Gounder, V. V. Iyer, A. Professor-ccis, A. Al Mazyad, and A. Prof, "A Survey on Business Intelligence tools for University Dashboard development," 2016.

[23] G. E. Aguilar, "Construction Real Time Information and Communication System for Safety," 2012.

[24] A. D. Russell, C. Y. Chiu, and T. Korde, "Visual representation of construction management data," *Autom. Constr.*, vol. 18, no. 8, pp. 1045–1062, Dec. 2009, doi: 10.1016/j.autcon.2009.05.006.

[25] W. W. Eckerson, *Performance Dashboards: Measuring, Monitoring and Managing Your Business*. John Wiley & Sons, Inc., 2006.

[26] T. D. Data and B. Design, "A Guide to Creating Dashboards People Love to Use," *Juicebox*, 2015.

[27] G. Ward, Matthew O. ; Grinstein, Georges; Keim, *Interactive Data Visualization: Foundations, Techniques and Applications*. Taylor and Francis Ltd., 2015.

[28] A. T. Kovacs and A. Micsik, "Building Information Dashboard as Decision Support during Design Phase," 2019.

[29] A. Satyanarayan, D. Moritz, K. Wongsuphasawat, and J. Heer, "Vega-Lite : A Grammar of Interactive Graphics," vol. 2626, no. c, 2016, doi: 10.1109/TVCG.2016.2599030.

[30] A. S. Bhat, "Data Visualization of Requests for Information to Support Construction Decision-Making," The University of British Columbia, 2017.

[31] A. U. C. Chen, W. Härdle, *Handbook of Data Visualization*. Springer, 2008.

[32] D.-J. Gibbs, "Development of Building Information Models (BIM) to Support Innovative Time Management and Delay Analysis," 2016.

[33] S. M. Beheshtian, "Visualizing the design and construction of roadway system: a case study," University of British Columbia, 2003.

[34] B. Flesch, "Design , Development and Evaluation of a Big Data Analytics Dashboard," Copenhagen Business School, 2014.

[35] SAS, "Data Visualization Techniques: From Basics to Big Data with SAS Visual Analytics," 2018.

[36] M. A. Borkin *et al.*, "What Makes a Visualization Memorable ?," vol. 19, no. 12, pp. 2306–2315, 2013.

[37] J. Heer, M. Bostock, and V. Ogievetsky, "VIISUALIZATION A Tour through the Visualization Zoo A survey of powerful visualization techniques , from the obvious to the obscure," pp. 1–22, 2010.

[38] A. Abela, "Chart Suggestions - A Thought-Starter," *Extreme Presentation*, 2009. [Online]. Available: https://extremepresentation.typepad.com/files/choosing-a-good-chart-09.pdf. [Accessed: 21-Mar-2020].

[39] S. Few, *Now you see it : simple visualization techniques for quantitative analysis*. Analytics Press, 2009.

[40] M. Behrisch *et al.*, "Quality Metrics for Information Visualization," vol. 37, no. 3, 2018, doi: 10.1111/cgf.13446.

[41] H. Tokola, C. Gröger, E. Järvenpää, and E. Niemi, "Designing manufacturing dashboards on the basis of a Key Performance Indicator survey," *Procedia CIRP*, vol. 57, pp. 619–624, 2016, doi: 10.1016/j.procir.2016.11.107.

[42] B. Marr, *Key Performance Indicators - The 75 Measures Every Manager Needs to Know*. Pearson Education Limited, 2012.

[43] S. Vilarinho, I. Lopes, and S. Sousa, "Developing dashboards for SMEs to improve performance of productive equipment and processes," *J. Ind. Inf. Integr.*, vol. 12, pp. 13–22, Dec. 2018, doi: 10.1016/j.jii.2018.02.003.

[44] J. Alexander, *Financial Planning & Analysis and Performance Management*. John Wiley & Sons, Inc., 2018.

[45] U. Bititci, P. Cocca, and A. Ates, "Impact of visual performance management systems

on the performance management practices of organisations," *Int. J. Prod. Res.*, vol. 54, no. 6, pp. 1571–1593, Mar. 2016, doi: 10.1080/00207543.2015.1005770.

[46] C. A. N. Dita, "Implementation of a Business Intelligence Solution in a Manufacturing Company: A Predictive Analysis Approach," 2019.

[47] A. I. Goncalves, "Evaluation of Business Intelligence Project Success in Tintas Robbialac, SA: An exploratory Case Study," Universidade Nova de Lisboa, 2016.

[48] O. Velcu-Laitinen and O. M. Yigitbasioglu, "The use of dashboards in performance management: Evidence from sales managers," *Int. J. Digit. Account. Res.*, vol. 12, pp. 39–58, 2012, doi: 10.4192/1577-8517-v12_2.

[49] L. Shi, L. Newnes, S. Culley, J. Gopsill, S. Jones, and C. Snider, "Identifying and visualising KPIs for collaborative engineering projects: a knowledge based approach," 2015.

[50] A. Zander and N. Hedin, "Using KPIs in decision-making tools in the construction industry," 2019.

[51] S. Hesse, V. Vasyutynskyy, M. Rosjat, and C. Hengstler, "Modeling and Presentation of Interdependencies between Key Performance Indicators for Visual Analysis Support," pp. 281–288, 2013.

[52] Svensk Trä, "Skogsindustri," 2020. [Online]. Available: https://www.traguiden.se/contentassets/4828782d1b514dbf9f0e6632d934a1d7/virkesutnyttjande-2011_avt17.png.

[53] S. V. AB, *Industry Regulations: Säker Vatteninstallation 2016:1*. 2015.

[54] U. Antonsson and I. Samuelson, "Funktionsprovning av tätskiktsystem av folietyp för våtutrymmen," 2014.

[55] J. G. Zheng, *Global Business Intelligence*. Taylor and Francis Ltd., 2018.

[56] U. Antonsson, I. Samuelson, B. Nordling, A. Jansson, and I. Demker, "Funktionsprovning av tätskiktsystem för våtutrymmen," 2016.

[57] U. Antonsson, B. Nordling, I. Demker, and M. Sjöqvist, "Funktionsprovning av tätskiktsystem för våtutrymmen 2019," 2019.

[58] S. Jones, S. Payne, B. Hicks, and L. Watts, "Visualization of Heterogeneous Text Data in Collaborative Engineering Projects," 2013.

[59] D. A. Keim, "Information visualization and visual data mining," *IEEE Trans. Vis. Comput. Graph.*, vol. 8, no. 1, pp. 1–8, 2002, doi: 10.1109/2945.981847.

[60] D. R. Fernandes, “Uma contribuição sobre a construção de indicadores e sua importância para a gestão empresarial,” pp. 1–18.

[61] A. Tezel, “Visual management in construction: Study report on Brazilian cases,” 2010.

[62] M. J. . C. P. Goncalves, Daniel; Fonseca, *Introducao ao Design de Interfaces*. FCA - Editora de Informática, 2017.

[63] M. Ferrari, Alberto; Russo, *Introducing Microsoft Power BI*. Microsoft Press, 2016.

[64] M. Ferrari, Alberto; Russo, *Analyzing Data with Power BI and Power Pivot for Excel*. Microsoft Press, 2017.

[65] B. Roseke, “Project Engineer: Cost Performance Index,” 2016. [Online]. Available: https://www.projectengineer.net/cost-performance-index-earned-value-analysis/. [Accessed: 11-Apr-2020].

[66] B. Roseke, “Project Engineer: Schedule Performance Index,” 2017. [Online]. Available: https://www.projectengineer.net/what-is-the-schedule-performance-index/. [Accessed: 12-Apr-2020].

[67] I. Maria and M. Pedrosa, “Monitorização do desempenho através de Dashboards Monitoring performance through Dashboards,” *2018 13th Iber. Conf. Inf. Syst. Technol.*, pp. 1–6.

[68] A. Wexler, Steve; Shaffer, Jeffrey; Cotgreave, *The Big Book of Dashboards*. John Wiley & Sons, Inc., 2017.

[69] J. Nielsen, “Why you only need to test with 5 users,” 2000. [Online]. Available: https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/. [Accessed: 25-Apr-2020].

[70] J. Nielsen, “How many test users in a usability study?,” 2012. [Online]. Available: https://www.nngroup.com/articles/how-many-test-users/. [Accessed: 25-Apr-2020].

[71] J. Kerren, Andreas; Ebert, Achim; Meyer, *Human - centered Visualization Environments*. Springer-Verlag London Limited, 2006.

[72] A. Bangor *et al.*, “An Empirical Evaluation of the System Usability Scale Usability Scale,” vol. 7318, 2008, doi: 10.1080/10447310802205776.

[73] J. Sharp, H.; Rogers, Y.; Preece, *Interaction Design: Beyond Human-Computer Interaction*, 2n edition. John Wiley & Sons, Inc., 2007.

[74] J. Nielsen, “Thinking Aloud: The #1 Usability Tool,” *Nielsen Norman Group*, 2012.

[Online]. Available: https://www.nngroup.com/articles/thinking-aloud-the-1-usability-tool/. [Accessed: 01-May-2020].

[75] N. Fox, *How to Use Observations in a Research Project*. Trent Focus Group, 1998.

[76] I. Jordan, Patrick; Thomas, Bruce; Weerdmeester, Bernard; McLelland, *Usability Evaluation in Industry*. Taylor and Francis Ltd., 1997.

[77] T. Will, "Measuring and Interpreting System Usability Scale (SUS)," *UX Research*, 2019. .

[78] J. Bangor, Aaron; Kortum, Philip; Miller, "Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale," *J. Usability Stud.*, 2009.

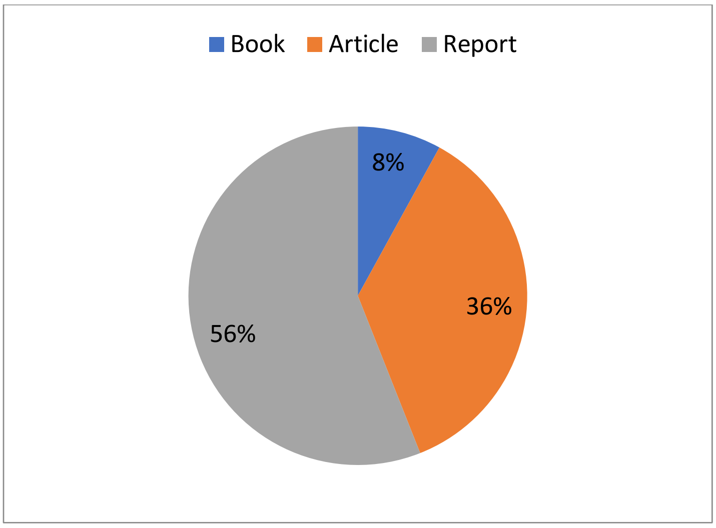
[79] K. Finstad, "The System Usability Scale and Non-Native," vol. 1, no. 4, pp. 185–188, 2006.

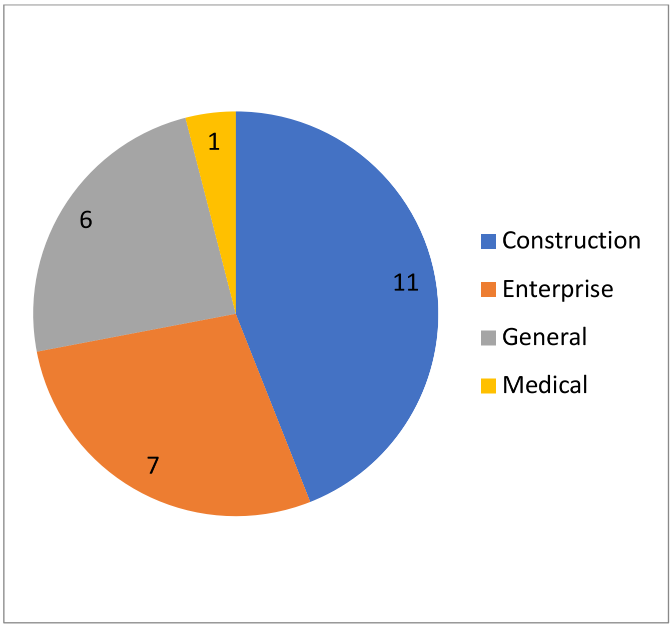
[80] J. Sauro, "Measuring usability with the System Usability Scale (SUS)," *Measuring U*, 2011. .

[81] J. Nielsen, "The Use and Misuse of Focus Groups," *Nielsen Norman Group*, 1997. [Online]. Available: https://www.nngroup.com/articles/focus-groups/. [Accessed: 05-May-2020].

Annexes

Annex A: Publication type and field of the selected papers


Book
Article
Report
8%
36%
56%


1
6
11
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Construction
Enterprise
General
Medical

Annex B: Matrix of Research Questions and Selected

Papers			How useful are dashboards for a SME within the wood construction industry?	Which are the most relevant KPIs for the decision-making process?	What are the visual techniques available and the most suitable for visual mapping of KPI data on the dashboards to be proposed?	Which data is needed, its characteristics, sources, structure and what information to be extracted from it?
Title	**Author**	**Year**				
Using KPIs in decision-making tools in the construction industry	Zander	2019	🔴	🟢	🟢	🟡
Developing dashboards for SMEs to improve performance of productive equipment and processes	Sousa	2018	🟡	🟢	🟢	🟢
The use of dashboards in performance management: Evidence from sales managers	Velcu-Laitinen	2012	🔴	🟢	🟢	🟡
Visual representation of construction management data	Russell	2009	🔴	🔴	🟢	🟢
Learning dashboards: An overview and future research opportunities	Verbert	2014	🔴	🔴	🟡	🔴
Visualization of Heterogeneous Text Data in Collaborative Engineering Projects	Watts	2013	🔴	🔴	🟢	🟢
Visual management in construction: Study report on Brazilian cases	Tezel	2010	🔴	🔴	🟢	🟢
Impact of visual performance management systems on the performance management practices of organisations	Ates	2016	🔴	🟢	🟢	🟢
Development of Building Information Models (BIM) to Support Innovative Time Management and Delay Analysis	Gibbs	2016	🔴	🔴	🟡	🟡
Data Visualization and discovery for better business decisions	Stodder	2013	🔴	🟢	🟢	🟢
Visualisation of data to optimise strategic decision making	Moore	2017	🔴	🟢	🟢	🟢
Construction Real Time Information and Communication System for Safety	Aguilar	2012	🔴	🔴	🟡	🟡
Modelo de Criação de Dashboards Clínicos	Moniz	2018	🔴	🔴	🟡	🟡
Identifying and visualising KPIs for collaborative engineering projects: a knowledge based approach	Shi	2015	🔴	🟢	🟢	🟢
Building Information Dashboard as Decision Support during Design Phase	Kovacs	2019	🔴	🟢	🟢	🟢
Data Visualization of Requests for Information to Support Construction Decision-Making	Bhat	2017	🔴	🟢	🟢	🟢
Visualizing the design and construction of roadway system: a case study	Beheshtian	2003	🔴	🔴	🟡	🔴
Implementation of a Business Intelligence Solution in a Manufacturing Company: A Predictive Analysis Approach	Dita	2019	🔴	🟢	🟢	🔴
Investigating the impact of data visualization based on real time construction project information	Valles	2016	🔴	🟢	🟢	🔴
Data Visualization Techniques: From Basics to Big Data with SAS Visual Analytics	SAS	2018	🔴	🟡	🟢	🔴
Project Management Metrics, KPIs, and Dashboards: A Guide to Measuring and Monitoring Project Performance	Kerzner	2013	🔴	🟢	🟢	🟢
Dashboards as a service: Why, what, how, and what research is needed?	Wiesel	2009	🔴	🟡	🟢	🔴
Providing visualisation of wood industry data with a user centred design	Lindell	2016	🟡	🟢	🟢	🔴
Introduction to Information Visualization	Mazza	2009	🔴	🟡	🟢	🟡
Management information Systems: Managing the Digital Firm	Laudon	2016	🔴	🟡	🟡	🟡

Annex C: Enquiry to choose the dashboard indicators

Enterprise Dashboards Enquiry

Questions Responses 6 Total points: 0

Enterprise Dashboards Enquiry

The growing amount of generated data has a direct connection to the increasing role of information systems in daily processes around all industries.

It´s not surprising the fact that with all this data, comes a need to organize it properly and connect the diversity of subjects in order to potentiate the information that the user will have access to. According to the definition of data, "Data are entities that, of themselves, lack any meaning. They constitute the "bricks" with which we build information and our communicative processes."

One way to facilitate the output of that information is through visualization. Relying in the definition of the word, it is "an activity in which human beings are engaged as an internal construction in the mind"

These two definitions make more sense when connected with a third: decision-making. Before, this type of interaction was limited to the management layer of the company. Nowadays, thanks to the access to information systems, it is possible to extend it to the lower levels of the business.

This study has the goal to build a dashboard to optimize the monitoring of a project, mainly within the construction sub-industries but extended to the technical paper and non-woven.

For that reason, you were invited to participate in an enquiry to understand which indicators and visual techniques would be more appealing for the industry we work for.

By participating in this study, you accept the fact that I will gather some data for academic purposes.

Thank you for your time.

Age? *

Short answer text

What's your Gender? *

- Female
- Male
- Prefer not to say
- Other...

Job title? *

Short answer text

How long have you been working in this company?

- Less than 1 year
- 1 - 2 years
- 3 - 5 years
- More than 5 years

How would you consider yourself as an Information Technologies (IT) user, based in frequency and experience of usage?

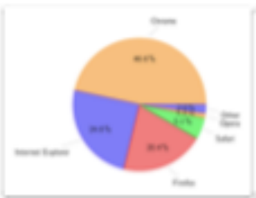
- ◯ Beginner
- ◯ Advanced Beginner
- ◯ Competent
- ◯ Expert

Of the following visual techniques, which ones do you use more often? (You can select multiple *

- ☐ Bar charts

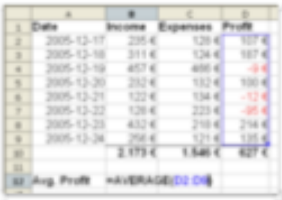
- ☐ Line charts

- ☐ Pie charts



- ☐ Tables

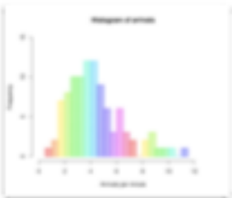
Spreadsheets



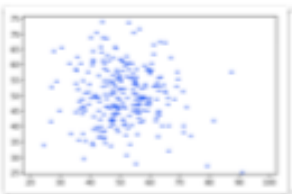
	A	B	C	D
1	Date	Income	Expenses	Profit
2	2005-12-17	235 €	128 €	107 €
3	2005-12-18	311 €	124 €	187 €
4	2005-12-19	457 €	466 €	-9 €
5	2005-12-20	232 €	132 €	100 €
6	2005-12-21	122 €	134 €	-12 €
7	2005-12-22	128 €	223 €	-95 €
8	2005-12-23	432 €	218 €	214 €
9	2005-12-24	256 €	121 €	135 €
10		2.173 €	1.546 €	627 €
11				
12	Avg. Profit	=AVERAGE(D2:D9)		

Data sheets

Histograms



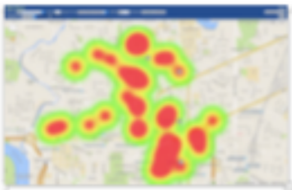
Scatterplots



Statistics

- [ ] Summary sheets / Report charts
- [ ] Common chart maps
- [ ] Bullet graphs

- [ ] Heat maps



- [ ] Gauges and dials

- [ ] Geo maps

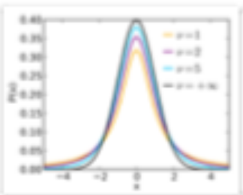
- [ ] Sparklines

- [ ] Text charts

- [ ] Time tables
- [ ] Tree maps

- [ ] Spatial maps

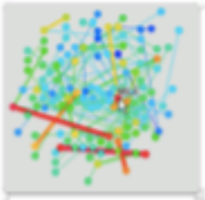
- [ ] Variance charts



- [ ] Logical maps

- [ ] Word clouds

☐ Data constellations



☐ Other...

Which, of the following indicators, are most significant to track a project evolution? (You can choose multiple answers) *

- [ ] Logged in Time in Main Project Categories
- [ ] Logged in Time in Specific Projects
- [ ] Logged in Time by Project Responsible
- [ ] Logged in Time throughout time period
- [ ] Percentage of time by Project Responsible for Project
- [ ] Location of Project Customer
- [ ] Location of Project Destination
- [ ] Estimate Time per Person in Main Project Categories
- [ ] Estimate Time per Person in Specific Project Categories
- [ ] Percentage of Completed Tasks
- [ ] Ratio of Completed / Estimated Tasks
- [ ] Ratio of Cost / Budget
- [ ] Estimated Time per Task
- [ ] Logged in Time per Task
- [ ] Schedule Performance Index
- [ ] Cost Performance Index
- [ ] Project Health
- [ ] Other...

If you answered "Other" in the previous question, which visual technique combination would you suggest?

Short answer text

When tracking the "TIME" of a project, which visual technique do you think it suits best? (You can select multiple answers) *

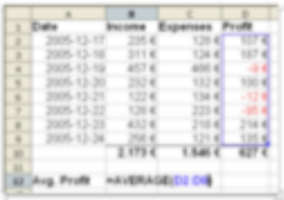
- [ ] Bar charts

- [ ] Line charts

- [ ] Pie charts

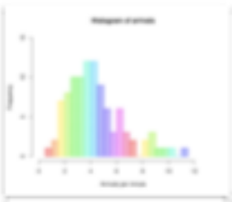
- [ ] Tables

- [ ] Spreadsheets

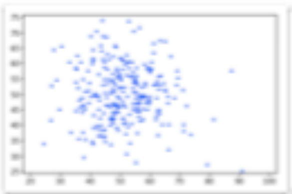


- [ ] Data sheets

- [ ] Histograms

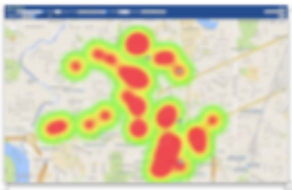


- [ ] Scatterplots



- [ ] Statistics
- [ ] Summary sheets / Report charts
- [ ] Common chart maps
- [ ] Bullet graphs

☐ Heat maps



☐ Gauges and dials

☐ Geo maps

☐ Sparklines

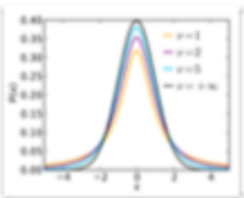
☐ Text charts

☐ Time tables

☐ Tree maps

☐ Spatial maps

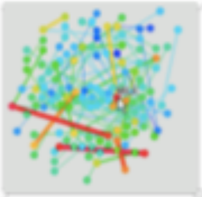
☐ Variance charts



☐ Logical maps

☐ Word clouds

☐ Data constellations



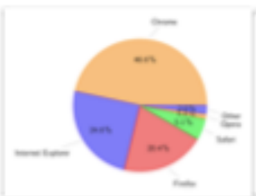
Other...

When tracking the "RESOURCES" of a project, which visual technique do you think it suits best? (You can select multiple answers) *

Bar charts

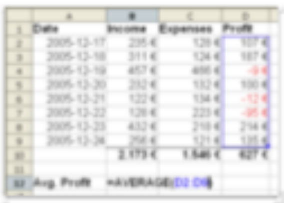
Line charts

Pie charts



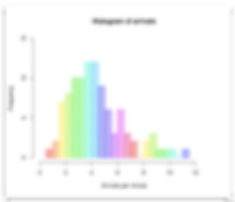
Tables

- [ ] Spreadsheets



- [ ] Data sheets

- [ ] Histograms

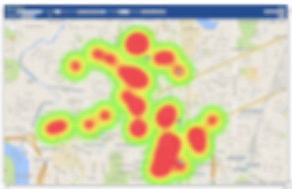


- [ ] Scatterplots

- [ ] Statistics

- [ ] Summary sheets / Report charts
- [ ] Common chart maps
- [ ] Bullet graphs

- [ ] Heat maps



- [ ] Gauges and dials

- [ ] Geo maps

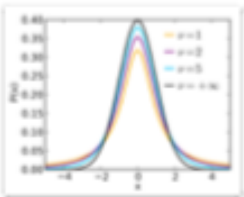
- [ ] Sparklines

- [ ] Text charts

- [ ] Time tables
- [ ] Tree maps

- [ ] Spatial maps

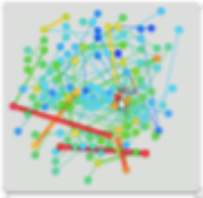
- [ ] Variance charts



- [ ] Logical maps

- [ ] Word clouds

☐ Data constellations



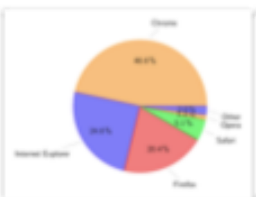
☐ Other...

When tracking the "COSTS" of a project, which visual technique do you think it suits best? (You can select multiple answers) *

☐ Bar charts

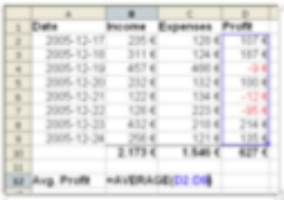
☐ Line charts

☐ Pie charts



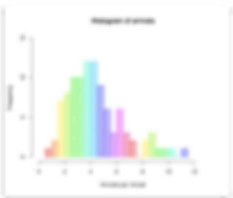
☐ Tables

Spreadsheets



Data sheets

Histograms

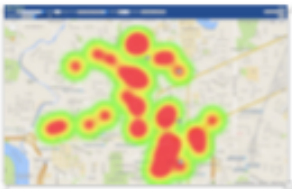


Scatterplots

Statistics

- [ ] Summary sheets / Report charts
- [ ] Common chart maps
- [ ] Bullet graphs

- [ ] Heat maps



- [ ] Gauges and dials

- [ ] Geo maps

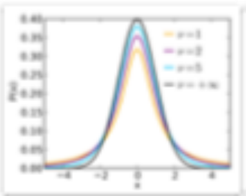
- [ ] Sparklines

- [ ] Text charts

- [ ] Time tables
- [ ] Tree maps

- [ ] Spatial maps

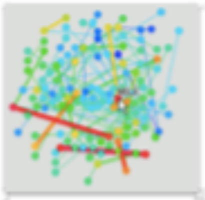
- [ ] Variance charts



- [ ] Logical maps

- [ ] Word clouds

Data constellations

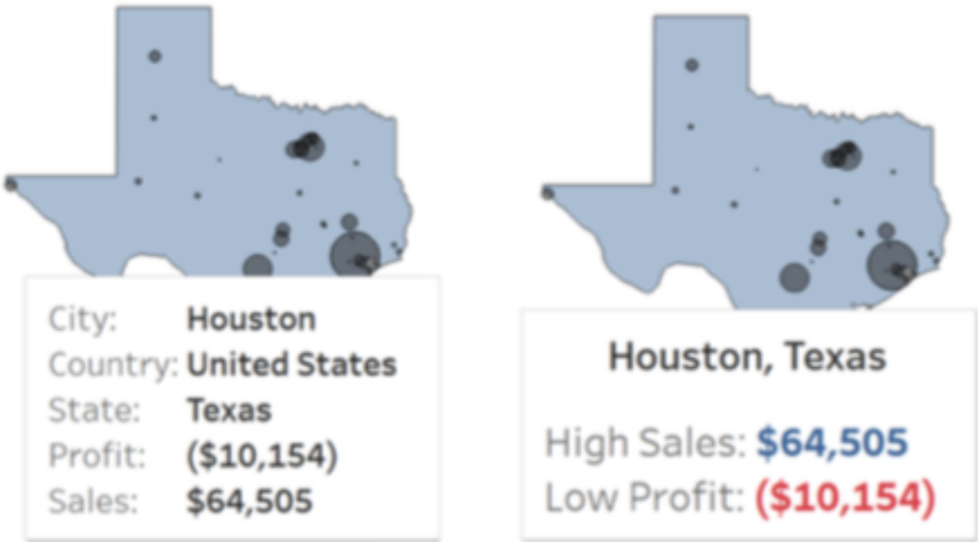


Other...

If you answered "Other" in the previous questions, which visual technique combination would you suggest for "TIME", "RESOURCES" and / or "COSTS"?

Long answer text

Consider the following image. If the purpose was to highlight the sales value, what do you think it should be changed? (You can choose several answers). *



- [ ] The colour of the indicator to be highlighted
- [ ] The font
- [ ] The size of the font
- [ ] The line thickness
- [ ] Zoom
- [ ] Other...

Consider the following dashboard. In your opinion, for each indicator, which visual atributes are most important? *

	Colour	Font Size	Line thickness	Zoom	Visual techniq...
Gantt chart					
Task progress...					
Ratio Price					
Schedule Perf...					
Cost Perform...					
Logged in Tim...					

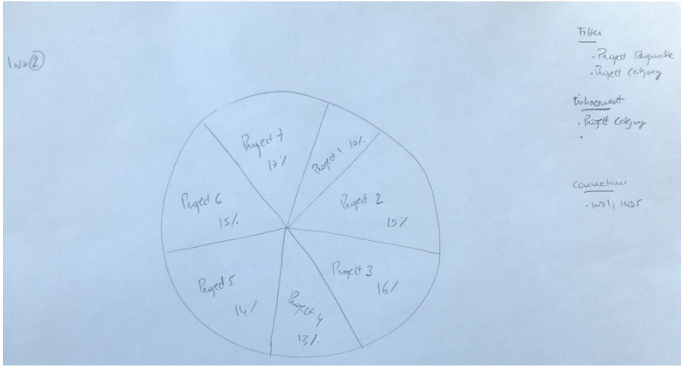
Consider the following dashboard. For the specified month, I want to know the percentage of time logged in for "Customer Maintenance". Which indicator shows that information?

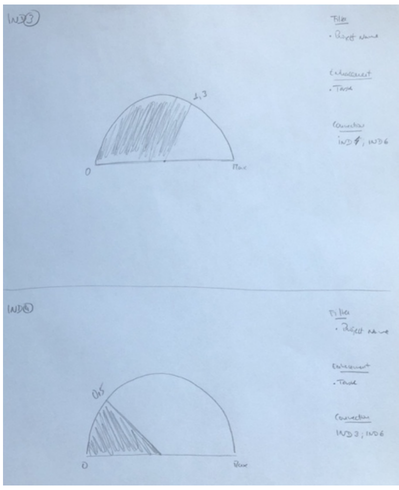
1. 1 (Top row, Left Pie Chart)
2. 2 (Top row, middle Pie Chart)
3. 3 (Geo map)
4. 4 (Bottom row, Left Pie Chart)
5. 5 (Center Gauge Chart)
6. 6 (Bottom row, Right Line Chart)
7. Don't know / Don't want to answer

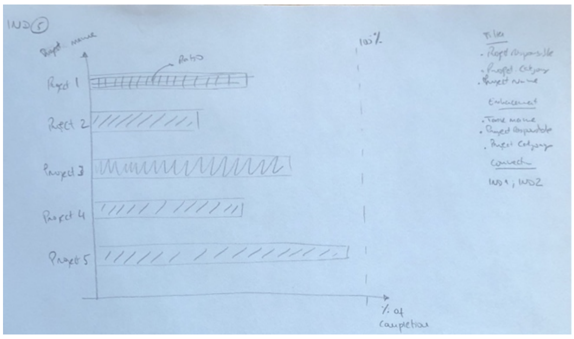
Consider the same dashboard. For each indicator, choose the visual attribute that you would change. (You can choose several answers)

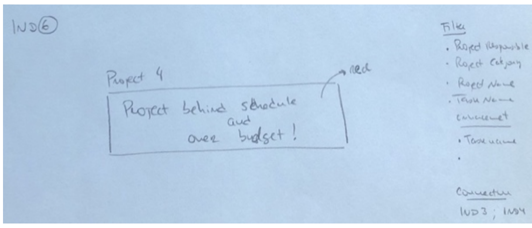
	Type of C...	Zoom	Motion	Font	Font Size	Colour Sc...	Nothing
Top row, ...	☐	☐	☐	☐	☐	☐	☐
Top row, ...	☐	☐	☐	☐	☐	☐	☐
Geo map	☐	☐	☐	☐	☐	☐	☐
Bottom ro...	☐	☐	☐	☐	☐	☐	☐
Center Ga...	☐	☐	☐	☐	☐	☐	☐
Bottom ro...	☐	☐	☐	☐	☐	☐	☐

Annex D: Low fidelity prototypes for the indicators


Project 7
17%
Project 6
15%
Project 2
15%
Project 3
16%
Project 5
14%
Project 4
13%




Project 1
Project 2
Project 3
Project 4
Project 5
100%
% of completion


Project 4
Project behind schedule and over budget!

Annex E: Usability Test Session Guide

Usability Test Session Guide
The dashboard you're about to test is comprised by three main sections: logged in time by user and project category; Specific Projects and Tasks; and Schedule and Cost Indicators and Project Health. During the test session, it is highly recommended that you speak whilst you think, indicating when you are starting a tasks within each scenario. This session will be recorded (audio). After you finish a scenario, you should fill in an enquiry associated to that scenario. At the end of this session, you're asked to fill in a system usability enquiry. Thank you for helping improving this system.

Demographical Data	
Age	__ 18-24 __ 25-34 __ 35-44 __ 45-54 __ +55
Gender	Male ___ Female _____
Job Title	
Work experience (in this company)	__ <1year __ 1-2 years __ 3-5 years __ >5 years

Scenario 1 (S1) – Identify the several project categories focused during the analysis period

- Can you identify the number of categories logged in by the team?
- Which categories did Responsible 1 focus time in?
- Which day has more logged in hours by Responsible 2?
- For that day, which category has more hours?

Please, evaluate how much you agree according to the following scale.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

	1	2	3	4	5
In general, I'm satisfied with the easiness that I concluded the tasks.	☐	☐	☐	☐	☐
In general, I'm satisfied with the time that I took to finish the tasks.	☐	☐	☐	☐	☐
Comments					

Scenario 2 (S2) – It is important to know which projects were involved during the period of analysis

- Can you identify which projects are under the category "Customer Maintenance"?
- Which projects were focused by Responsible 2?

Please, evaluate how much you agree according to the following scale.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	1	2	3	4	5
In general, I'm satisfied with the easiness that I concluded the tasks.	☐	☐	☐	☐	☐
In general, I'm satisfied with the time that I took to finish the tasks.	☐	☐	☐	☐	☐
Comments					

Scenario 3 (S3) – Within each project, before making any decision, it's crucial to understand tasks were completed, undergoing and what is the status concerning time and cost.

- Under project "X", can you identify which tasks are completed?
- For the same project, what is the Project Health status for 3 tasks that are undergoing?
- Can you identify the CPI and SPI for each of those tasks?

Please, evaluate how much you agree according to the following scale.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	1	2	3	4	5
In general, I'm satisfied with the easiness that I concluded the tasks.	☐	☐	☐	☐	☐
In general, I'm satisfied with the time that I took to finish the tasks.	☐	☐	☐	☐	☐

Comments

Scenario 4 (S4) – The understanding of the Project Health indicator determines the ability of making a decision regarding a specific project

- Which projects are "over budget"?
- Which projects are in worst condition regarding the costs? Identify the CPI for each of them.
- Which projects are "behind schedule"?
- Which projects are in worst condition regarding the schedule? Identify the SPI for each of them.

Please, evaluate how much you agree according to the following scale.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	1	2	3	4	5
In general, I'm satisfied with the easiness that I concluded the tasks.	☐	☐	☐	☐	☐
In general, I'm satisfied with the time that I took to finish the tasks.	☐	☐	☐	☐	☐

Comments

System Evaluation Enquiry					
Please, evaluate how much you agree according to the following scale.					
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
	1	2	3	4	5
By using this system, I'll improve the project monitoring.	☐	☐	☐	☐	☐
The interaction of these indicators are a good tool for feedback and cross information.	☐	☐	☐	☐	☐
This system will be helpful to reduce project errors when considering time and costs.	☐	☐	☐	☐	☐

Comments

Annex F: System Usability Scale (SUS) Enquiry

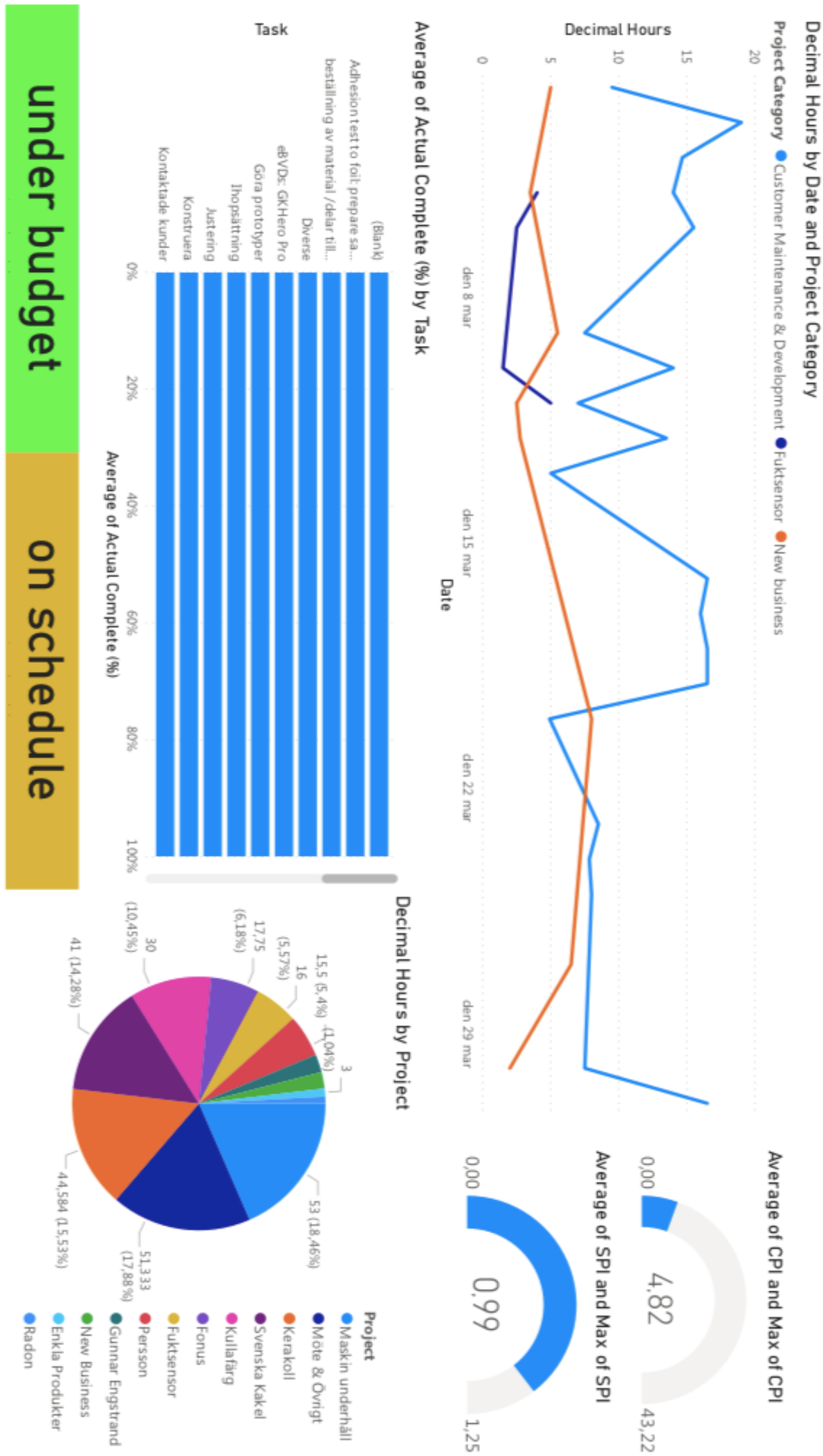
Usability Evaluation

Please, evaluate how much you agree according to the following scale.

	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
I would like to use this system frequently.	☐	☐	☐	☐	☐
I believe this system is more complex than necessary.	☐	☐	☐	☐	☐
I think the system is easy to use.	☐	☐	☐	☐	☐
I think I would need someone experienced to help me using the system.	☐	☐	☐	☐	☐
I think all the functionalities in this system are well integrated.	☐	☐	☐	☐	☐
I think this system has too many inconsistencies.	☐	☐	☐	☐	☐
I think the majority of people would be able to use this system quickly.	☐	☐	☐	☐	☐
I think this system is too complicated to use.	☐	☐	☐	☐	☐
I felt confident when using this system.	☐	☐	☐	☐	☐
I had to learn a lot before being able to use this system.	☐	☐	☐	☐	☐

Comments

Annex G: High fidelity prototype used during tests


Decimal Hours by Date and Project Category
Project Category
Customer Maintenance & Development
Fuktsensor
New business
Decimal Hours
20
15
10
5
0
den 8 mar
den 15 mar
den 22 mar
den 29 mar
Date
Average of CPI and Max of CPI
0,00
4,82
43,22
Average of SPI and Max of SPI
0,00
0,99
1,25
Average of Actual Complete (%) by Task
Task
(Blank)
Adhesion test to foil: prepare sa...
beställning av material /delar till...
Diverse
eBVDs: GKHero Pro
Göra prototyper
Ihopsättning
Justering
Konstruera
Kontaktade kunder
0%
20%
40%
60%
80%
100%
Average of Actual Complete (%)
Decimal Hours by Project
3
(1,04%)
15,5 (5,4%)
16
(5,57%)
17,75
(6,18%)
30
(10,45%)
41 (14,28%)
44,584 (15,53%)
51,333
(17,88%)
53 (18,46%)
Project
Maskin underhåll
Möte & Övrigt
Kerakoll
Svenska Kakel
Kullafärg
Fonus
Fuktsensor
Persson
Gunnar Engstrand
New Business
Enkla Produkter
Radon
under budget
on schedule