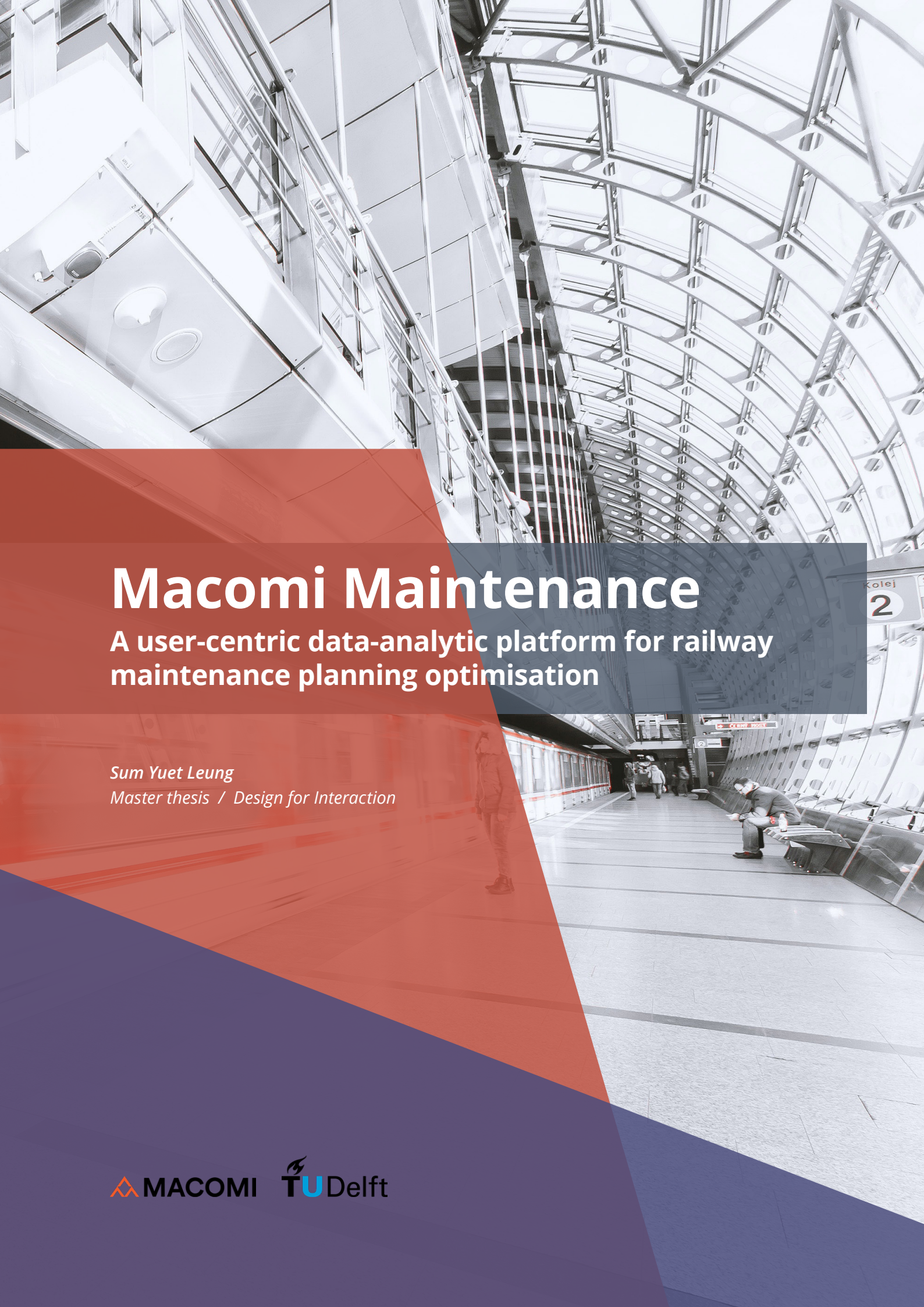

Macomi Maintenance

A user-centric data-analytic platform for railway maintenance planning optimisation

Sum Yuet Leung

Master thesis / Design for Interaction

MACOMI TU Delft

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Master Thesis

Macomi Maintenance: A user-centric data-analytic platform for railway maintenance planning optimisation

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Author

Sum Yuet Leung
MSc. Design for Interaction
Faculty of Industrial Design Engineering
Delft University of Technology

Supervisors

Chair / Jacky Bourgeois
Section / Internet of Things
Industrial Design Engineering
Delft Univiersity of Technology

Mentor / Lyè Goto
Section / Applied Ergonomics and Design
Industrial Design Engineering
Delft Univiersity of Technology

Company mentor / Marina Gerace
Macomi B.V.

External expert support / ProRail
ProRail

MACOMI TUDelft

Executive summary

This thesis project investigated how user-centred design(UCD) contributes to the railway maintenance planning optimisation. A new UX concept and digital prototype were designed to provide intuitive interaction and clear structure to support the planners confidently and independently optimise railway maintenance planning on a digital platform.

This project is under the context of the Dutch railway infrastructure maintenance. With increasing demands for transport on the Dutch railway, optimising maintenance planning for existing infrastructure is challenging for the Dutch railway network management organisation ProRail. Thus, a data-analytic software ProRail Maintenance(PRM) for railway maintenance planning optimisation was developed for the maintenance planners at ProRail. However, as an analytic tool, the outcomes and functions came first for the company while the user experience(UX) was neglected at first, which leads to a series of usability problems and requires much learning time from the users.

Based on the above situation, two initial research questions were proposed: ***"What are the causes of these usability problems?" "Will UCD help to improve the UX of PRM and How?"*** A series of UCD methods were used in the whole process to understand users' needs, generate and iterate concept and the final design was evaluated by the final evaluation test.

The initial goal in the research phase was to understand the context, problems of PRM and causes and users. Literature research was conducted combined with interviews with experts to understand the Dutch railway maintenance planning. By analysing the qualitative and quantitative data collected from interviews and user testing of PRM, a list of problem statements, design goal and requirements were defined. In the design phase, a series of design activities with users(e.g co-creation session, prototype tests) were conducted to generate ideas and iterate the concept by prototype tests with users. By involving users in every stage of the process, I got instant feedback and had a deeper understanding of the users' needs and quickly verify the hypothesis and iterate concept.

The final concept called Macomi Maintenance consisting of four main functional pages: Homepage, Input, Analysis and Result. It covered the main operations needed to optimise the planning, which achieved an excellent usability performance evaluated by 8 participants in the online evaluation tests. It was found that showing information in an organised way(in this case I used cards and tabs) and provide enough guidance helped to reduce the time and fear of learning new software. All participants could finish the assigned tasks without hints in the evaluation test and show more willingness and confidence to learn Macomi Maintence.

ABBREVIATION

UCD
User-centred Design

TVP
Train free period ('Treinvrije periode' in Dutch)

PRM
ProRail Maintenance

TWAS
Future-proof work on the railways
('Toekomstbestendig werken aan het spoor' in Dutch)

UX
User Experience

IDE
Industrial Design Engineering

TPM
Technology, Policy and Management

Low-fi
Low fidelity

High-fi
High fidelity

SUS
System Usability Scale

VisWAI-S
Visual Aesthetics of Websites Inventory-Short

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01 INTRODUCTION

This chapter introduces the initial project context, problems and the research and design approach used in this thesis project.

Overview

1.1 Project introduction

This project was initially proposed by Macomi, a business consulting company based in Rotterdam, aiming at improving the user experience(UX) of its data-analytic platform: Macomi platform. There are three main tools in the platform respectively focus on optimising railway operation, railway maintenance planning and workforce planning.

This initial proposal was quite broad for me as each tool is quite complex and professional and it would be too hard for me to design for the entire platform within a few months. After learning the commons and differences between these tools and discussing with my supervisors, I decided to focus on ProRail Maintenance(PRM), one of the data-analytic tools in the Macomi platform which focuses on optimising railway maintenance planning. Compared to the other two tools, it would be easier for me to involve the client of PRM (ProRail, the Dutch railway management organisation) and conduct research activities with the end-users as Macomi still has a close collaboration with them.

Thus, this thesis is based on the background of the Dutch railway infrastructure maintenance planning. The Netherlands owns one of the most modern yet densest railway networks in the world and railway maintenance is crucial for the safety and availability of the railway system. As the demand for passenger and freight transport by railway is increasing rapidly, ProRail has invited Macomi to create an analytic software for optimising the railway maintenance planning in 2018.

Macomi has successfully designed ProRail Maintenance(PRM), the analytic software that met the goal of maintenance planners at ProRail. As an analytic tool, the outcomes and functions come first for the company while user experience(UX) was neglected at first. However, the usability problems of PRM has become noticeable gradually due to the complexity of the system. Thus, the initial research questions were proposed: ***"What are the causes of these usability problems?" "Will user-centred design(UCD) help to improve the UX of PRM and How?"***

This thesis focuses on understanding the behaviours and discovering the potential needs of the railway maintenance planners, in order to redesign the UX of the tool to provide a more intuitive and supportive experience for the planners. By introducing a series of UCD methods(e.g. interviews, co-creation, user tests, etc.), it helps to discover the causes of usability problems, find potential opportunities and iterate the design.

1.2 Approach

This project mainly utilised User-centred design (UCD) methods combined with the Double Diamond design process(Design Council, 2019). UCD is an iterative design process focusing on the users and their needs and it is important to involve the end-users for every stage of the design process(Interaction Design Foundation, n.d.).

By introducing UCD, I used various research methods(e.g. interview) to understand the context and users, invited users to generate ideas (e.g. brainstorming, co-creation) and evaluate concepts with the end-users(e.g. iteration prototype testing, evaluation test). In this case, I could better understand the users' needs and got quick feedback(positive and negative) on my ideas which helped to iterate and improve the research direction and design.

This project mainly followed the Double Diamond design process(Design Council, 2019), which could be summarised as four phases: Discover, Define, Develop and Deliver (Figure 1). The process was not completely linear from left to right, as small sprints were going back and forward between activities in different phases to help validate and iterate insights.

Discover

The goal of this phase was to understand the context, discover problems of the current situation and explore design opportunities. Interview with experts at Macomi combined with literature research was used to understand the context knowledge about railway transport, railway maintenance planning, data analytics and the mechanisms of PRM.

After understanding the background knowledge, user-research methods(e.g. contextual interview, user-testing, etc.) were used to understand user behaviours, needs and motivation(Usability.gov, 2013) and discover problems of the current PRM. By conducting contextual interviews and user-testing with users, I could understand how the end-users use the tool in the real environment, what problems they were facing and their needs.

Define

In this phase, all data and information gathered in the first phase were analysed. The goal of this phase was to extract useful insights to define problem statements and design goal.

Stakeholder mapping was used to visualise the connection between various stakeholders involving in using the PRM, from which I could identify their motivation and the main end-users who are actually interacting with PRM. Persona was a vital method for defining target users and their qualities. At the end of this phase, problem statements and ideal situation were summarised, based on which a design goal and a list of design requirements were created as criteria for designing and evaluating.

Develop

The Develop phase was diverging in which ideas and concepts were generated. In this phase, Co-creation and prototype test with users were used for generating ideas and iterating concepts.

Co-creation helps to generate fresh ideas from different perspectives and more likely to create better ideas that are based on users' needs (Fournier, 2019). Concepts created from Co-creation sessions were demonstrated as low fidelity(low-fi) prototype and evaluated in prototype tests with users. Low-fi prototype test helps to evaluate ideas and hypotheses in the early design stage and get feedback on the flow quickly, through which I could gain insights efficiently and iterate the concept.

Deliver

Deliver is the final phase of the project, which aimed at delivering the final design and results of the evaluation. In this phase, a high fidelity(hi-fi) interactive prototype and wireframes were created to demonstrate the final design.

Prototype tests were conducted with the target users to evaluate whether the final design has achieved the design goal and requirements. The results of the evaluation were analysed and demonstrated by qualitative and quantitative results. The System Usability Scale(SUS) and the Visual Aesthetics of Websites Inventory-Short(VisAWI-S) were used for assessing the usability and aesthetics of the design from the quantitative perspectives while interviews and observations were used to gather qualitative insights.

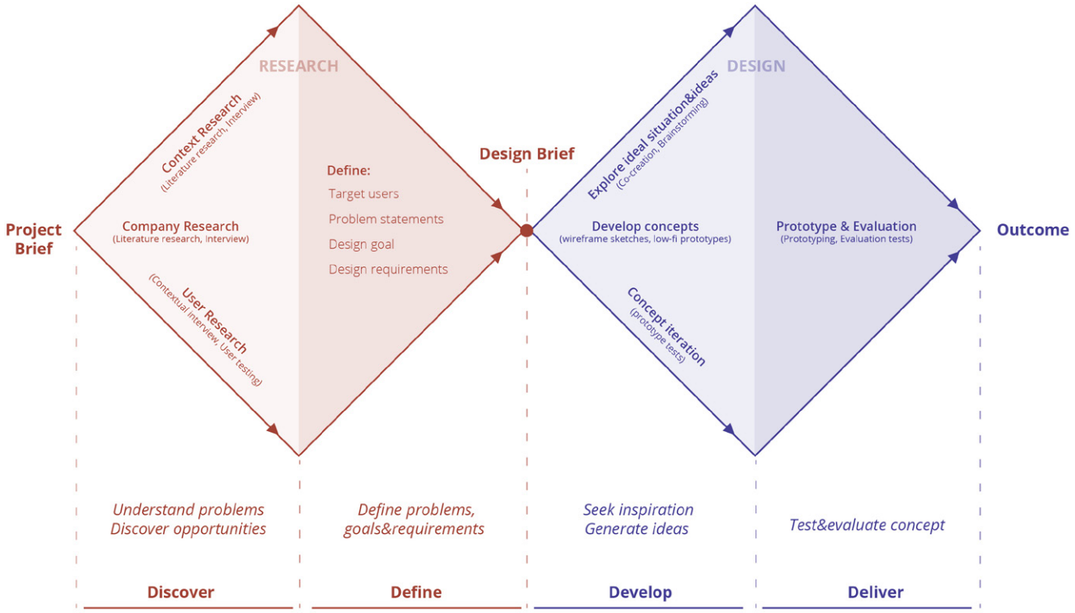


Figure 1. *Overview of the project design process*

02 CONTEXT RESEARCH

This chapter introduces the background knowledge about this project. It starts with an introduction to the current Dutch railway system, explaining how the infrastructure maintenance planning works and influences the railway system in the Netherlands. Knowledge about Data analytics is introduced for the audience to have a brief understanding of how data analytics works and helps to optimise maintenance planning.

Overview

2.1 The Dutch railway system

2.1.1 The Dutch railway network

Rail travel comprises the majority of the distance travelled on Dutch public transport(Wikipedia, 2020e), with the rail network spanning more than 7300 kilometres in the Netherlands (Leijen, 2018). The national rail network is managed and maintained by the railway infrastructure management organisation ProRail and train operators like NS(Nederlandse Spoorwegen = 'Dutch Railways' in English) (Wikipedia, 2020b) ProRail manages 7,021 kilometres of track in the Netherlands from Eijsden to Den Helder and from Roodeschool to Vlissingen (Figure 2). The tracks equipped are with 2,589 level crossings, 1598 of which are secured, 7,071 points, and 12,036 signals(ProRail,2019).

As a densely populated and highly developed country, the Netherlands owns a very dense and modern infrastructure supporting transport with the road, rail, air and water networks. (Wikipedia, 2020) In the 2019 Global Competitiveness Ranking, the Netherlands ranked fourth globally with transport infrastructure got the second place in the Infrastructure index. (World Economic Forum, 2019)

Figure 2. *Dutch rail network map (ProRail, 2020)*

2.1.2 The Dutch rail transport

Rail transport is a means of transferring passengers and goods on wheeled vehicles running on rails, which are located on tracks(Wikipedia, 2020a). The Dutch railway network primarily supports passenger transport while partial freight transport also relies on the railway network (others rely on road transport or ship transport).

Passenger transport

In 2015, travellers make 1.1 million train journeys per day on average with a total of 152 million kilometres (ProRail, 2019), while the total number of passengers in 2004 was 129 million(Kruidhof, 2018), which indicates a huge increase in the past ten years. As ACM(The Netherlands Authority for Consumers and Markets) predicted, the number of passenger-kilometres is expected to grow by around 14% between 2017 and 2023(ACM,2019)

Freight transport

Over 41.5 million tones of goods were transported on Dutch railways in 2018, showing a considerable increase compared to 2017 (Gompel, 2019). Although rail freight companies were worried about losing their competitive positions as they might need to spend more expenditure on getting access to railway services and facilities from ProRail, the Dutch Ministry of Infrastructure and Water Management has announced a series of measures for rail freight transport(e.g. provide subsidies in the period 2019-2023), in order to align the rates of the infrastructure charge with those in neighbouring countries (ACM, 2019). Therefore, the needs of freight rail transport are expected to grow in the next few years.

2.1.3 Challenges for the Dutch railway management

The railway system is complex and divided into infrastructure and rolling stock (for passenger and freight). The infrastructure system is usually divided by different technical branches i.e. track, electrical system, signalling system, and telecom system, which are managed by ProRail. All these branches varying functional needs put challenging demands on the railway management (Lichtberger, 2005)

Although the Netherlands has the world-leading rail infrastructure, there is a noticeable challenge for the railway manager: How to deal with the conflict between the increasing need for rail transport and the limited capacity of the current railway infrastructure?

Back in 2012, the Dutch railway network was almost reaching its maximum utilisation given the current infrastructure and process design, while the Dutch railway sector aimed to have 50% more trains and 20% fewer costs by 2020 (Middelkoop et al., 2012). However, there is nearly no room for building new railway lines and optimising the use of the current network seems the only way to handle more train traffic(Leijen,2018). Thus, it is crucial and challenging for planners at ProRail to optimise the operation and maintenance planning to achieve high safety and a low hindrance to passengers and goods transport with given resources in the near future.

2.1.4 Dutch railway management organisation-ProRail

ProRail is an independent Dutch organisation closely working with the government and transport operators, who is mainly responsible for the management of the Dutch rail network. The goal of ProRail is to provide a 'reliable and safe rail network with sufficient capacity for passenger and freight transporters.' (ProRail, 2020) .

ProRail manages 7,021 kilometres of track and numerous railway asset. There are three main organisations at ProRail that are mainly responsible for the performance of the rail network: Transport and timetables, Projects and Operation. (ProRail, 2020a)

Transport and Timetables

This department mainly focuses on the customer relationship with carriers, the distribution of rail capacity and the optimal utilisation of the track.

Projects

Projects is in charge of railway projects, construction and renovation of stations.

Operation

Operation is responsible for the availability, reliability and safety of tracks, maintenance and daily supervision of train traffic to optimise the use of the available resources.

As the demand for passenger and freight transport is increasing rapidly, and the railway market is defined by demand and supply of rail path availability, both transport operators and ProRail's maintenance requirements are competing for availability in this market. (Leijten & Koppenjan, 2010)

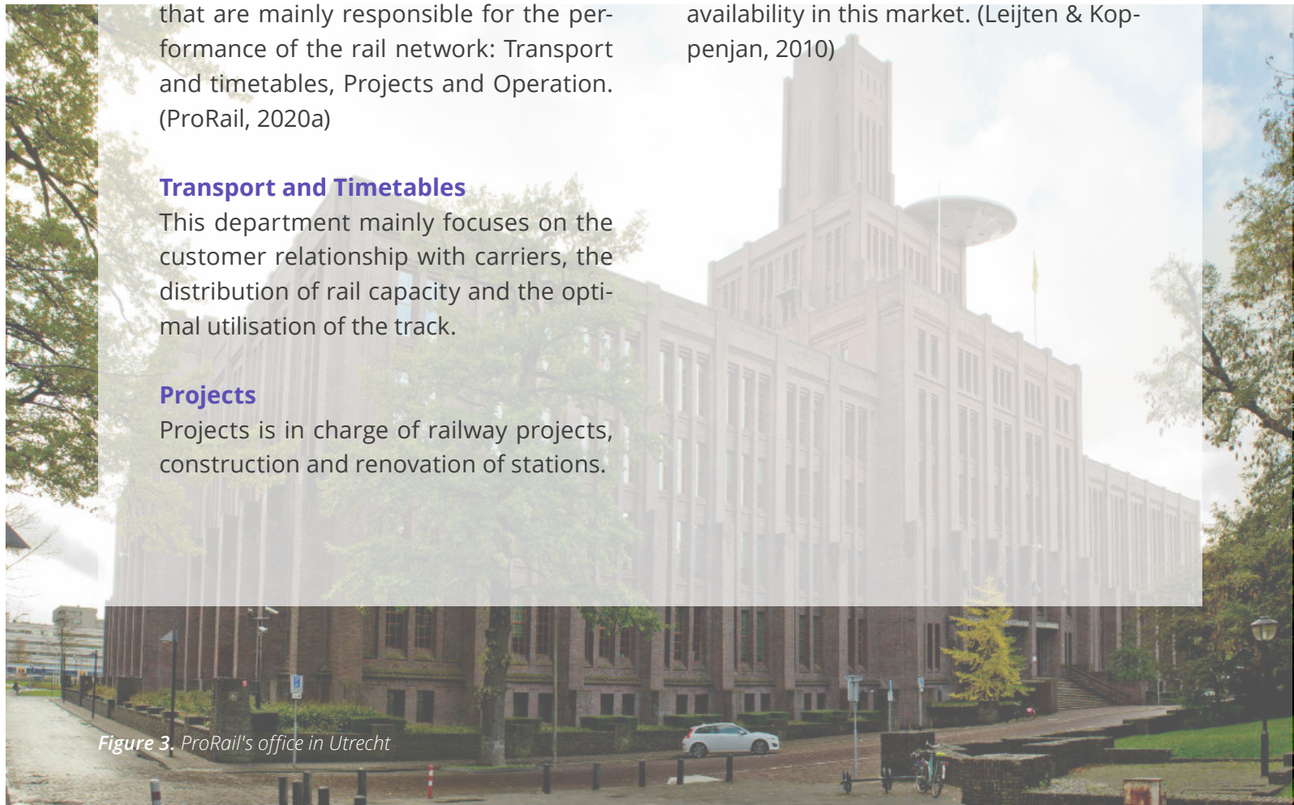


Figure 3. *ProRail's office in Utrecht*

2.2 Railway infrastructure maintenance

2.2.1 Railway maintenance activity

Railway maintenance is crucial for the safety and availability of the railway system. Railway maintenance activity aiming to maintain something in good working order, prevent operational disturbance and/or uphold a given technical standard (Lidén, 2016). The European standard EN 13306 for maintenance terminology divide maintenance into the terms ***preventive*** and ***corrective*** maintenance, for work taking place before and after a failure that has been detected.

Preventive maintenance

Preventive maintenance is a task that uses regular maintenance intervals or inspections to monitor the conditions of the railway and carry out the preventive operation before a failure occurs. (railwaysignalling.eu, 2017) Preventive maintenance can help to enhance crucial equipment productive life, reduce critical equipment breakdowns, allow better planning and scheduling of needed maintenance work and so on. (Dhillon, 2002)

Corrective maintenance.

Although preventive measurements have been taken to make the system as reliable as possible, there could be unexpected deficiencies from time to time. Corrective maintenance is executed when unpredictable failure happens and urgent measurements are needed, for instance, fixing short circuits, repairing broken fasteners, work after accidents etc. (Lidén,2016)

2.2.2 Railway infrastructure maintenance

Railway infrastructure consists of several sub-systems (track, power distribution, interlocking etc) that are spread out over vast geographic distances and which all must function properly. (Lidén, 2016)

Travelling safely and comfortably on high-speed railway lines requires excellent conditions of the whole railway infrastructure. The maintenance process required to achieve such excellent conditions is largely complex and expensive, demanding an increased amount of both human and technical resources(Quiroga & Schnieder, 2010).

2.3 Railway infrastructure maintenance planning

2.3.1 TVP Planning and stakeholders

TVP ('Treinvrije periode' in Dutch) planning is a method used at ProRail to plan and schedule preventive maintenance activities for the Dutch railway infrastructure. 'TVP' represents 'Train free period' in English, which means a period in time where trains cannot run, as trains are not allowed on the track(or even adjacent tracks) during maintenance time (Lidén, 2016).

TVP planning was done by timetable planners who are responsible for planning all the maintenance activities. Traditionally, TVP planning was made by planners manually in Excel and mainly focus on capacity and availability. Planners would collect data and project requests from the project management team(who propose maintenance projects) and plan all the maintenance activities for a year in a timetable, which usually took 4-6 months for a couple of planners together. With given constraints and their rich experience, planners aim to make a plan that has as less hindrance to passengers and goods transport as possible.

Usually, the planners need to discuss and communicate with different stakeholders: project managers, external stakeholders like NS and decision-makers at ProRail to get feedback from various perspectives(Figure 4).

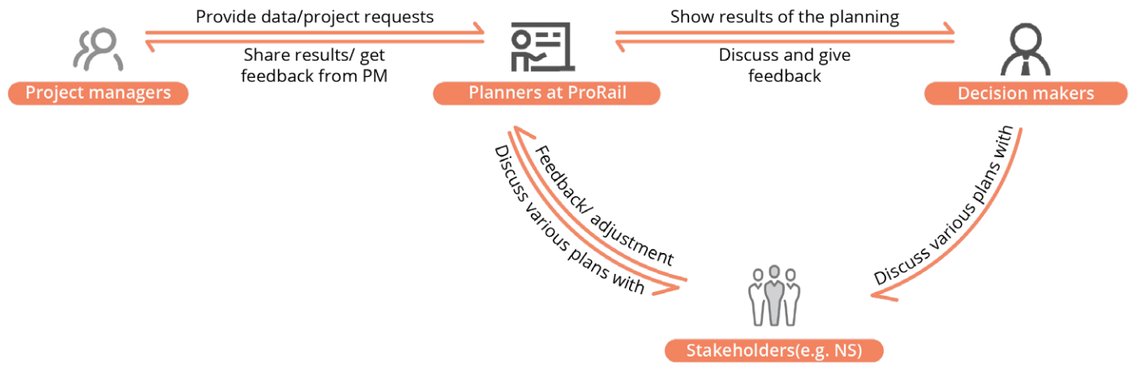


Figure 4. *Main stakeholders involving in TVP planning*

2.3.2 Data for TVP planning

To make TVP planning, a series of input data is needed. These data can be sorted into four categories: ***Project requests, Data on availability, Routing data, Cost data*** and ***Scenarios(Constraints).***

Project requests

A project request is usually created by project managers at ProRail, using a set of quantified data to describe a project. It included information such as type of work, length of the track, location, duration of a maintenance project, start and end date&time, day type, degree of the nuisance, implementation costs, critical resources risk, impact, etc.

Data on availability

Data on availability describe the impact and inconvenience of TVP per transport type and execution time.

Routing data

Routing data provided Path and location data to calculate detour routes for passenger flows. Since trains are not allowed on the track during maintenance time, ProRail needs to rearrange the transportation between the places.

For instance, there is a maintenance project scheduled from A to B, so the train is not allowed to travel directly between them. To ensure passengers can still travel between A and B and lower the dissatisfaction, a plan of travelling from A-C-B is needed(Figure 5) These plans and impact for the rearrangement also need to be considered.

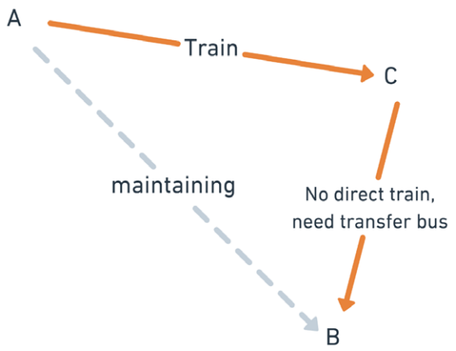


Figure 5. *An example of how ProRail might rearrange the transport plan for a maintenance project*

Cost data

Cost data illustrates the effect of the number of affected travellers on transport costs and the effect of day type & time on implementation costs (contractors).

Scenarios(Constraints)

The scenario consists of various settings assigned by the users with constraints as one of the most important settings. Constraints are a series of rules set to limit the planning. Constraints such as 'Maximum applications simultaneously at a location' could be used to limit the number of maintenance projects at the same location. 'Events' is also another important for the planner to set a time slot and location for big events(e.g. King's day). Since many people would be travelling around the Netherlands when big events were held, it should avoid planning big maintenance activities during that time.

Constraints are divided into different severity: ***Hard, Warning, Soft*** and ***Exclude***. Basically, a hard constraint should not be broken while Soft constraints leave more space for broken rules (consider there were thousands of maintenance planned for the entire country, it was near impossible to have zero broken constraint even with the optimal plan).

2.3.3 Output of the TVP planning

When TVP planning is finished, various outcomes were generated. One of the most important outcomes of the planning is maintenance timetable (Figure 6) The timetable was manually made by the timetable planners in Excel, which demonstrates which maintenance projects would be executed on which tracks during which time period.

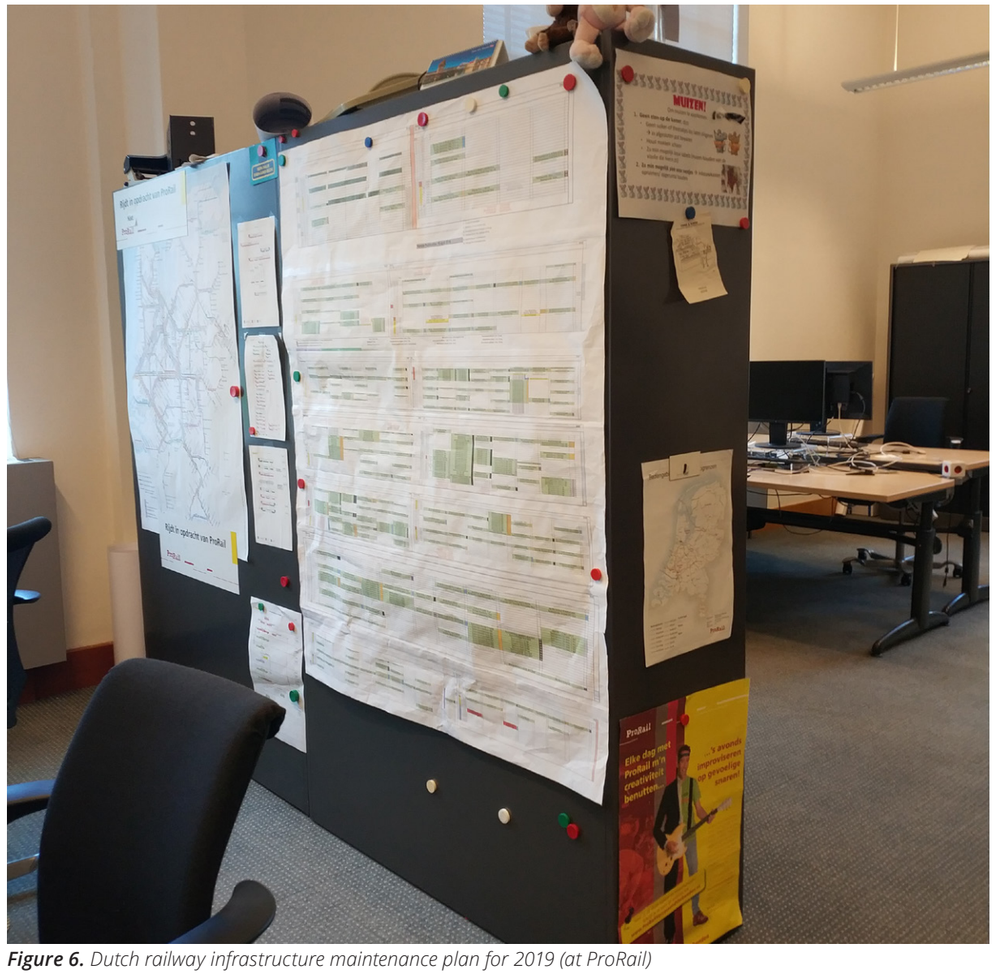


Figure 6. *Dutch railway infrastructure maintenance plan for 2019 (at ProRail)*

2.3.4 Limitation of the conventional TVP planning

As has mentioned before, an annual nationwide TVP planning made by hand is time-consuming. Planners can only deliver one planning variant and can not compare various scenarios to evaluate or optimise the plan within the given time. Also, traditional TVP planning was primarily focusing on minimising passenger hindrance while optimisation in terms of cost has not yet been achieved due to time constraints.
Furthermore, it was nearly impossible for planners to generate conflict-free planning as more than 1000 activities needed to be planned yearly nationally. Thus, the quality of the planning can not be verified with hard numbers.
Thus, ProRail decided to integrate data analytics and intelligent algorithms into the planning process to find the optimal balance between restrictions for passengers and freight and costs.

2.4 Data analytics

2.4.1 What is Data analytics?

Data analytics is the science of analysing raw data in order to make conclusions about that information. (Frankenfield, 2019) The process of data analysis can be framed by the DIKW(Data, Information, Knowledge, and Wisdom) hierarchy model from bottom to top (Figure 7)

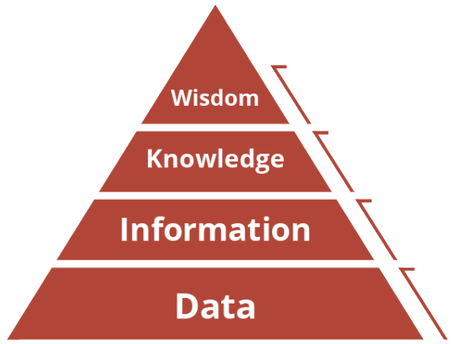


Figure 7. *DIKW hierarchy (Ackoff, 1989)*

Data
The first layer of the model is Data, which is unstructured raw data like signals or symbols. Data can be any type of materials that can be collected(e.g. notes, numbers, pictures, etc.), which is scattered and basically has no meaning.

Information
Information is interpreted by people based on the collected data, which is structured and has meaning chosen by people through classification frameworks (Sanders & Stappers, 2018) Thus, information is data with meaning while not all information is useful for us.

Knowledge
After generating Information, we can use and organise the information to discover patterns and theories, which happens at the layer of Knowledge. Knowledge is a foundation for building predictive models and helps to extract useful insights.

Wisdom
Wisdom is the final layer of the model, which is about the actionable decisions and know the 'Why' of these decisions based on the knowledge that was found. Wisdom is about the future, it helps to shape 'gut feeling' and intuition and predict the future correctly. (Figueroa, 2019)

2.4.2 Types of data analytics

Data analytics techniques can be categorised into four primary types: Descriptive, Diagnostic, Predictive and Prescriptive analytics. (Frankenfield, 2019)

Descriptive analytics
Descriptive analytics describes what has happened and provide insights into past performance. This process requires the collection of relevant data, processing of the data, data analysis and data visualization. By developing specialised metrics, this type of analysis can summarise data and describe outcomes to stakeholders.

Diagnostic analytics
Diagnostic analytics focuses more on why something happened. Based on the outcomes of descriptive analytics, it digs deeper to discover the reasons for success or failures. This analytic usually process in three steps: Identify anomalies in the data, Collect data that is related to these anomalies and use statistical techniques to find relationships and trends that explain these anomalies. (What Is Data Analytics?, 2020)

Predictive analytic
Predictive analytics helps to predict what will happen in the future. This analytic uses historical data to ascertain trends, which usually involves various statistical and machine learning techniques.

Prescriptive analytics
Prescriptive analytics provide recommendations on what should be done for the predicted outcomes. Theoretically, a combination of machine learning, business rules, artificial intelligence and algorithms will be used to find patterns and simulate various approaches to the outcomes and the optimal potential plan would be recommended for the stakeholders to optimise their business. (McDaniel, 2019b)

2.4.3 Benefits of data analytics

Data analytics helps to save time for stakeholders to understand the meaning of data, figure out what is going on, what will happen and what they should do to cope with the potential situation. It supports decision-makers to find out and understand problems more efficiently and leave more time for them to make decisions and create better plans to optimise their business system. Furthermore, for prescriptive analytics, it reduces human error or bias with the help of advanced algorithms.

2.5 'TWAS' programme

2.5.1 The goal of the 'TWAS' programme

'TWAS' ('Toekomstbestendig werken aan het spoor' in Dutch) is a programme set by ProRail in 2018, which means 'Future-proof work on the railways' in English. The goal of this programme is to achieve an optimal maintenance plan on the rail network that strikes the right balance between hindrance to passengers and freight, reliability of the track, and implementation costs. (Macomi, 2020)

To achieve the goal of the programme, ProRail has set the following requirements:

1. ***support various planning scenarios to determine the optimum***
2. ***Consider and process a variety of restrictions, e.g. detour routes and binding planning periods***
3. ***With critical resources such as by-pass available professionals***
4. ***Process data in real-time in a live cloud-based production environment through direct integration.***

2.5.2 Participants of the 'TWAS' programme

To reach the goal and requirements of the programme, a couple of project managers, planners and data professionals at ProRail were gathered together. Besides, an external consulting company(Macomi) who specialises in advanced business analytics, was an important role in this programme, specifically for designing intelligent algorithms for TVP planning.

2.5.3 Results of the programme

As a result of the 'TWAS' programme, a maintenance planning optimisation software - ProRail Maintenance(PRM) was created. Macomi has successfully utilised the specialised optimization algorithm to assist ProRail to optimise planning. This algorithm can evaluate more than 3 million schedules in a short period (Macomi, 2020). In the past, it took months for several planners to make a plan while PRM can generate optimised planning in hours. Planners are not only able to see the impact of planning on hindrance but also compare different scenarios to get the optimal balance between availability, reliability and costs.

PRM was put into use and has successfully help ProRail to reduce passenger hindrance by 35% and the total cost of the entire construction plan by 10% for one year compared to the original manual planning (Macomi, 2020).

Eric Thieme, a programme manager at ProRail said:

"In an ever-changing rail world where scarcity dominates the game, optimisation algorithms can help to always make the best choices."

"Macomi has helped ProRail make the railways affordable, available and reliable. The enthusiasm of the planners for the new possibilities when using this first tool is the best indicator for me that we are on the right track."

The functionality and quality of PRM have been acknowledged by the team of ProRail planners, which showed that the application of PRM in the railway maintenance domain is valuable and promising.

Although PRM has successfully assisted ProRail to optimise the maintenance planning, some problems have become noticeable for the users gradually. PRM provides a lot of functionalities but it is also very complex and not user-friendly enough. As the developer of PRM, Macomi needs to provide tutorial workshops and weekly technical support in the past year for the planners at ProRail to assist them to use the software. Therefore, it would be valuable for Macomi to think about how to improve the software and provide a better experience for the current client(PRM) and potential clients.

2.6 Conclusion

This chapter gives an introduction to the current situation of the Dutch railway, which challenges the Dutch railway manager ProRail has been facing and how they coped with these challenges by using data analytics.

The Netherlands owns one of the busiest railway networks in the world while the demands of railway transport are increasing rapidly these years. As there is almost no place for building new railway infrastructures, it is crucial and challenging for ProRail to manage the availabilities and capacities of the infrastructures. Therefore, planning railway infrastructure maintenance activities is vital as maintenance closely relates to safety and availabilities of the railway.

To cope with this challenge, ProRail partnered with Macomi to build a data-analytic software(PRM) for optimising railway maintenance plannings that strikes the right balance between hindrance to passengers and freight, reliability of the track, and implementation costs in a short time. PRM has achieved the goal while the complexity of this software and usability problems have become gradually obvious.

As the developer and supporter of PRM, Macomi was looking for a new design to improve the UX of PRM, which was the initial goal of this thesis project. In order to do so, it is important to understand the problems and needs of the users. Thus, in the next chapter, I focused on conducting research activities at Macomi and ProRail to understand the current situation and problems from various perspectives to identify causes of problems and discover design opportunities.

03
DESIGN RESEARCH

After understanding the background knowledge of the project, it is time to understand the users and the tool in the real context. This chapter is about the research activities conducted at ProRail and Macomi and insights about how the (potential) end-users interact with the tool currently and how they envision the ideal design.

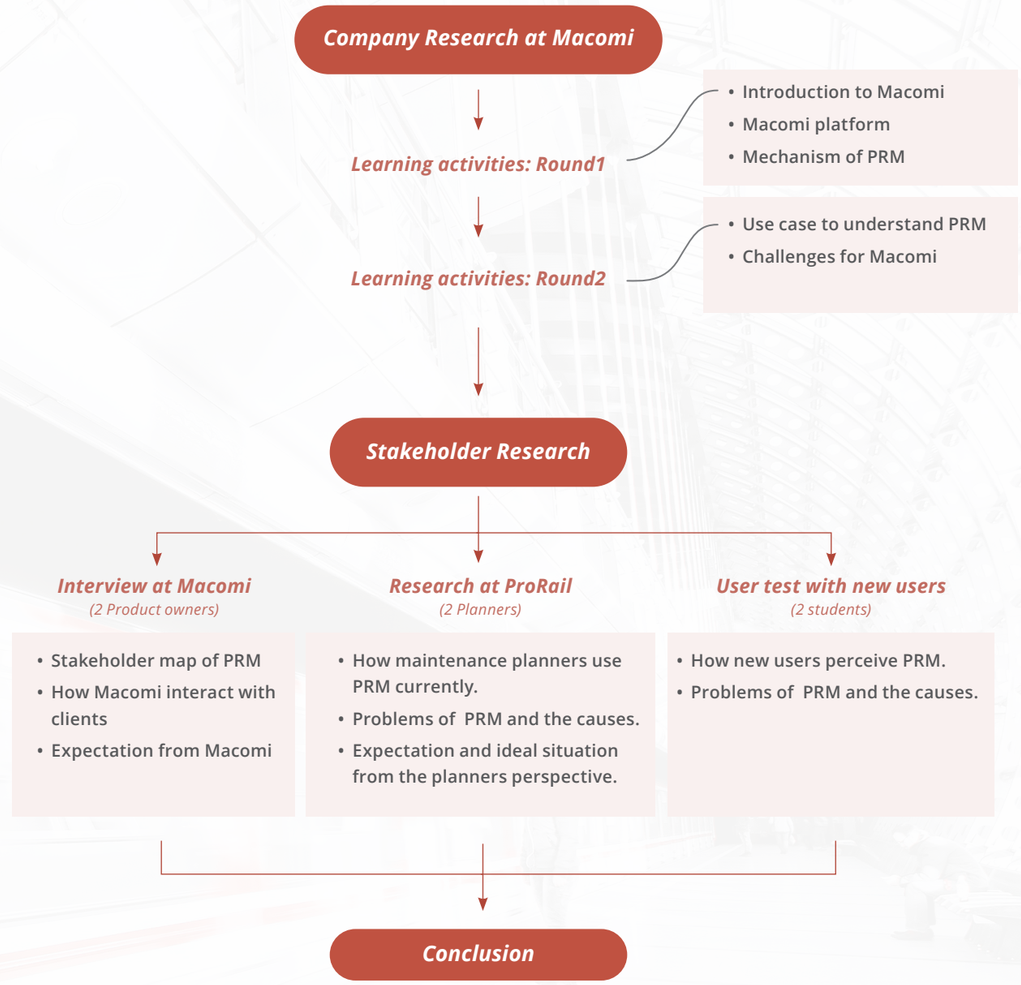


Figure 8. *Overview of Chapter 03: Design Research*

- The gray texts in the coloured box are the learning objectives of the research activities

OVERVIEW

3.1 Company research-Macomi

3.1.1 Research goal and approach

Macomi is one of the most crucial stakeholders in this project, who has joined the 'TWAS' programme and designed PRM for ProRail to optimise the railway maintenance planning. Therefore, it is important to understand who is Macomi, how does PRM work and what problems Macomi is facing. Thus, the goal of company research was to find the answer to the following questions:

1. ***What types of service Macomi can provide?***
2. ***How does PRM work?***
3. ***What are the challenges for Macomi?***

In this phase, two rounds of learning activities were set. The first round started with an introductory presentation given by the product owners explaining what Macomi does and the basic mechanisms of PRM and terms or scenarios in railway maintenance domain. The second round started with a demonstration of using the tool with a typical case by the project owners to show how they expected to use PRM in a real context.

After the demonstration or presentation, I would summarise insights combined with literature study and present to the project owners at the end of each sprint. In this case, I could verify the insights and iterate my knowledge.

3.1.2 Result1: Introduction to Macomi

As one of the active participants of the 'TWAS' programme cooperated with ProRail, Macomi has designed the algorithm and created PRM based on the Macomi platform(an analytics platform built by Macomi), to help ProRail achieve the goal of the programme.

Macomi is a business consulting firm in Rotterdam in the Netherlands and specialises in advanced analytics. It has a group of scientists, engineers and consultants who are expert on transport, logistic and workforce planning. Macomi works with its clients to foresee the future of their business environment and help them optimise resources, processes, and competencies to strengthen and sustain their competitive advantage. (Macomi, 2019)

3.1.3 Result2: The Macomi platform

The Macomi platform is an innovative platform built by Macomi for data analytics and helps companies to tackle their analytic business challenges. It contains different analytic tools for different industries and leverages data and process maps to understand, forecast, and optimise business. (Macomi, 2019a)

The essence of the Macomi platform is customised algorithms for different business challenges. With specialised algorithms and simulation, the Macomi platform can generate predicted future scenarios based on given input data and constraints from companies. By comparing different scenarios, it helps to propose optimal planning through various types of dashboards or tables for decision-makers.

3.1.4 Result3: Analytic tools in the Macomi platform

As has mentioned before, Macomi is experienced with transport, logistic and workforce planning, thus, the Macomi platform contains three main tools that support the analytics for these domains: Railgenie, ProRail Maintenance and Staffgenie (Figure 9)

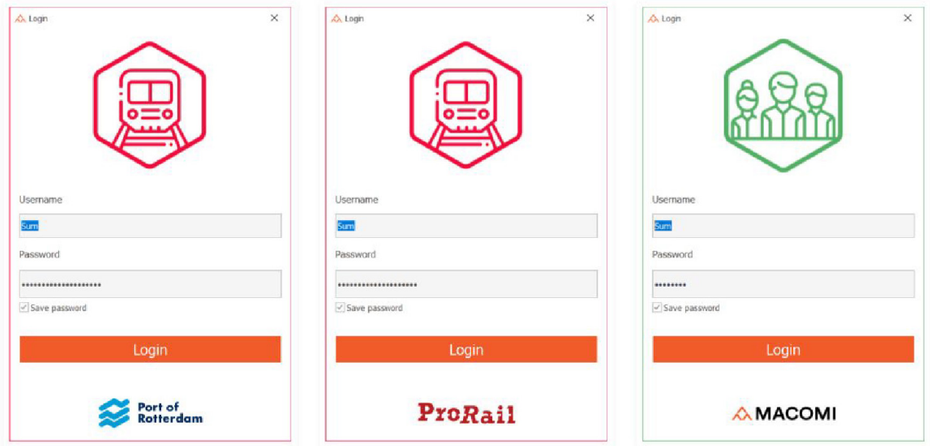


Figure 9. *Login page: (from left to right) Railgenie, ProRail Maintenance and Staffgenie*

Railgenie

Railgenie is mainly focusing on the analytics for railway operations. The tool enables to improve rail operations, railway infrastructure, rolling stock, control and logistics throughout the entire lifecycle. The tool helps to determine whether the infrastructure can cope with future train frequencies; assess the impact of new infrastructure projects on future operations; Explore novel ways of managing how volumes are being transported and assets maintenance needs and risks.

ProRail Maintenance(PRM)

PRM is designed for optimising the planning of railway infrastructure maintenance activities. It aims to strike the perfect balance between availability and costs and propose optimal maintenance planning for planners.

Staffgenie

Staffgenie is an analytic tool for companies to analyse their current personnel situation and predict future scenarios and potential personnel shortage. With prescriptive analytics, it helps companies and organisations to better allocate their human resource and optimise business strategies.

These tools help companies to better utilise (large amount of) data and predict the future by simulating the future and manage to provide evidence for decision-makers to optimise their strategy.

3.1.5 ProRail Maintenance(PRM)

PRM is a satisfying result of the 'TWAS' programme, which has helped timetable planners at ProRail to iterate and optimise the TVP planning. The mechanism of PRM can be simplified as Figure 10. A series of input data for TVP planning and constraints were collected and imported to PRM by the planner, then the algorithm would work on minimising costs and maximising availability to calculate optimal maintenance planning. When the analysis was finished, various outputs would be generated and shown through tables or visuals.

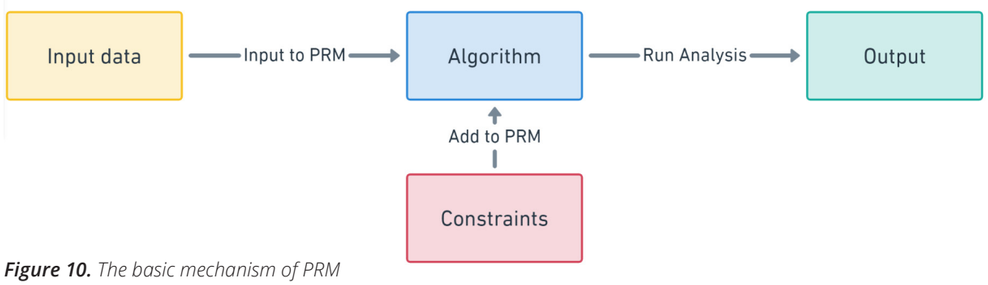


Figure 10. *The basic mechanism of PRM*

Open the tool

The tool starts with the main view of an overview of the dataset and a list of the dataset on the left. Basically all the operations are listed in the toolbar on top of the tool (Figure 11).

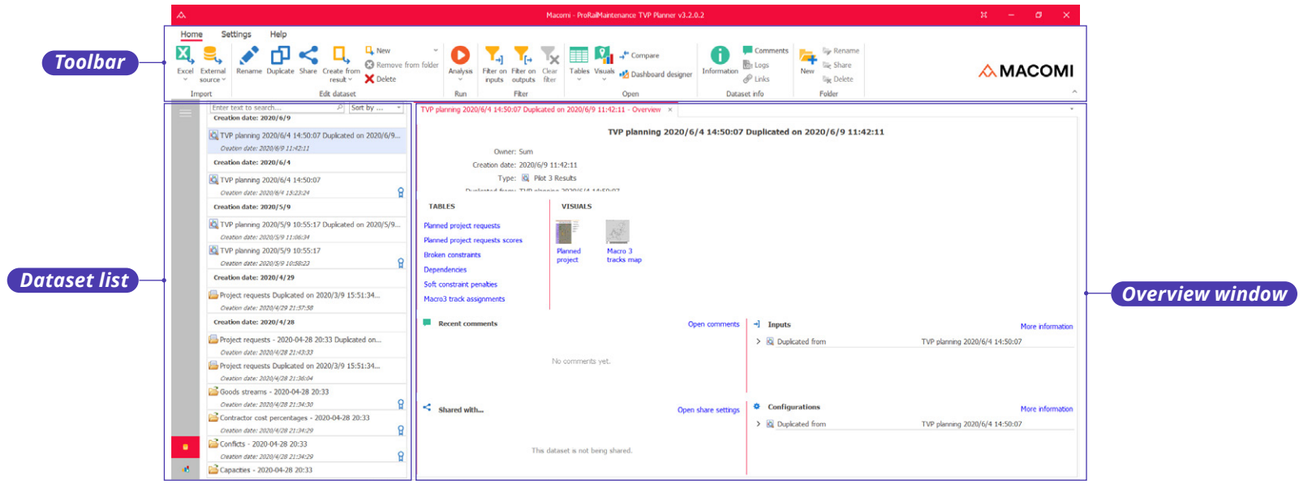


Figure 11. *The first page of PRM*

Import data

When the user first opens PRM, he/she needs to first import data into PRM as the input data for making new analysis. There are two ways to import input data: Import Excel file from the computer and Import from External source(Figure 12).

Creating Excel files and then importing into software is common while many companies may have their own database which could be used as input data. In this case, the user can import from External source to import data from their own database through data pipelines(Data pipelines help to transmit different formats of data into the one that fits PRM)

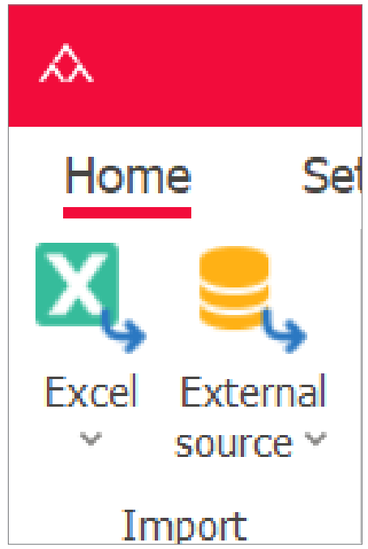


Figure 12. *Import buttons for importing data into PRM*

Make a new TVP planning

After a user imported input data to PRM, he/she can make a new TVP planning by selecting the right input data needed for the planned period and setting the configuration for the analysis (Figure 13)

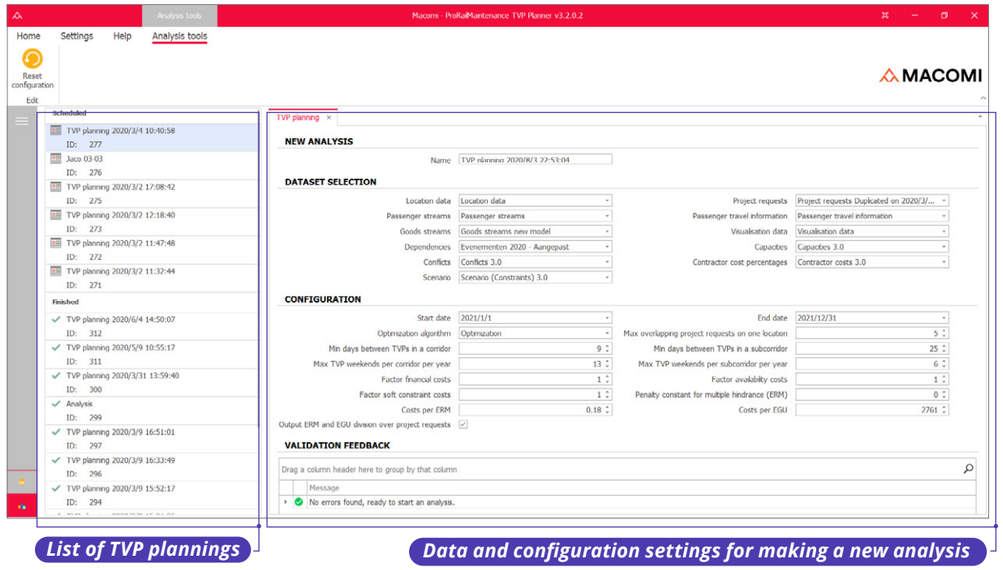


Figure 13. *The page for making a new TVP planning in PRM*

Check output

When an analysis is finished, the user can find the TVP planning in the dataset list. The outputs can be roughly divided into two groups by types: Tables and Visuals (Figure 14)The 'planned project requests Gantt' was regarded as one of the most important and interesting results for planners (Figure 15).

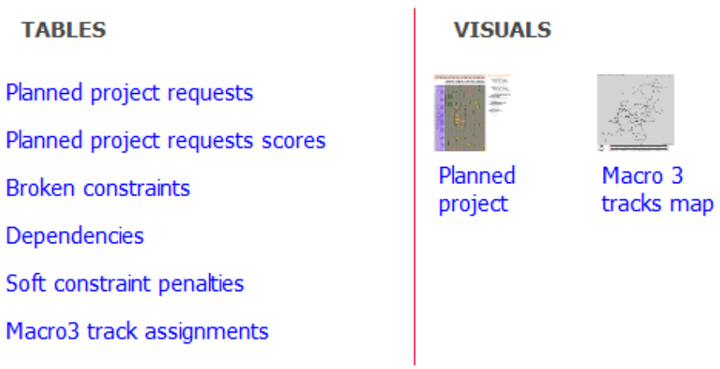


Figure 14. *Overview of the results of a TVP planning analysis in PRM*

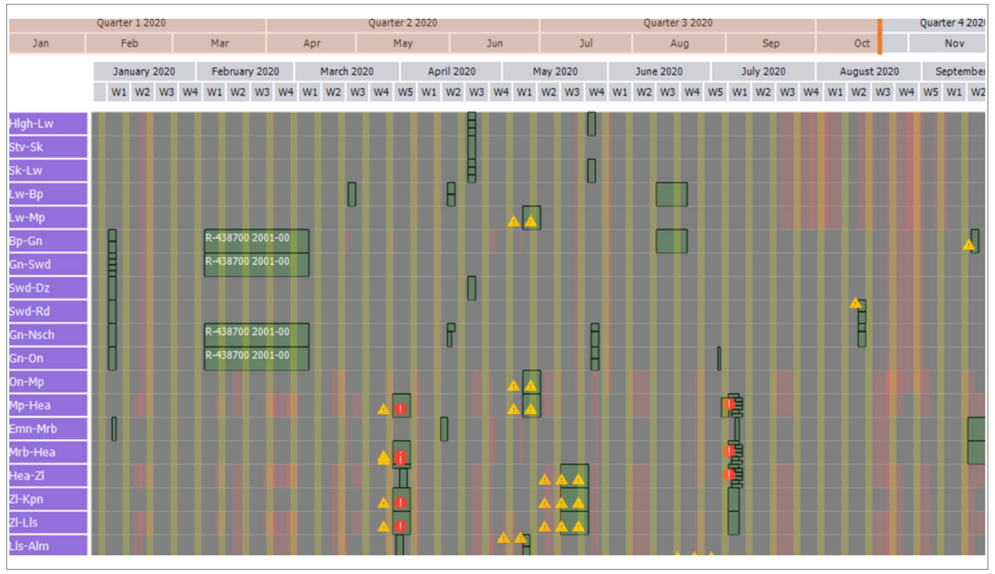


Figure 15. *An example of a Gantt for a TVP planning (with the icons showing conflicts or errors)*

When viewing a Gantt, the planner was able to have a visual overview of all the planned projects. A block in the Gantt represented a project request. The location of the tracks was listed on the left and time slot was on the top (Figure 16. The Gantt is interactive and the execution time of a project request can be modified through drag&drop interaction.

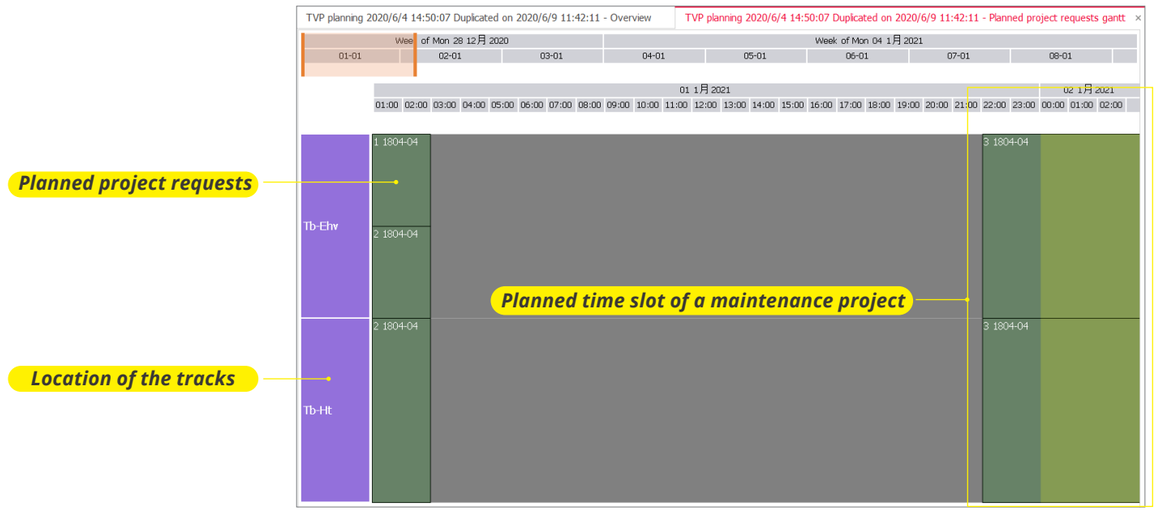


Figure 16. *A Gantt showing planned project requests*

Another vital outcome for the planners was 'Score', an overview of the impact and cost of the planning (Figure 17). Costs were divided into two parts: Financial costs and Availability costs. The former showed the costs needed to execute the maintenance while the latter was the cost of rearranging transport. ERM('Extra travel minutes' in English) and EGU('Extra travel hours' in English) showed the hindrance for passengers and goods transportation.

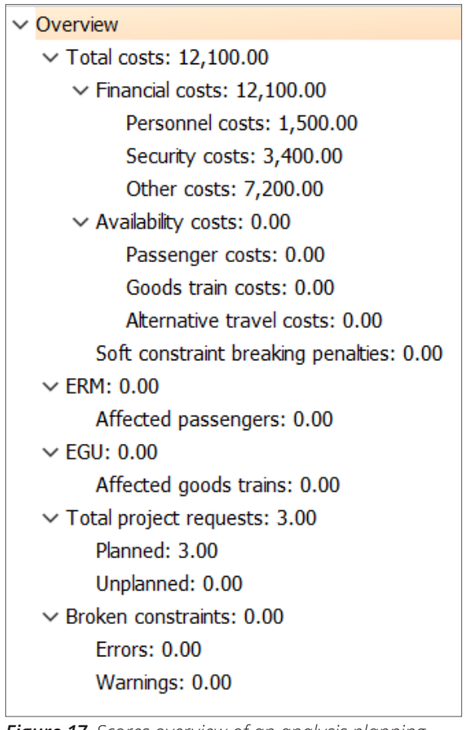


Figure 17. *Scores overview of an analysis planning*

3.1.6 Challenge for Macomi

Although PRM has achieved the goal of helping planners to optimise maintenance plannings, another problem has become noticeable. Due to the vast and growing possibilities of the platform and the complexity, it took quite a long time for new users to learn to use the tool. Regular technical support from Macomi was needed by ProRail during their daily usage.

Macomi is gradually extending its client groups from various domains while a complex and hard-to-learn platform is not user-friendly for new users. Therefore, Macomi was looking for a new User experience(UX) design for the PRM that can reduce the learning time and usage problems.

3.2 Interviews at Macomi

3.2.1 Research goal and approach

After understanding Macomi and the Macomi platform, it is time to dive deep into discovering what challenges Macomi had with PRM and understanding the stakeholders in this project. Thus, the goal of the interviews was to:

1. ***Understand who are the main stakeholders of PRM and the relationships between each other.***
2. ***Understand how does Macomi interact with the clients currently***
3. ***Discover the expectation from Macomi***

To achieve the goal of this research activity, interviews were conducted at Macomi with the co-partner in Macomi and two product owners of PRM. Interview insights can be found in Appendix B.

During the interviews, the audio recorder was used to record the interview for later analysis. After the interviews, the audio record would be transcribed and important quotes and insights would be extracted and organised as results of this session.

3.2.2 Results

After the interviews, I got a better understanding of the relationship between different stakeholders and their expectations(based on previous feedback from clients) when using the tool was summarised as a stakeholder map (Figure 18). Also, the experience about interacting with their clients and the challenges Macomi is facing is elaborated below.

Stakeholder map

There are 3 main stakeholders that are closely related to the tool: Planners, Macomi, and Decision-makers of the companies.

The goal of Macomi is to sell the tool to their clients(decision-makers of the companies) during the demonstration presentation. Decision-makers are the ones who decide whether the company use the tool or not, but they would not use the tool afterwards.

The main end-users are planners in the company who would use the tool to make maintenance plannings. Once the company decided to use the tool, Macomi would provide tutorial workshops and regular technical support for the

planners. When making planning, the planners would get project requests from Project managers and discuss the plans with different stakeholders that involved(e.g. train operators, government, etc.).

Thus, planners are the ones who are mainly using the tool frequently, while Decision-makers, Project managers and different stakeholders care more about the results and have less interaction with the tool.

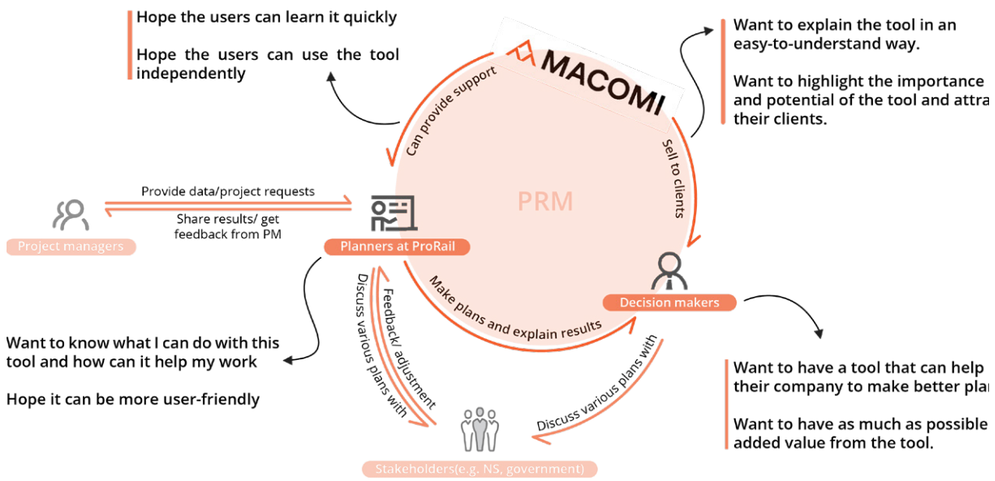


Figure 18. *Stakeholder map*

Interaction with clients (Demonstration presentation)

As has mentioned before, Macomi wants to sell its product to clients and reduce the time and work for tutorial sessions or technical support. The co-partner and product owners from Macomi shared their experience about how they presented their products and what was the feedback from their (potential) clients.

During the demonstration meeting with the clients, Macomi had to compete with other competitors and present the tool within the given time. According to the boss of Macomi, he usually showed 2-3 input data as examples and explained some terms with examples to help the clients to understand it quicker (Showing all input data is too much and not necessary). Then, he would demonstrate the result (maps and Gantt chart) to the clients to show what they could achieve with the tool, which is one of the most interesting and important parts for the clients.

Challenge for Macomi

However, even the clients were usually quite interested in the tool, it was challenging to explain it in an easy-to-understand way. Due to the complex interaction and numerous data as well as functions, it was difficult for the clients to grasp the essence and understand the tool in a short time and they felt confused and lost sometimes. Therefore, Macomi expects to have a new design of PRM which can be demonstrated in a concise and understandable way.

Another noticeable challenge for Macomi is that the current PRM is a complex analytic tool, which contains a lot of data and looks very technical. According to the product owners, they need to provide tutorial workshops and weekly technical support for planners at ProRail to learn to use PRM, while Macomi would like the tool to be easy to learn and have enough guidance so that planners can use it independently.

3.3 Research at ProRail

3.3.1 Research goal and approach

To better understand the real end-users(planners at ProRail), I visited 2 maintenance planners at ProRail to figure out how they use PRM in their work, and the goal of this research activity is to:

1. ***Understand how maintenance planners use PRM currently.***
2. ***Discover the problems and limitations of the current PRM.***
3. ***Explore the expectation and ideal situation for the future design from the planners perspective.***

To achieve the research goal, I conducted contextual interviews combined with user tests, and use an embed mouse tracking tool to record how the planners interacted with PRM. The whole session was recorded by an audio recorder for later analysis.

Contextual interview and user test

The contextual interview is a research method conducted in the users' own environment. By visiting the users, I was able to see their working environment and observe any issues they were facing when they were working. (Usability.gov, n.d.)

A user test in the contextual interview is a bit different from the traditional user test. It doesn't ask participants to complete the same scenarios to get comparative data, but instead, it lets the user work as his/her usually does and also do some of the prepared tasks.

Mouse tracking tool

Mouse tracking is a data collection technique that use software to collect users' mouse positions on the computer. (Wikipedia, 2020c) The goal of the technique is to automatically collect rich information about what users are doing, which is typically for improving the user interface of a software or website.

With the mouse tracking tool embed in PRM, it could automatically create Mouse tracking heatmaps(Figure 19), which uses thermal imaging to indicate where the users are clicking, pausing and scrolling (Little, 2019). The heatmap indicates the mouse movement: the warmer is the colour, the longer the mouse stays at that place.

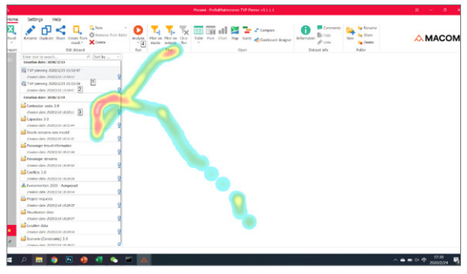


Figure 19. *A mouse tracking heatmap created when using PRM.*

Procedure

The contextual interviews started with a short interview regarding the background information about their daily work related to the tool and their first impression of the tool(see Appendix C for the interview questions and extracted quotes and insights). After that, participants were asked to use PRM as usual and think aloud during the whole process.

During the interviews, interviewees would guide me through the tool as they usually did(Figure 20), and I would observe and ask questions to understand what they were doing and why.

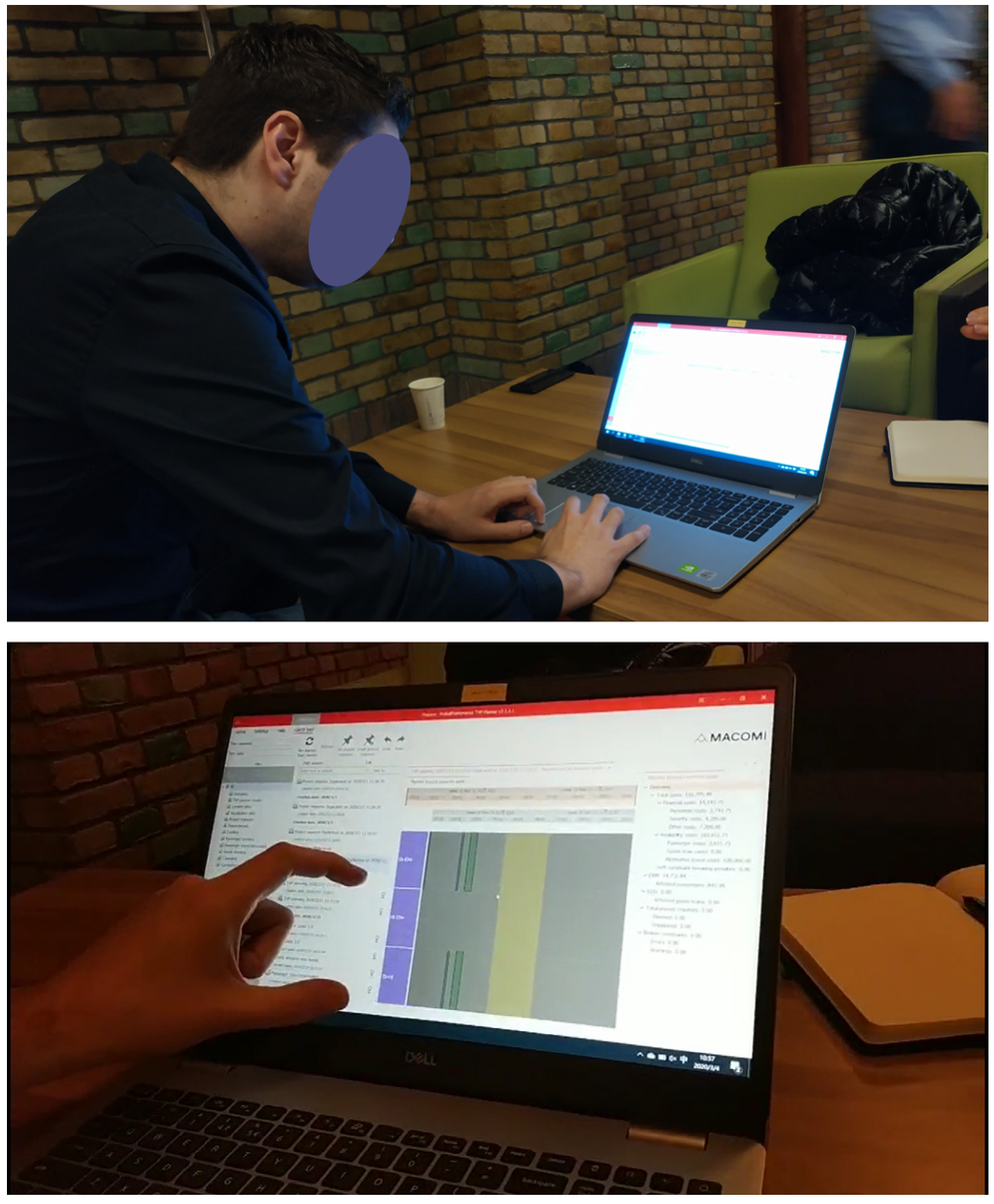


Figure 20. *Contextual interview with planners at ProRail*

3.3.2 Results

Through the contextual interviews I had with two planners, I summarised the user flow they had when using PRM as usual.

User flow of experienced users

This flow introduces the process of Starting a new analysis, Comparing plans and Adjusting plans (Figure 21).

When the planner first started a new TVP planning analysis, he needed to import/update input data into PRM. Then, the planner would edit the input data (e.g. project requests) and filter the right input dataset that fit the time period he wanted to make plans for. When input data was prepared, the planner can start a/several new analysis, then wait for around 8 hours to get the outputs(-during the interview, the waiting time was skipped, and the planners used the existing TVP planning to show the next steps).

When the analysis was finished, the planner compared different plans and checked the results of the comparison to select the better one. Also, the planner could modify the plan and then rerun an analysis, which is one of the most frequently used functions, as they would like to compare different scenarios.

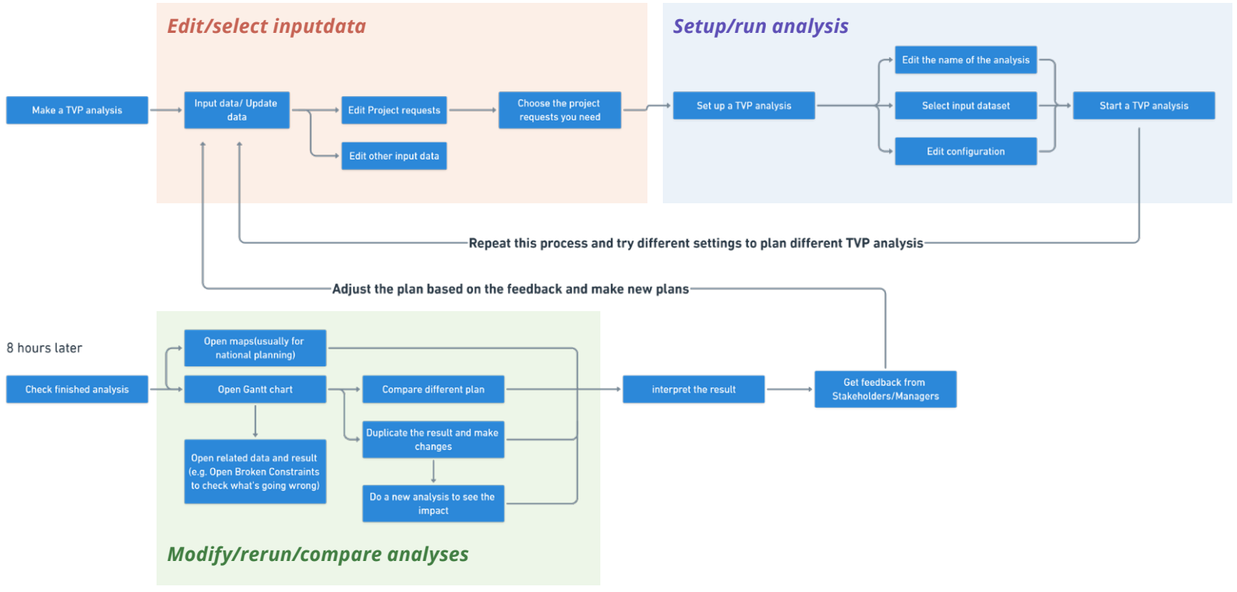
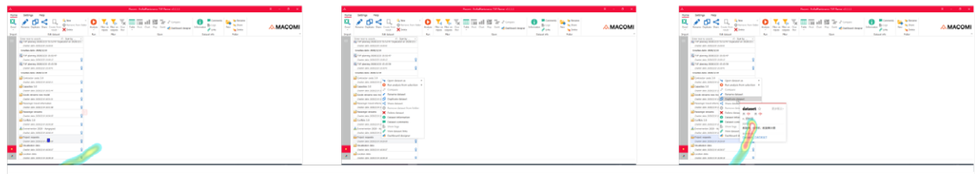


Figure 21. *User flow of planners when using PRM*

User flow heatmaps

Below is a step-by-step explanation about what the participants were trying to do(click) when executing the flow mentioned above. The processes were visualised by the mouse tracking heatmaps with explanations underneath. (see Figure 22, Figure 23 & Figure 24)

Make a TVP analysis



1. Right click "Project requests" and duplicate a new one

2. Open the "Duplicated project requests"

3. Select the project requests that are needed from all the requests/ "Pin" some big project requests

4. Share default setting with others (optional)

5. Select the project requests that are needed from all the requests/ "Pin" some project requests

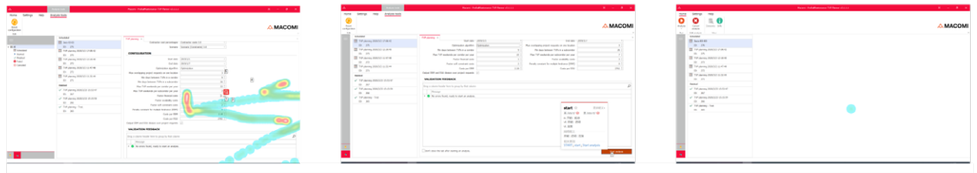
6. After setting up dataset, choose TVP planning analysis

7. Edit the name of the analysis

8. Select input dataset

9. Choose start date and end date of the analysis

10. Edit configuration: usually keep the default setting for the first analysis to get original result



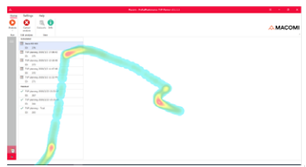
11. Can change some configurations if we want and compare with the original one

12. Start analysis

13. Analysis would be scheduled. Usually schedule a list of analysis at the end of the day (takes around 8h to run the analysis)

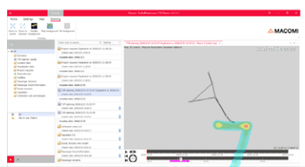
14. When the user double click the finished planning here, it will show the input information of the analysis

15. The input infomation here helps to remind them of what this analysis is about while they also expect to see the result after clicking the finished planning



16. Once the analysis is finished, the user go back to dataset page

17. Right click to open the finished analysis (maps and Gantt chart are two main outcome they would like to see)

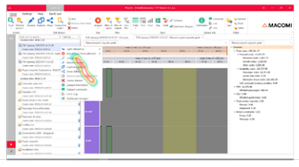


18. The map is very useful for national planning: the user can select the time and the map would show which part should be maintained

19. Gantt chart shows the maintenance time slot. There is a cost list as well.

20. If there are errors or warning, they would like to check other parameters(e.g. Broken constraints...)

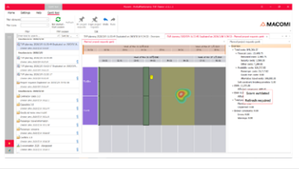
Edit result & Pin project requests



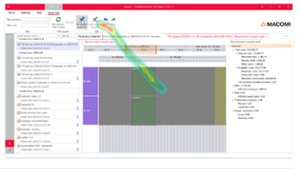
1. Duplicate the original dataset (can't edit the original result and users would usually keep it)

2. Open the Gantt chart

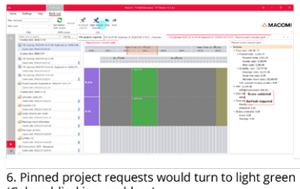
3. Right click and hold the mouse to drag the block to move the time slot



4. Get a new schedule while the cost is not the latest after you make changes(not automatically updated)

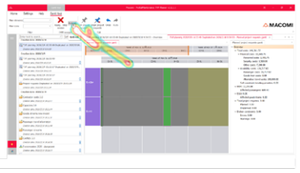


5. To pin the block: Right click to select the block and click "Pin project requests"



6. Pinned project requests would turn to light green (Colour blind is a problem)

7. Click "Start session" to send request to the server

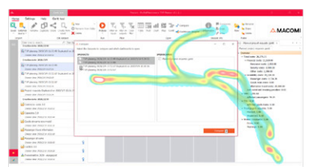


8. Click "Refresh" every time after making changes

Figure 23. *User flow : Edit result& Pin project requests*

Compare analysis results

1. Press "Ctrl" to select multiple planning and click "Compare" to compare different plans



2. Compare the plans

3. The result of comparing: showing differences of costs, plans...

Figure 24. *User flow*: *Compare analysis results*

Insights from the research

Based on the interview with the planners at ProRail, observation and interview during the test, I found these valuable insights after analysing both the qualitative and quantitive data:

The tool seems too 'technical' to learn. According to a planner at ProRail, many project managers or some planners refused or were afraid to learn PRM because they did not know what they could do with PRM at first glance and lots of buttons and data in PRM 'scare' them away. What's more, most of them only cared about the outcomes and did not even try to use the tool.

The whole process could be more user-friendly. Some interactions of the tool are not intuitive (for example, the process of choosing the right input data before starting an analysis was not straightforward), and it is hard to demonstrate and introduce the tool to more new users.

The outcome was very helpful for making plans. According to the planners, the functions and outcomes were very useful for decision-making. A planner said, "It could be more user-friendly even for me, but the outcome is the most important." Therefore, It is a pity that many people(e.g. project managers) were 'scared' and resisted using the tool, thinking it was hard to learn or would take over their work.

3.4 User tests with new users

3.4.1 Research goal and approach

In order to get a holistic understanding of the tool, I also conducted user tests with new users who had never used the tool before. Two Master students from TU Delft were invited to join the tests, one was from the Faculty of Technology, Policy, and Management(TPM), and the other was from Industrial Design Engineering(IDE).

The goal of the tests was:

1. ***Understand how new users perceive PRM.***
2. ***Discover problems of PRM and understand the causes.***

Similar to the tests at ProRail, the participants were asked to use the PRM(embed with the mouse tracking tool) to finish given tasks. The sessions were audio-recorded.

Procedure

The user tests started with an introduction about the context(Appendix D) to help the students to understand the context in order to work on the tasks. After the introduction, the students were asked to use the tool to finished the following tasks (which are the common tasks that planners performed) :

1. ***Freely explore the PRM and describe your first impression on it.***
2. ***Make a new TVP planning analysis.***
3. ***Find the result of the planning***
4. ***Adjust the planning.***

The session was wrapped up by an interview in terms of sharing their experience and explaining the behaviours I observed during the test.

3.4.2 Results

Based on the user tests and interview, I analysed the heatmaps and audio record and then summarised the user flow they had when using PRM and insights I got about the problems and reasons behind them.

User flow of new users

This flow summarised the actions that the students took to finish each task mentioned above (Figure 25).

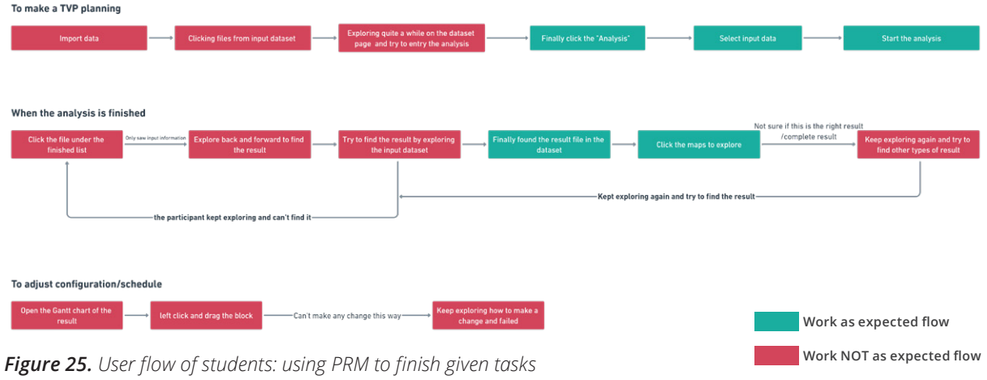


Figure 25. *User flow of students: using PRM to finish given tasks*

When the students were asked to make a new analysis, they couldn't find the button to start the analysis. Instead, they tried to explore in the input dataset and could finally get to the right place to start a new analysis after some exploration.

When the analysis was finished, the participants were supposed to go to the list of the dataset to find the result, but they didn't realise that and kept exploring in the analysis page. They couldn't find it until one of the students accidentally switch to the list while the other one got hints from me. When they finally got to the result page, neither of them was confident about the results and kept trying to find other types of results.

In the current setting of PRM, the users could not modify the original planning unless they duplicate it. There were no instructions mentioning that and the participants failed to finish this task.

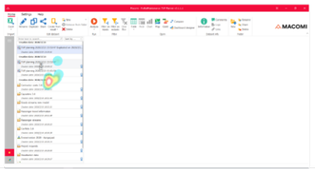
User flow heatmaps

Below is a step-by-step explanation about what the participants were trying to do(click) when executing the flow mentioned above.

The processes were visualised by the mouse tracking heatmaps with explanations underneath.

Make a TVP analysis

1. Click “Excel” to import data

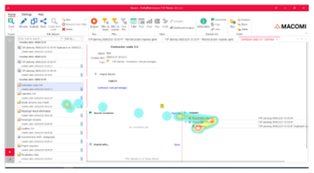


2. Click “TVP planning” from the dataset

3. Click the “Gantt”

4. Explore a while, couldn’t find where to start the analysis

5. Go back and explore



6. Explore the dataset

7. Finally click the “Analysis” button

8. Select input data

9. Start

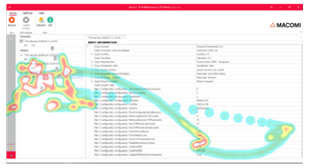
10. Successfully scheduled the analysis

11. The analysis is scheduled

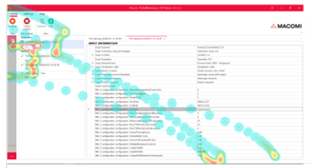
Figure 26. *User flow of students: Make a new TVP analysis*

Find results of the planning

1. Click the scheduled analysis, show input information on the right

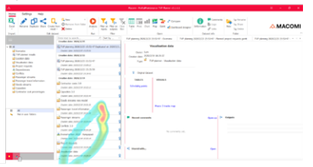


2. When the analysis is done, the user try to click the planning under the finished list, but there is input information instead of the outcome



3. Try to click the “Menu” button

4. Try to click the cluster



5. Go back to the dataset page and explore

6. Go to the analysis page again(go back and forward to find the result)

7. Try to click the input data and see if there is any output

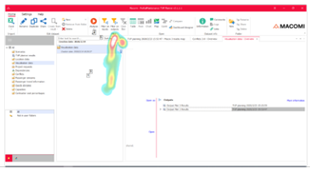
8. Click the “Gantt”

9. Click “Visualisation data” check if there is visual of the result

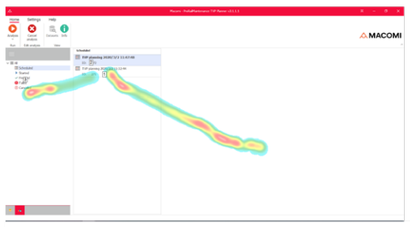
10. Click “TVP planner results” in the filter, and finally found the result

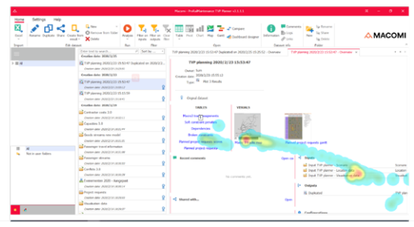
11. Choose maps to explore the result

12. Go back and try to find other result (the user was not sure if she got the right result)



13. Click “Analysis” again to find other result





14. Go back and forward to explore and try to find other types of result

Figure 27. *User flow of students: Find results of the TVP analysis*

Edit result & Pin project requests(failed)

1. Left click and try to drag the block but it didn't move

2. Explore and see how to adjust the schedule but failed

Figure 28. *User flow of students: Edit result& Pin project requests*

Insights from the research

From the analysis of the flow and information gained from the interview, some insights became obvious :

It is not clear how the tool can help the users' work at first glance. When first open the tool, there was a toolbar with a lot of buttons without instructions or guidance. Thus, the users did not know what they could do with it or how to start an analysis.

It is difficult to find the results confidently. When the participants were trying to find the result after the analysis was finished, they kept exploring and making mistakes before getting to the right page. What's more, when they finally got to that page, they thought these were incomplete results because of the unprofessional layout and lack of clear indication.

Some interactions are confusing and unexpected. For example, when the participants tried to adjust the result directly in order to get a new plan to compare with the original one, they failed to do it and there was no feedback or guidance telling them how they can successfully adjust the plan. Therefore, they were confused when things did not work out as expected.

3.5 Conclusion

This chapter introduces the research activities and findings of the Design research, which consists of two main parts: Company research and Stakeholder research.

There were various research activities(interview, literature research, etc.) going on in Macomi in the company research stage, aiming at understanding PRM and the current situation, stakeholders of PRM and problems that Macomi was facing. The stakeholder research stage was more towards the end-users: planners at ProRail and potential new users. Many user research methods were used such as contextual interview at ProRail and user testing for discovering and identifying problems of PRM. This part concludes the answers to the following research questions based on the findings gained from the research activities:

What types of service Macomi can provide?

Macomi is a business consulting company specialises in advanced analytics in transport, logistic and workforce planning domain. With the Macomi platform (an integrated platform including various analytic software), Macomi works with its clients to optimise resources, processes and business plannings. PRM is part of the Macomi platform aiming at optimising railway maintenance plannings for railway management companies(e.g. ProRail), for which Macomi would provide tutorial workshops and regular technical support when the clients need.

How does PRM work?

PRM is an analytic software that can help planners to iterate and optimise TVP planning with a specialised algorithm. Based on the input data and preset configurations, the algorithm runs an analysis and provides optimal maintenance planning. The user can run different analyses with different input data or configurations and then compare the results to iterate and optimise the planning.

What are the challenges for Macomi?

The outcomes of PRM was satisfying according to ProRail, but the software itself is complex and not user-friendly enough. These take more effort from Macomi to provide regular support for the clients and it is difficult for Macomi to present the software to potential clients in an easy-to-understand way.

Who are the main stakeholders of PRM and the relationships between each other?

How does Macomi interact with the clients currently?

Maintenance planners at railway management company(ProRail in this project) are the main user of PRM. Decision-makers of the company are the ones who decide if the company would 'buy' the software-PRM from Macomi, while the decision-makers would not directly use PRM and they mainly care about the re-

sults. Macomi gives a presentation to the decision-makers, once they decide to co-operate, Macomi would provide tutorials and technical support for the planners.

What are the expectations of Macomi in this project?

Macomi would like to improve the UX of PRM so that the user can quickly learn how to use it and use it independently with nice experience. What's more, they hope the new design could be easily demonstrated to their clients so that they can attract the decision-makers to buy the software.

How maintenance planners use PRM currently?

First import input data, then make a new analysis or several analyses with different input data and configurations. When the analyses were done, the planner would check the planning, and iterate the planning by modifying and comparing.

How did new users perceive PRM?

When they first saw PRM, they thought it was very professional because there was a lot of buttons and data. It was not clear for them how the tool could help the users' work at first glance and they could not find the results confidently. They failed to finish some tasks(e.g. modify the planning) as they did not get clear guidance or feedback about how to do it, which was confusing.

What are the problems and limitations of the current PRM?

There are too many buttons and data on the first page, which make it 'scary' and new users were not confident to learn. What's more, many interactions are not intuitive or user-friendly enough, for example, selecting input data is quite cumbersome even for experienced users. Lacking clear guidance and feedback is also a noticeable problem due to which the user might not be able to finish the tasks(e.g. new users fail to modify the planning as they did not know they need to duplicate the original planning first).

What are the expectations and ideal situation for the future design from the users' perspective?

For the users, they would like the software to be more user-friendly and expect more clear instructions or feedback when using PRM. As it is complex and has a lot of information, they expect a cleaner and easy-to-organise surface for them to manage the information so that they can find data or results easily and confidently.

These research findings helped me to understand the current situation and discover problems and design opportunities. Thus, based on the findings of this chapter, the next chapter is about a more concrete design brief in terms of target users, problem statements, design goal and design requirements.

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04
DESIGN BRIEF

Based on the findings of previous research stages, more concrete Target users, Problem statements, Design Goal, Interaction Vision and Requirements were created in order to guide the activities of the Conceptualisation stage.

Overview

4.1 Target users

As mentioned before, planners are the users who mainly interact with the tool. These main users could be divided into two groups: Experienced users (Figure 29) and Potential new users (Figure 30). Experienced users mean users who have been using the tool for a long time and understand how to operate it. Potential new users mean people who know some background knowledge about rail maintenance but did not use the tool before.

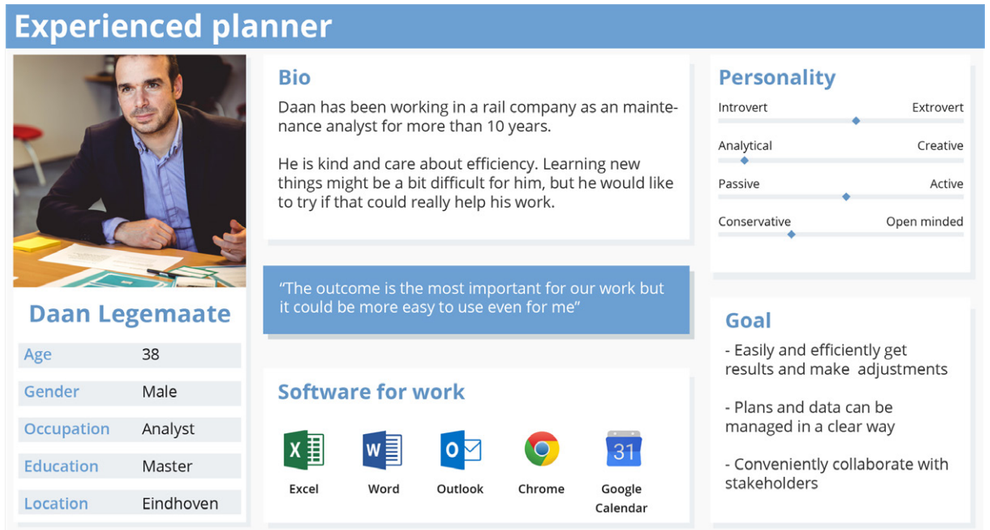


Figure 29. *Persona1: Experienced planner*

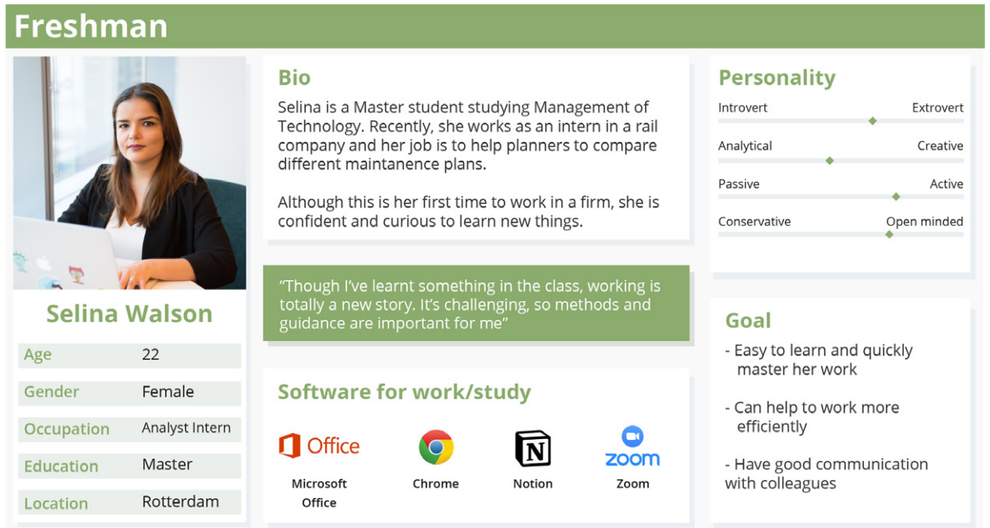


Figure 30. *Persona2: Freshman*

4.2 Problem statements

After analysing what problems the users have encountered during the user research phase(chapter02&03), I summarised a list of problem statements for the tool that indicates factors that lead to those problems.

Table 1 summarised the problems and ideal situation. It starts from the problems or feelings the users had when using PRM, from which concludes the problem statements from the tool's perspective(what leads to these problems. After that, the ideal situation from the user's perspective is summarised for creating the Design goal and Design requirements in the next step.

Problem statements of PRM	***Problems/feelings that the users have***	***Ideal situation***
• ***It demonstrates from the perspective of data instead of planning***	• Feel 'scary' / refuse to learn when saw lots of data/info/buttons • Feel lost when look for functions or results	• The tool can provide clear structure of the information so that the user can easily and quickly understand how to use the tool • The tool can provide enough guidance and support during the whole process so that the user would have a sense of in control when using the tool • The interaction is intuitive and user-friendly so that the user can quickly learn how to use it • The user can independently and confidently use the tool.
• ***Lack of information hierarchy***		
• ***Lack of guidance/ indication is not clear***	• Can't find where to start/functions and feel confusing and helpless	
• ***The layout is less professionally designed***	• Can't find the results or not confident(trust) about the results	
• ***Did not match the users' expectation***	• The interaction is not intuitive/ user-friendly, which requires more effort to learn the tool • Can't finish the tasks and feel confusing and helpless	
• ***Lack of feedback***		

Table 1. *Relationships between users' feelings and usage problems, the problem of PRM, ideal situation*

- ***It demonstrates from the perspective of data instead of planning.*** The tool shows dataset first instead of showing how the user can start an analysis. When first opened the tool, there was a lot of information and the users felt lost and did not know where to start.

- ***Lack of information hierarchy.*** Everything was shown in the dataset. No categories/hierarchy. New users failed to find the results as there were no clear categories of different types of data and just put everything in the list.

- ***Lack of guidance/ indication is not clear.*** The tool did not provide enough guidance when the user felt lost. For example, there was no instruction about how to modify the planning.

- ***The layout is less professionally designed.*** The of the layout of some pages(e.g. results) lacks hierarchy and looks like a draft, which might make the user less confident when doing tasks. (The new users was not confident about the results as they were not well organised and structured)

- ***Did not match the users' expectation.*** When the users clicked the list of TVP planning, it showed input information instead of the result.

- ***Lack of feedback.*** When the new users fail to edit the data, there was no feedback showing what's wrong or what the users should do next. This would make the users feel confusing and frustrated.

4.3 Design goal

"Redesign an interface and experience flow for a railway maintenance planning optimisation digital platform that provides ***clear structure and instructions*** for the users to make planning ***intuitively*** and ***confidently***."

Clear structure

According to the findings in the research phase, one of the biggest problems of the current PRM lies in the information structure. To make a mainteance planning, various data and information is needed. Showing data and information without clear hierachy or structure would increase the complexity of the system and make it harder for the users to understand the flow and find things they need. Therefore, to have a clear structure became the top objective in the new design as many users expected.

Clear instruction

During the user test in the research phase, it was found that many users expected more explicit instructions or help from external support (e.g. Macomi) when using the tool, especially for new users. As a complex system, PRM has a lot of useful functions while not enough guidance was given to the users in the tool, which could lead to unexpected failure or confusions. By giving clearer instruction in the tool, Macomi might reduce human resource on providing technical support and the users might feel more confident when using it.

Intuitively and confidently

These two characters were defined as the main ideal interaction the users should have with the redesign.

Based on the interview and user tests, all users(especially new users) were diffident and confused when they first got in touch with PRM. There were unexpected interactions or problems from time to time which could have negative impact on the UX of PRM. Many participants have explicitly mentioned that they would expected PRM to be more user-friendly and the interaction could be more intuitive. Therefore, it is important to provide a design that could support the users to make planning intuitively and confidently.

4.3 Design requirements

To achieve the design goal, a series of Design requirements were generated. These requirements would be used as guidelines for ideation concepts and also the criteria in the evaluation tests to validate the final design.

The Design requirements are divided into two types. One are the requirements for the tool in general, which means these requirements are needed all the time. The other are requirements for (part of) the process when using the tool.

In general:

- ***Structured overview***: In general, the design should display input data and results of TVP planning in an organized way so that the user can easily manage the data and information.
- ***Self-explanatory function areas***: The meaning and functions of each page (input data, TVP analysis, results, etc.) should be clear, which means that the users should know what they can do with each area.

When using:

- ***Clear guidance/support***: The new design should provide guidance for making analysis, finding results, modifying plans, and provide support/help to tell the users what they should do when they fail to finish a task.
- ***Frequently used functions:*** (adjust plans, analysis, result, modify plans, rerun...) ***should be obvious and easy to access*** and the user would not feel confused or lost when they need these functions.
- ***Easy to choose the input data.*** After importing data into the tool, it should demonstrate the input data in an organised way and it should be easy to filter or select input data that needed for the new TVP planning analysis
- ***Information about the changes or status of the Analysis should be clear and noticeable***, in other words, the user can quickly check the progress of the analysis or be informed when the analysis is finished or something goes wrong.

05 CONCEPTUAL-ISATION

After the conceptualisation phase, an iterated conceptualisation was generated based on the insights I got from the previous tests. This chapter explains the final concept, highlights, and the prototype made for evaluation.

Overview

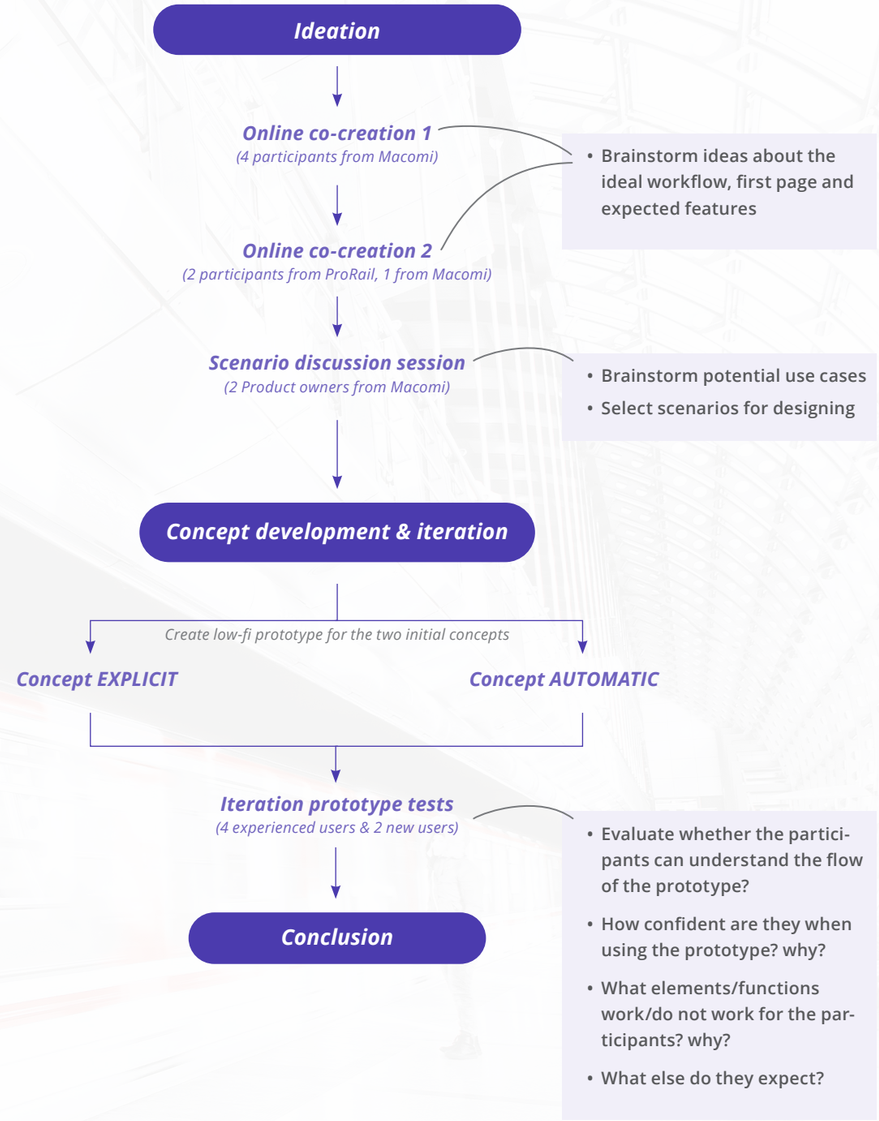


Figure 31. *Overview of Chapter 05: Conceptualisation*

OVERVIEW

5.1 Co-creation

After figuring out problems of the current situation and design goal of the project, it is time to finalise requirements and brainstorm ideas. Therefore, I have organised two Co-creation sessions with different participants.

5.1.1 Goal

The goal of these sessions is to collect ideas about the ideal situations in terms of first impressions, work flows, functions and so on. For the second session with planners from ProRail, I tried to get feedback on a concept generated by me and use the concept as a trigger to help them reflect on what is the ideal tool and work flow they need.

5.1.2 Participants

I have conducted two separate co-creation sessions with different participants. In the first session, there were 4 participants (1 Marketing consultant, 1 Analytics consultant, 1 Product Owner, 1 Software developer) from Macomi invited to the session. The Product Owner was seen as an experienced user, while the other three had some background knowledge of planning but not specific to ProRail Maintenance, so they were regarded as potential new users in this case.

In the second session, 2 planners from ProRail were invited and 1 Product Owner from Macomi also participated in the session. In this case, all of them were experienced users.

5.1.3 Approach and settings

Due to the COVID-19 situation, I have to organise the session online. I used the online conference software ***Microsoft Teams*** to stay in contact with all the participants during the session and used the online collaboration tool ***Miro*** co-creation(Figure 32)

Figure 32. *Tools for online co-creation: Microsoft Teams(left), Miro(left)*

Each session lasted for around 90 minutes with 3 rounds of ideation. For each round, there were four steps: ***drawing concepts, presenting, voting*** and ***discussing***. Participants were asked to draw concepts on A4 paper within a given time and uploaded them on the board（Figure 33&Figure 34）. Then each participant presented his/her concepts one by one, after which they would vote(put colour dots on the drawings: Figure 35) for the elements they like. We ended each round with a discussion about why did you like or dislike those elements.

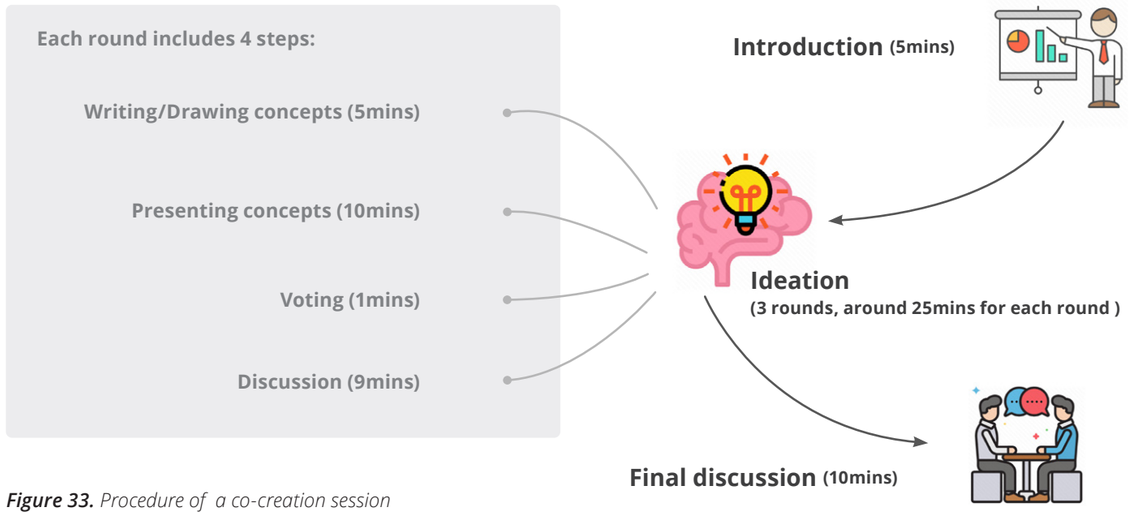


Figure 33. *Procedure of a co-creation session*

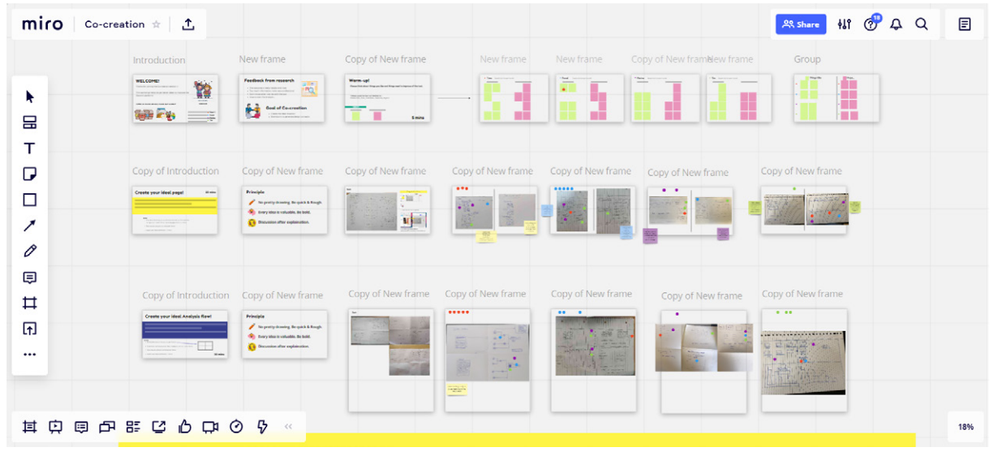


Figure 34. *Overview of the co-creation settings in Miro*

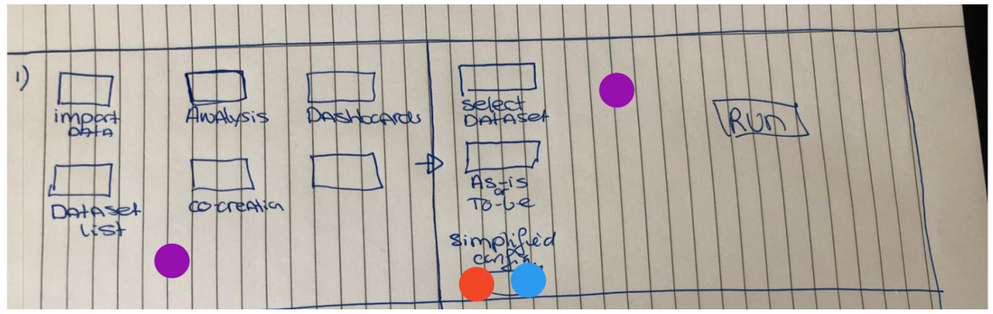


Figure 35. *Voting: Put dots on the elements you like*

The activity of the second session was slightly different from the first one (Figure 36). Detailed introduction of each round sees Appendix E. After the first session, I got a few new ideas and experiences and would like to create something quick and rough and get feedback on it. Therefore, I iterated the setup of the second session and add my first concept in the second round to evoke discussion and help the participants to understand how to ideate the ideal work flow.

Session 1
R1: Positive&negative elements of PRM
R2: Create your ideal first page
R3: Create the ideal work flow

Session 2
R1: Create your ideal first page
R2: Discuss my first idea
R3: Create the ideal work flow

Figure 36. *Activities of each round in the two sessions*

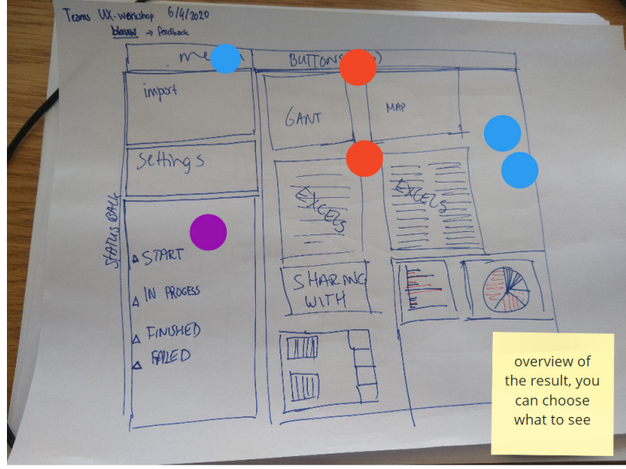
5.1.3 Results

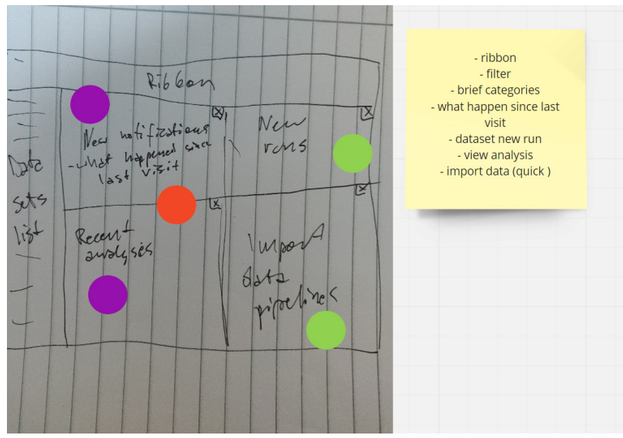
After each session, I collected all the drawings and selected the ideas/features that got more than 1 vote and then categorised these ideas.

Figure 37 are the top three ideas of the 'ideal' first page created by the participants. From the voting and discussion, I found that they would like to have a clear overview and quick access to the data/results. A visual and dashboard-looking way of demonstrating data(like the idea on the top of figure 35) might be more popular than just a long list of dataset.

Feedback and discussion on my first concept was noted on post-its in Figure 38. Blue represents positive feedback, pink means negative feedback or elements they wanted to add while yellow is the inspirations they had based on the concept.

Some elements got positive feedback from the participants, for instance, customisable homepage, use tabs to organise data and convenient operation buttons. During the discussion, the participants also brainstorm some ideas (e.g. selecting input data directly after importing, comparing different planning , etc.) This round evoked discussion and helped the participants to understand what ideal work flow means.





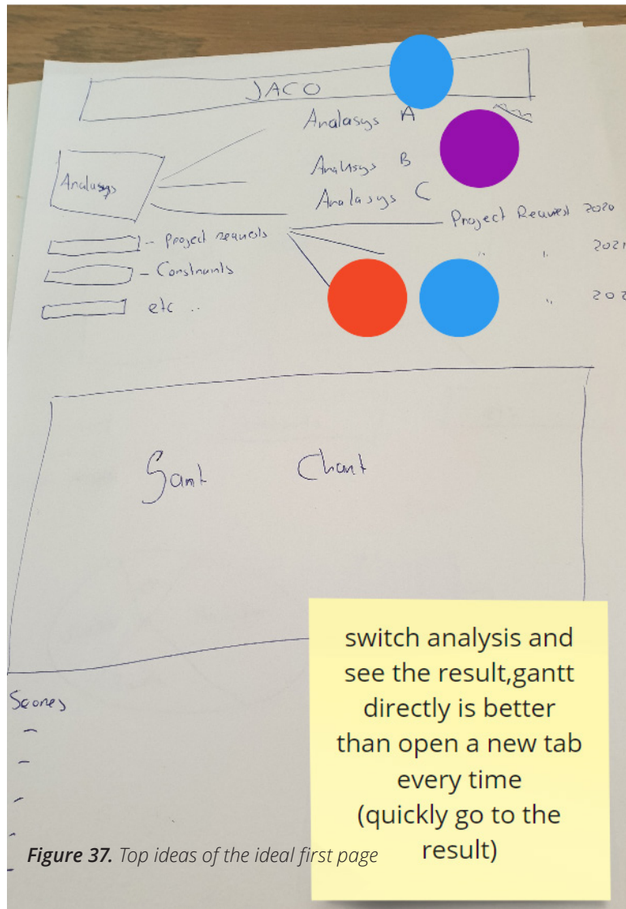


Figure 37. *Top ideas of the ideal first page*

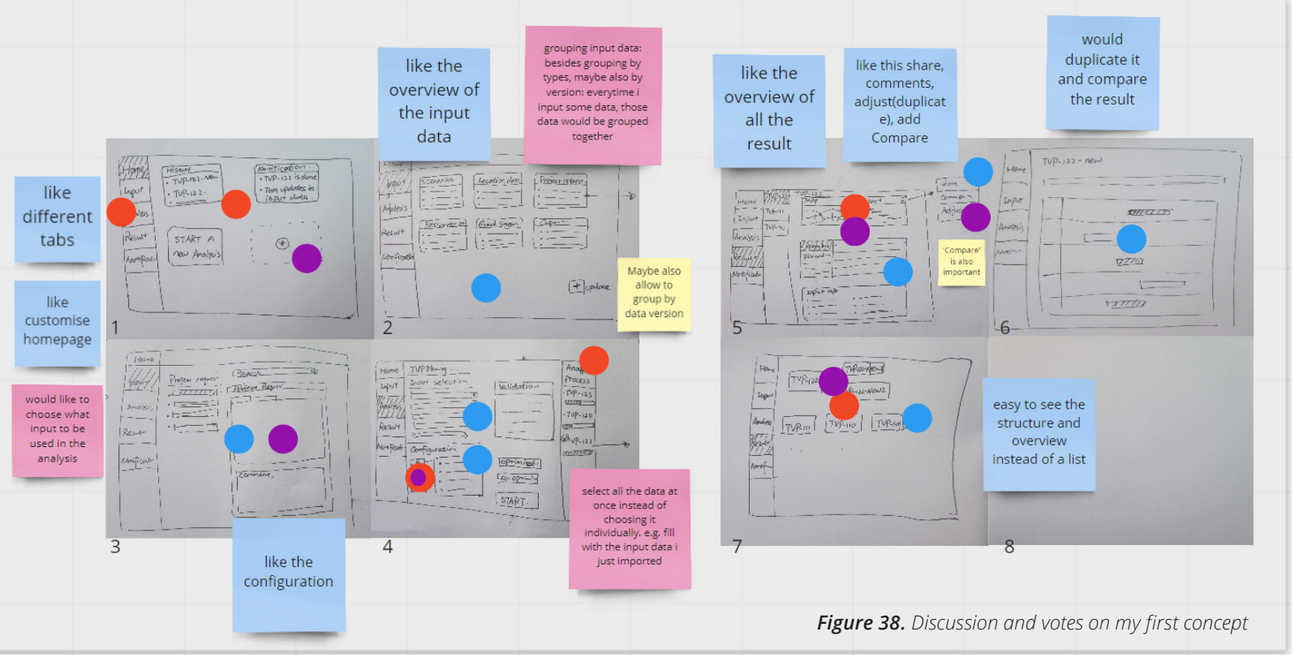


Figure 38. *Discussion and votes on my first concept*

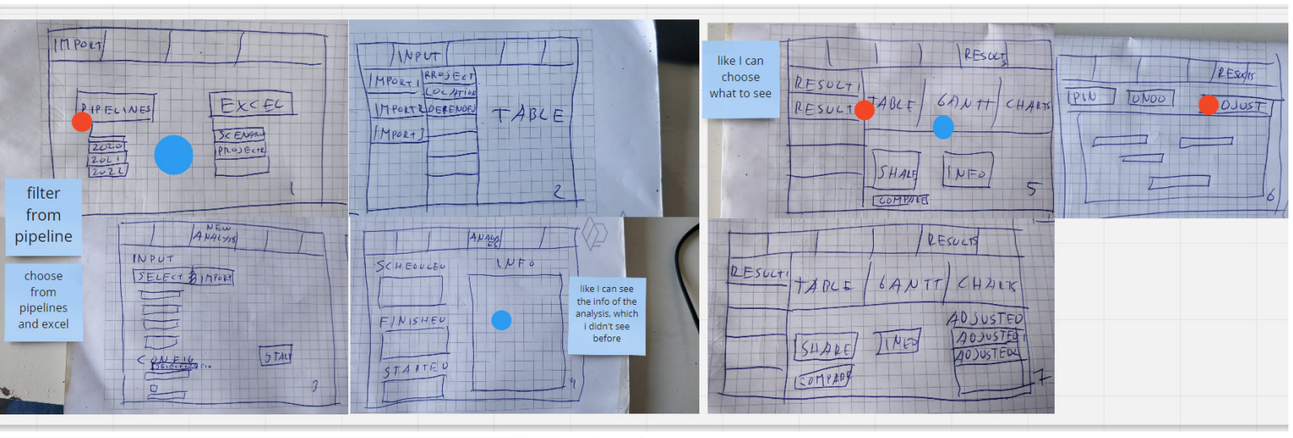


Figure 39. *Top ideas of the ideal work flow*

In the last round of ideation, each participant generate their ideal work flow from selecting input data to getting the results. Figure 39 shows some top ideas which got many votes. From the discussion, I found that it is important for them to have a clear structure and flow for making analysis or finding results. Some ideas about quickly selecting data or clear demonstration of information were highly acknowledged by the participants.

All the selected ideas were categorised into five categories(Figure 40): ***Organised structure, Convenient interaction, Noticeable information, Creating focus*** and ***Instant feedback***.

Through the discussion I found that an organised structure and overview of the tool is important for the users to feel confident to manage the data, especially with such a complex tool.

At the same time, there were many popular ideas about convenient interaction, clear information and feedback, which might be useful to improve and solve the problems mentioned in the problem statements.

There were also some interesting ideas about creating focus for users, which means creating hierachy among information and showing less things on one page.

Besides, the participants have explicitly mentioned that the overview of the scores and the Gantt are the most interesting results for them. Comparing different analysis planning is crucial for them to iterate and select the optimal planning.

The insights and some of the ideas gained from the co-creation sessions were used for creating the initial concepts.

Organised structure

- ***Homepage***
- ***Overview of information***
- ***Navigation bar***
- ***Tabs/lists to show the structure***
- ***Personal workspace with important information***
- ***Use visual***

Convenient interaction

- ***Quick access to results***
- ***Quick selection of data***
- ***Filter data***
- ***Direct operation on the same page***

Noticeable information

- ***Progress bar for analysis***
- ***Information/operation pop-ups***

Creating focus

- ***Show the most important info first***
- ***Grouping data***

Instant feedback

- ***Use colour to highlight***
- ***Pop-up hints***
- ***Use icons to attract users***

Figure 40. *Five categories for collected ideas*

5.2 Scenario discussion session

5.2.1 Goal

From the co-creation sessions, I gained many nice ideas and new features while this ideation session was focusing on creating the ideal scenario and work flow in general. The goal of this session was to:

1. ***Explore the scenarios/use cases that could be achieved in the new design.***
2. ***Brainstorm the ideal work flow for each scenario.***
3. ***Selected the main scenarios which could be the main focus in the final design.***

5.2.2 Procedure

One week before the session started, two product owners from Macomi were asked to collaborate and prepare for the session. They needed to think about the current/potential scenarios of the PRM, and then listed the ideal work flow they would like to have when using the tool in each scenario. The session was held online via Team as the physical discussion was not allowed due to the COVID-19 situation.
The product owners first explained the scenario and the ideal work flow they listed and I asked questions during the process. We had a discussion about these ideal workflows at the end of the session and defined the main scenarios that could be the focuses for the final design.

5.2.3 Results

The discussion was based on the ideal scenarios created by the product owners(see complete scenarios in Appendix F). There were two types of scenarios: ***Single person interactions*** and ***Multiple person interactions***. Single person interactions include scenarios that only involve one user, which means there is no other stakeholder interact with the tool except for the user. Multiple person interactions are scenarios that might involve more than one user, for instance, Discussing optimised(/modified) plannings with (external) stakeholders(e.g transport operators), showing results to a manager, etc.

After the discussion, I found that single person interactions most frequently happened and are more important for the planners, which are the core of the tool. Therefore, I decided to focus on single person interactions and extracted the ideal work flow created by the product owners (Figure 41).

Combined with the insights of the co-creation sessions, a series of scenarios were defined for the design phase:

- ***Importing data***
- ***Merging updated data into input datasets***
- ***Making analysis***
- ***Modify existing planning by a single user***
- ***Rerunning optimisation on a modified planning***
- ***Compare analysis planning***

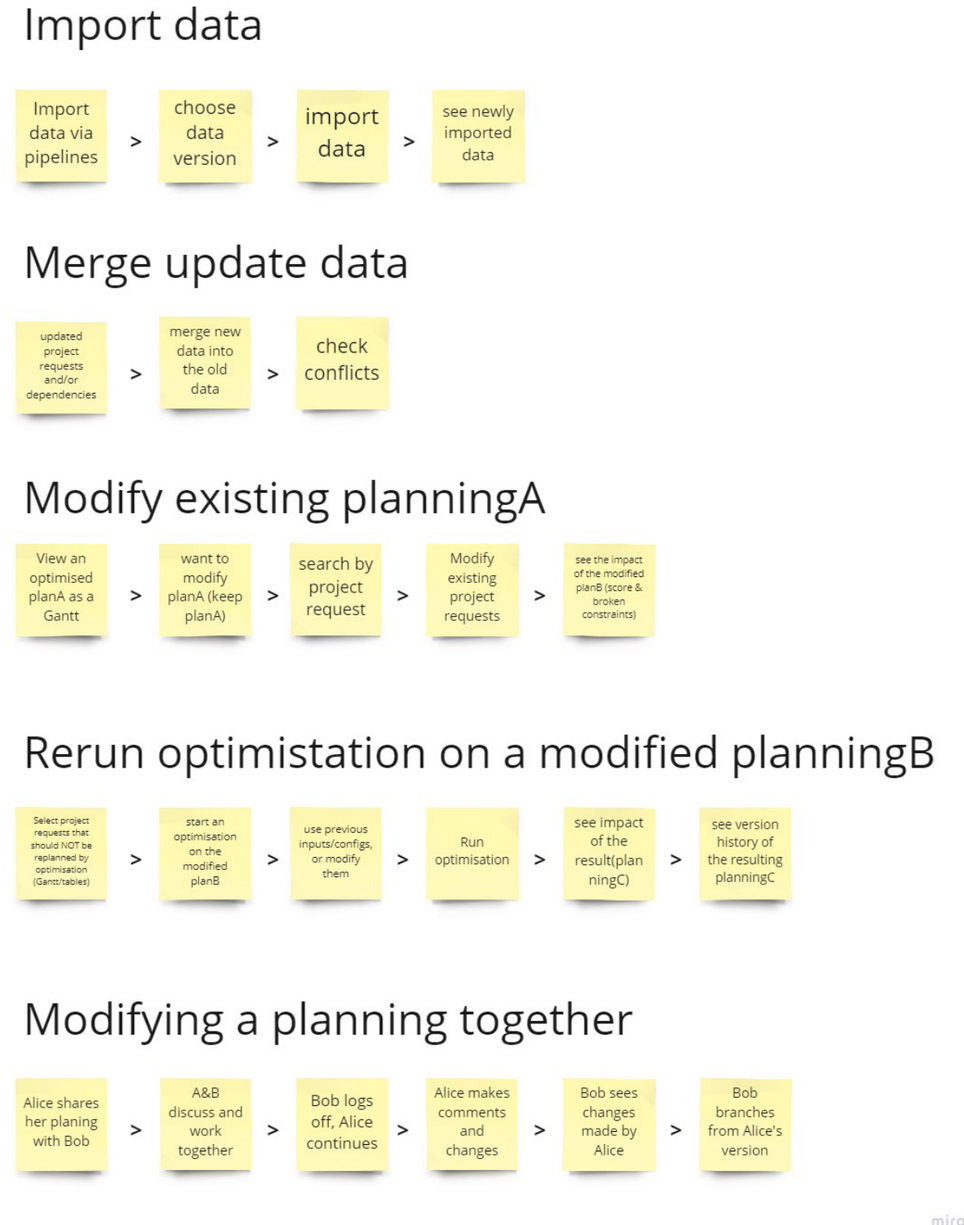


Figure 41. *The main ideal scenarios for TVP planning created by the product owners*

5.3 Concept generation

Based on the ideas and scenarios from the co-creation and discussion sessions, I created two concepts and made as a low fidelity(low-fi) prototype through Adobe XD. These two concepts were made for the iteration tests, in which participants could comparably evaluate the concepts and it would be easier to trigger discussions and for them to measure the concepts.

5.3.1 Approach

According to the Scenario discussion session mentioned above, I decided to design for the following main functions: Input data, Make new analysis, Result of the analysis, Modify plans, Rerun optimisation and Compare analysis.

I started creating the concept by sketching on paper(Figure 42), which helped me to organise the ideas and work flows efficiently. After that, I used Adobe XD to create the digital low-fi prototype with simple but clickable interactions. The low-fi prototype aimed at getting quick feedback on the flow and layout of the concepts regardless of aesthetics like colour etc. The low-fi clickable prototype enabled the participants to interact with the concept but required less time than making a high fidelity(high-fi) prototype.

Figure 42. *Concept sketch*

5.3.2 Concept introduction

Two concepts were created in this phase: 'EXPLICIT' and 'AUTOMATIC'. Both concepts have a homepage as this idea was highly acknowledged by the participants in the co-creation sessions, but the content and layout of the homepage are different.

For the concept EXPLICIT, there are more explicit interactions, for example, more obvious buttons and more confirmation for operations. Also, the information listed is more detailed and has more information on one page.

For the concept AUTOMATIC, data is organised by cards and showing one thing at a time on a page. The interactions are more implicit and automatic(e.g. the scores would be automatically updated when modifying the plan).

5.3.3 Concept 'EXPLICIT'

A home page concept was added to this concept to make this tool easier to use and less overwhelming. When the user first opens the tool, he/she can see a clear overview showing what he/she can achieve with it. There are four main parts on the home page: Navigation bar, Recent Analysis, Start New Analysis button, and Task Progress bar (Figure 43)

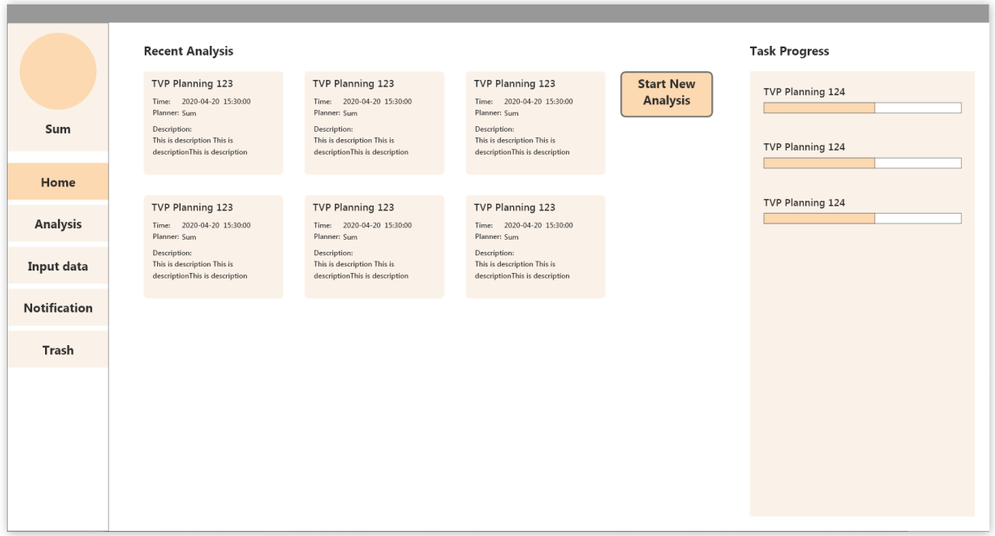


Figure 43. *Concept EXPLICIT: Homepage*

The main idea of EXPLICIT is to show more information at a time in lists (Figure 44), which might be easy for the user to look for information/data. This concept provides more explicit indication and feedback and more information would be demonstrated at a time.

The interaction of EXPLICIT is more explicit and require more manual operation. For example, when the user wants to modify the plan, he/she would click the 'Duplicate&Modify' button to first duplicate the original plan. After modifying, a 'Refresh Score' button reminds the user to refresh the outcome manually(-Figure 45). In this case, the tool provides more detailed and clear instructions for the user to achieve his/her goal.

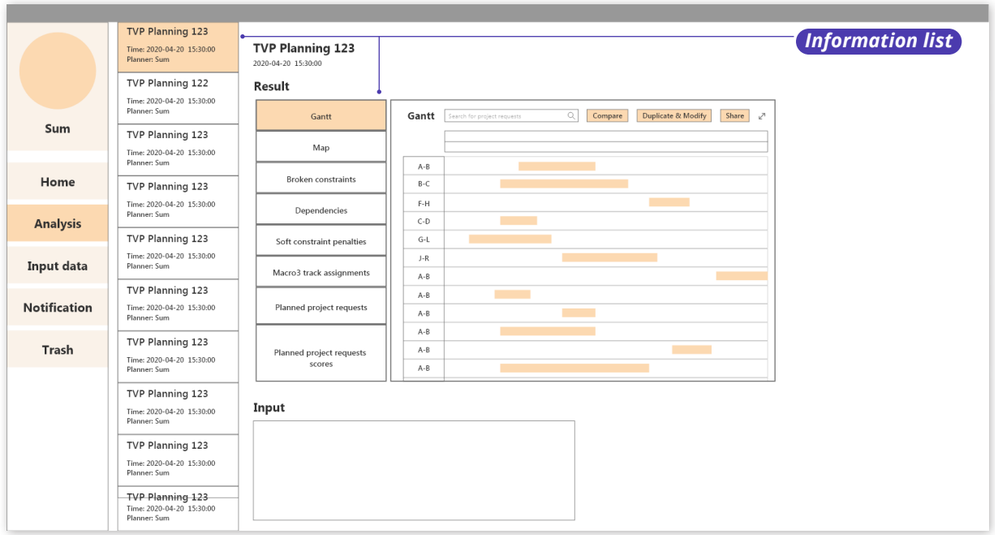


Figure 44. *Concept EXPLICIT: Results of the analysis*

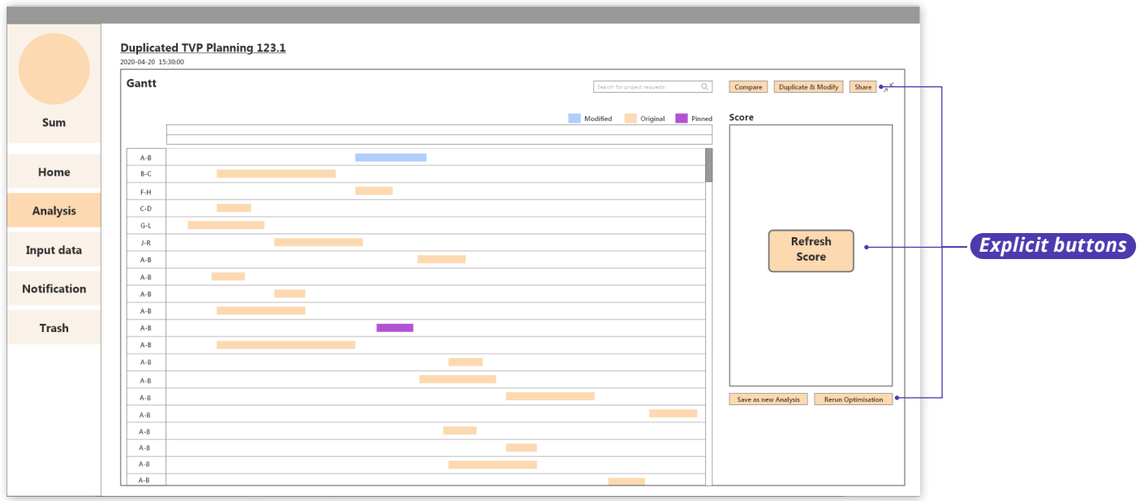


Figure 45. *Concept EXPLICIT: Modify the plan need to click the Refresh button to update scores*

5.3.4 Concept 'AUTOMATIC'

A dashboard view was used to demonstrate the latest data for each part. There are four parts on the home page: Analysis, Input data, Notification, and Agenda. (Figure 46).

The main idea of this concept is to show one thing at a time so that the user would not be overwhelmed by too much information. To achieve this goal, data is organised by cards instead of a long list(-Figure 47).

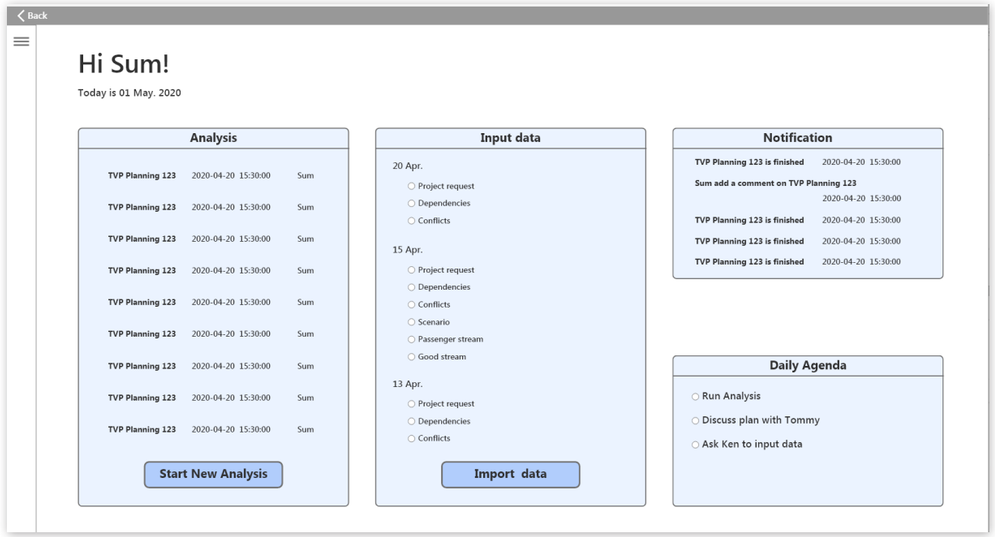


Figure 46. *Concept AUTOMATIC: Homepage*

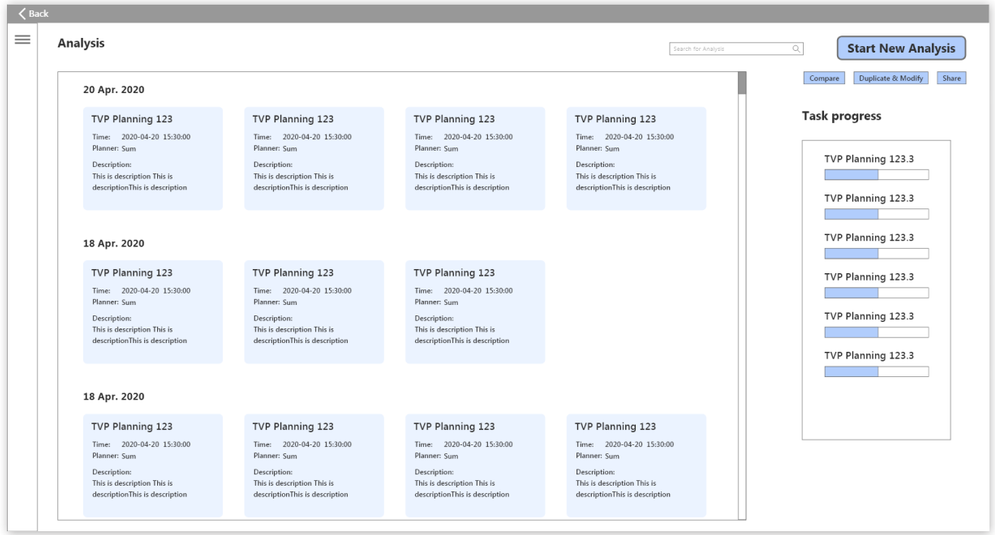


Figure 47. *Concept AUTOMATIC: Result of Analysis - each card represents the result of an analysis planning*

In terms of modifying the plan, the interaction is more intuitive and requires less effort. The user can directly move the project requests in the Gantt chart and the tool would automatically duplicate the plan while the score would be automatically updated(Figure 48).

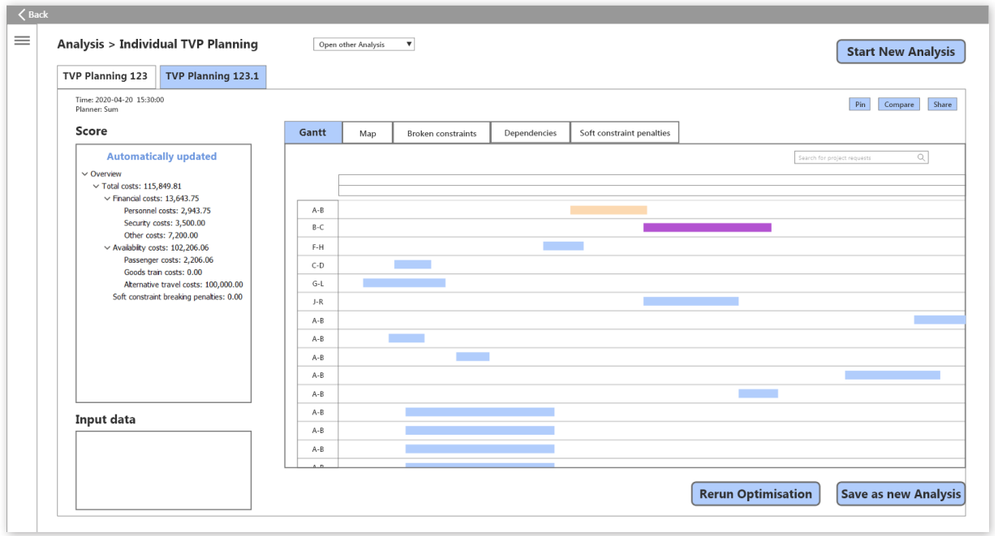


Figure 48. *Concept AUTOMATIC: Modify plan - automatically duplicate and update the score*

5.4 Iteration tests

5.4.1 Goal

In the iteration tests, two low-fi prototypes were created for testing.The goal of this sprint was to test the contents and flow of each prototype, compare the two initial concepts and get feedback on them.

Evaluate concepts comparably can help to evoke discussion and identify the 'level' of a function. For example, the there was a desire for convenient interaction which could be translate into implicit interaction or automatically operation. But to what extent does the user wants it to be 'automatic'? By having two concepts with different interpretation of a function/interaction can help the testees to evaluate the concept.

The questions for this iteration test were:

1. ***Whether the participants can understand the flow of the prototype?***
2. ***How confident are they when using the prototype? why?***
3. ***What elements/functions work/do not work for the participants? why?***
4. ***What else do they expect?***

5.4.2 Participants

6 participants were invited to online concept evaluation tests. There were 4 experienced users(1 planner and 1 tester from ProRail, 1 product owner and 1 project director from Macomi) and 2 TUD Master students who were new to this tool.

5.4.3 Procedure

The tests were held online through an online conference software Zoom. Each test started with a brief introduction of the project and the process of the test. After getting the consensus from the participant to recording the session, I started guiding them to test the prototypes by giving them tasks. Scripts of the introduction and tasks are shown in Appendix G

The test started with a first impression evaluation. The participants would be asked to describe what they saw on the homepage, what they thought each part means and used for and How do they feel about it.

After the first part, the participants were asked to finish the following tasks and think aloud during the test:

- ***Make a new Analysis for 2021***
- ***Select input data***
- ***Find result***

- ***Modify the plan***
- ***Rerun optimisation based on the modified plan***
- ***Compare plans***

An evaluation chart was used as a quantitative tool to trigger conversations in terms of usability and functionality. Combined with observation during the test, I was able to ask questions to figure out the reasons behind the scores and their behaviour.

When finished testing both prototypes, a wrap-up discussion was conducted triggered by a comparable ranking session. In this part, the participant was asked to compare the two concepts and ProRail maintenance in terms of usability and functionality.

5.4.4 Analysis methods

All the test sessions were recorded and for analysing. After the test, I reviewed the recorded video and noted down important insights and quotes from each participant for each task. After extracting all the valuable insights(positive and negative), I summarised and categorised the feedback. Some typical insights are elaborated below and some quotes from the participants were shown to support the feedback.

Number in the brackets represents participants that supported this statement. For instant, (P6) represents 'Participant no.6'; (3/6) means 3 participants out of 6 have shared the same opinion. Quotes in blue are positive feedback from the participants while orange means elements that could be improved/negative.

5.4.5 Result

Evaluation chart

During the discussion after the test, each participant was asked to compare the two concepts(for the experienced users who have used PRM also compared the concepts with PRM) in terms of usability and functionality with a scale from 1 to 7. The results are visualised in Figure 49.

In general, it was acknowledged that the usability of both concepts was better than PRM. But some participants found it difficult to compare them in terms of functionality because the prototypes did not have all the functions that PRM has, which might make the prototype less complex to some extent.

Thus, this scale was mainly used as a tool to trigger conversation and discussion instead of criteria for selecting one of the concepts. As these were low-fi prototypes, the functionalities and interactions were not well developed, the quantitative results of this scale were less representative.

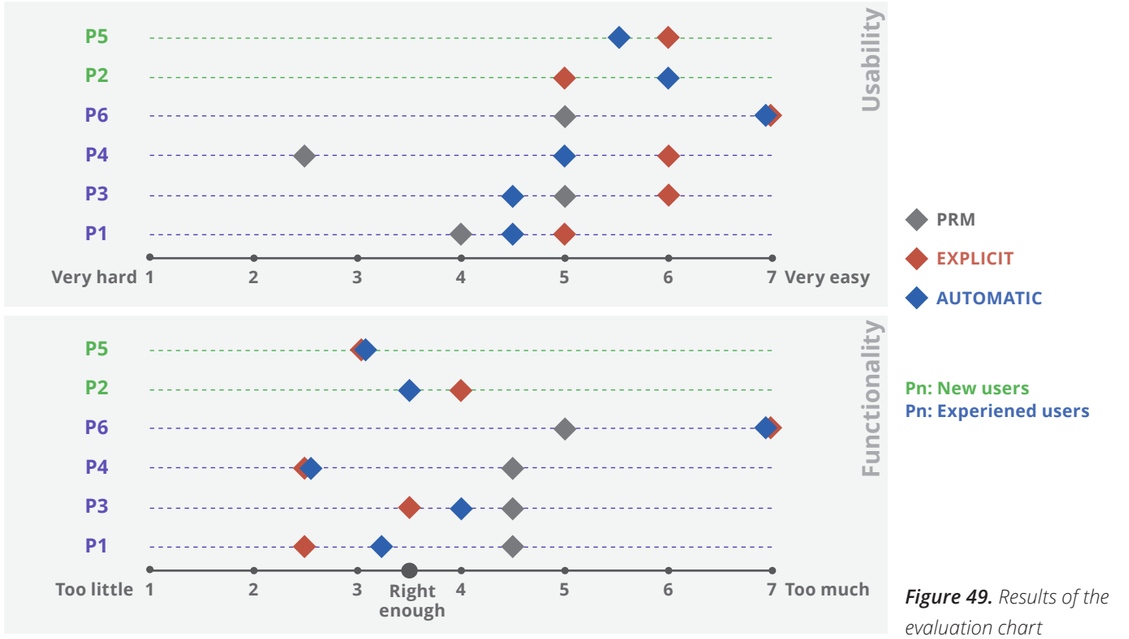


Figure 49. *Results of the evaluation chart*

Qualitative feedback on EXPLICIT

Positive feedback

+ In general, concept EXPLICIT was quite ***easy to understand*** for the participants. The Homepage and navigation bar helped the participants quickly grasp the main functions and structure of the prototype.
"It provides a clear overview of the main function and everything that is happening"(P6)

+ ***Quick access*** to the result from homepage (5/6)

+ ***Individual result page***: easy to organise and find the results of the analysis planning(4/6)
"I like the view of the result. I don't need to go to the database and search for it"(P4)

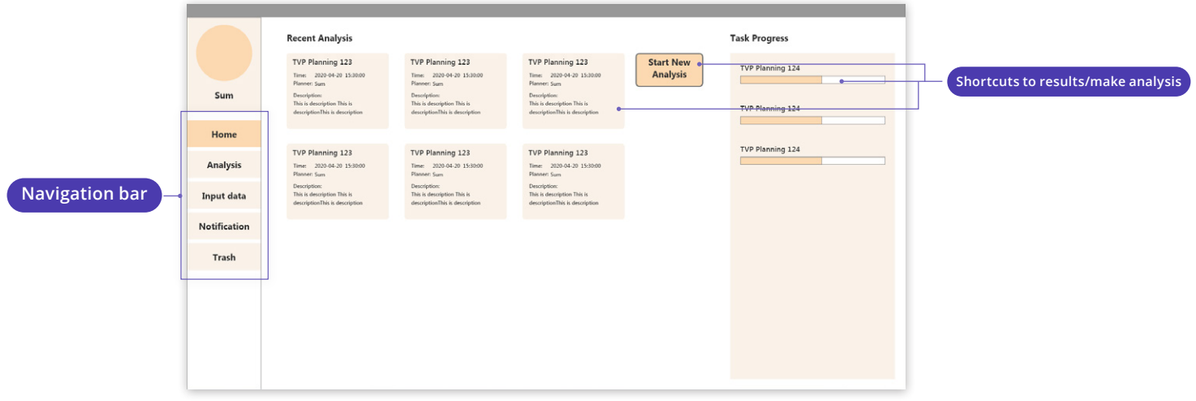
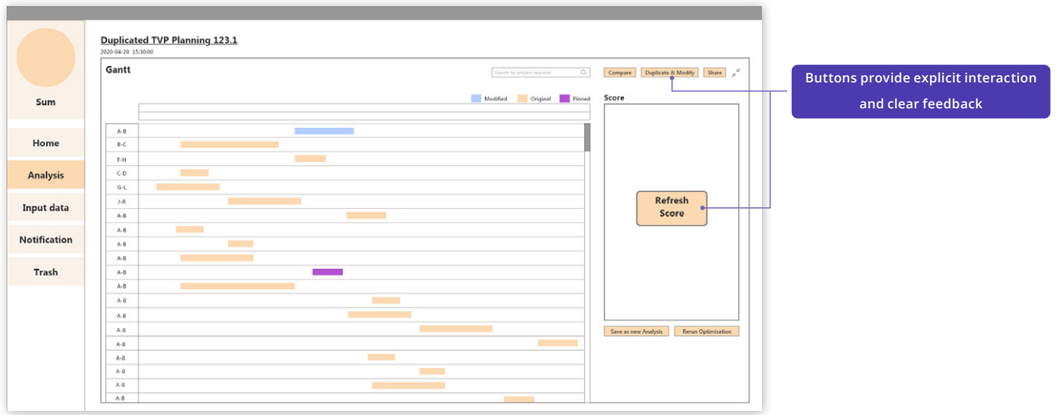


Figure 50. *EXPLICTIT: Homepage*

+ Indication for modifying the analysis planning is more clear and explicit than PRM.



Potential improvements

- ***Some naming or terms could be confusing***. 'Analysis' is the page where shows the results of the analysis while 4/6 participants thought it would lead to the page where they could make a new analysis(Figure 51)

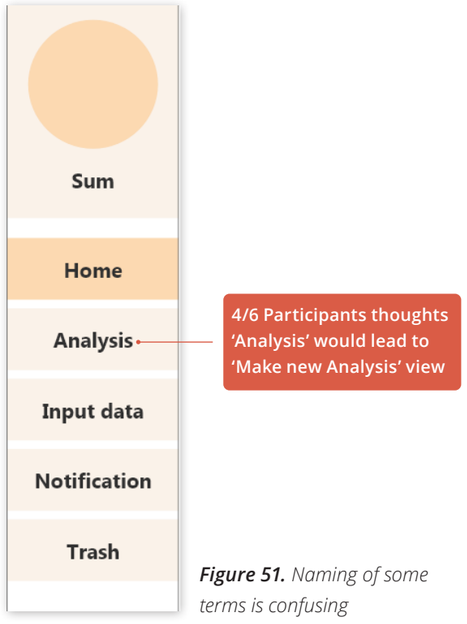


Figure 51. *Naming of some terms is confusing*

- ***The flow of selecting and grouping input data is fuzzy and unclear(6/6)***

There are some new features introduced in the input data page(e.g. grouping input data, filter and merging new input data). These features might have potentials but the interaction flow of selecting/ grouping input data in this page was unclear to the participants(Figure 52).

"I'm not sure what kind of group I added, what change and what is finished"(P1)

" I feel like this idea(grouping input data) could be helpful, but now flow is unclear"(P3)

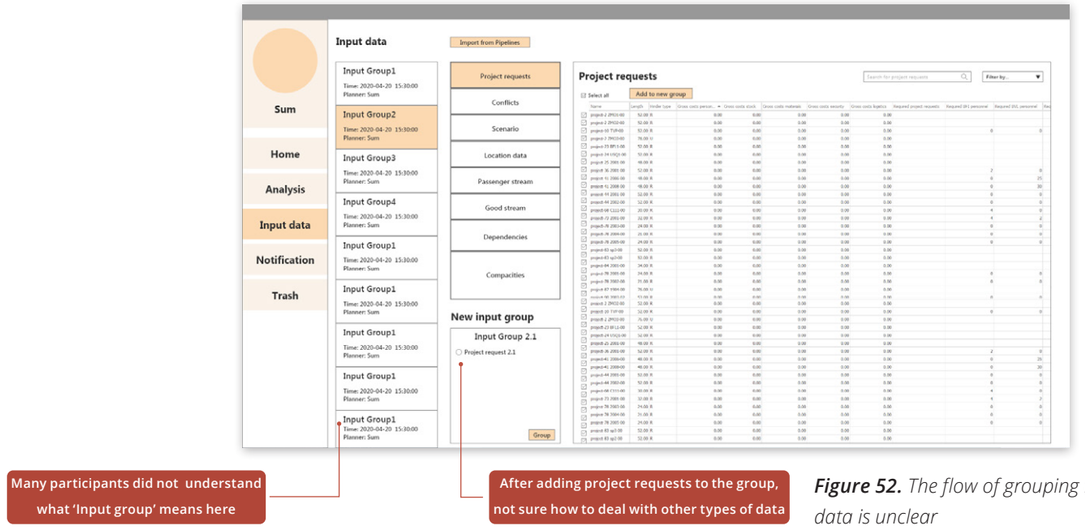


Figure 52. *The flow of grouping input data is unclear*

Qualitative feedback on AUTOMATIC

Input page

+ Easy to select input data needed for a new analysis.

"It's nice that I select what I want to use as input in the 'input data' then it automatically fills in."(P1)

+ Showing less info at a time

- "Expect to directly select the input data I needed instead of click a 'select' button first." (P2)

- Naming of 'Task progress' is confusing(3/6)

Half participants thought the progress bar is about the running analysis.

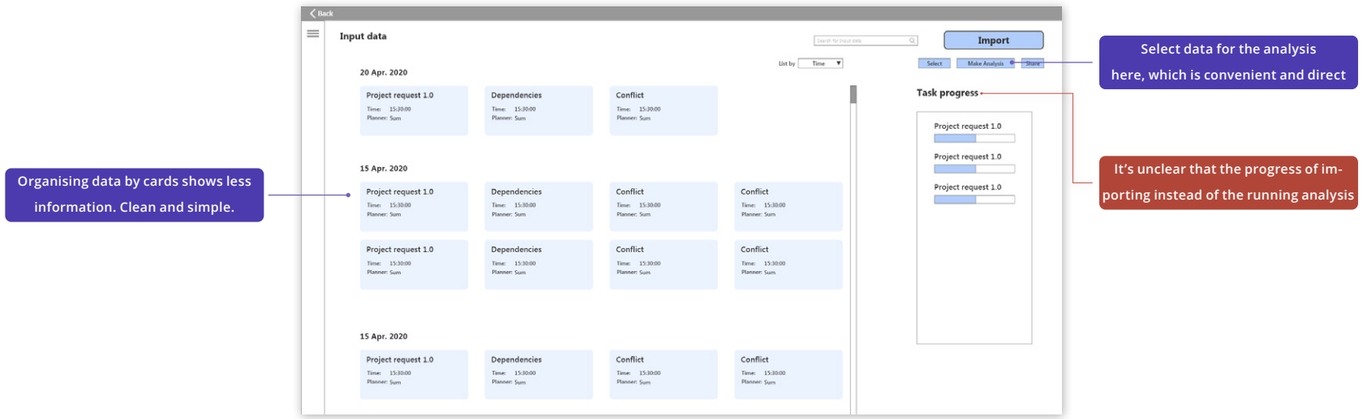


Figure 53. *Feedback on Input data page*

Make a new analysis:
+ Clear logic of the layout (select input>-configuration >validate>result)(P2).

- Progress bar for running analysis(6/6)
All participants liked this new feature as it informs the status of the analysis and the user can jump to the results when it is finished.

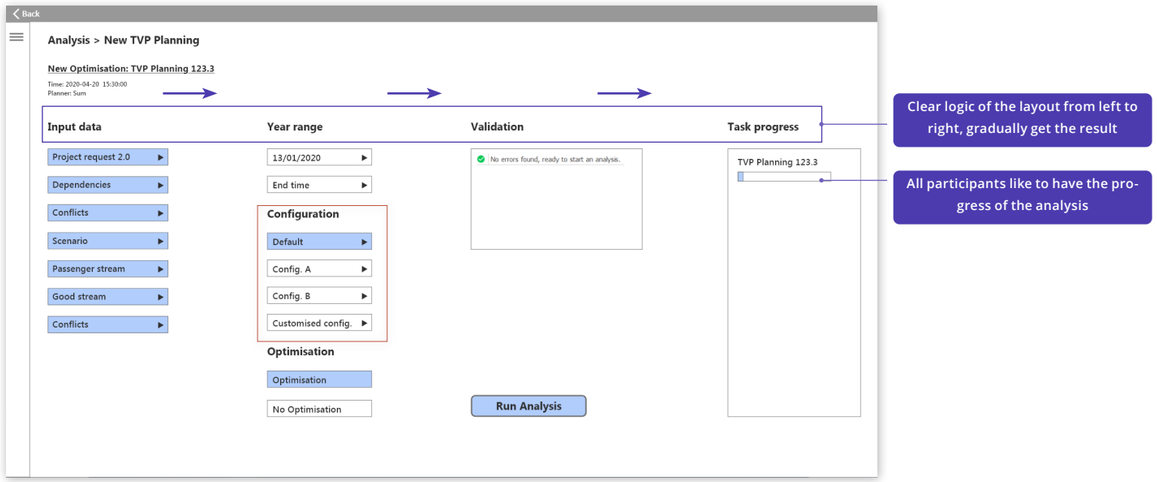


Figure 54. *Feedback on Analysis page*

Results & Modify the planning:
+ More intuitive and convenient(3/6)
e.g. automatically updated score, duplicate the plan automatically when the user drag the project requests, which requires less operation from the users

- Lack of feedback
Some interaction was quite implicit which might be unclear enough for the users what they could do with this function.
"I would like to be asked before duplicating"(P5)

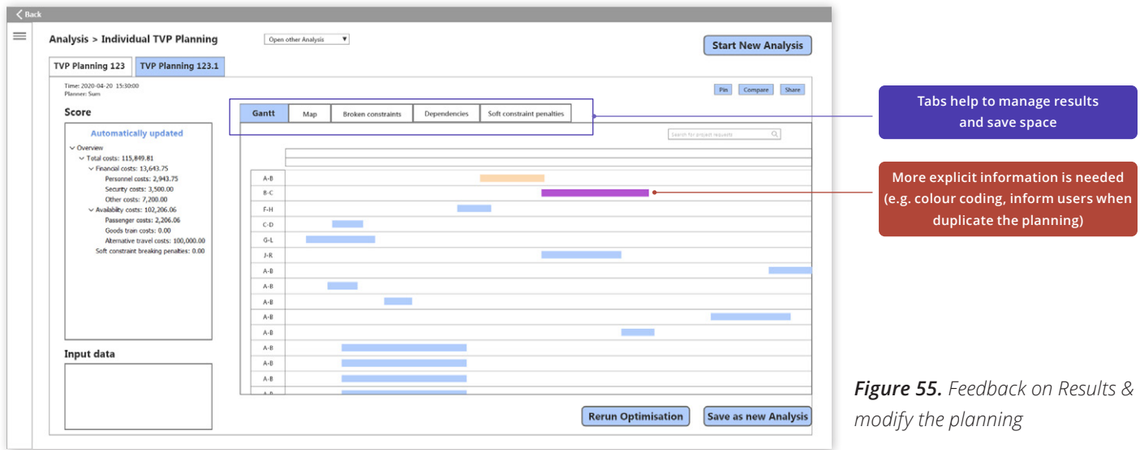


Figure 55. *Feedback on Results & modify the planning*

5.4.6 Takeaways

- Both prototypes provide a clearer overview than PRM.
- The home page and the result view got positive feedback from all the participants that they make the tool looks less scary and organise the data clearly, which could be kept in the iterated design.
- 'Input data' is the most confusing part, which needs more detailed design of the flow in the next design.
- Concept EXPLICIT has more explicit indication and shows more information at a time, which would be too overwhelming.
- Concept AUTOMATIC provides more intuitive interaction while sometimes has too little indication/feedback.
- Based on the insights gained from the test, I decided to create the iterated concept based on the structure of AUTOMATIC, because it has more intuitive and convenient interaction acknowledged by participants(especially new users). But more clear and explicit information/indication might be needed to help the users understand how to use it and be more confident.

5.5 Conclusion

This chapter introduces the ideation process before getting the final design. In this phase, users were highly involved in the activities from co-creation to iteration tests. To get inspiration and ideas from various perspective, two co-creation sessions were held with planners from ProRail and consultant and product owners from Macomi to brainstorm ideas about the ideal pages and workflow.

Top ideas from the co-creation sessions were categorised into 5 categories: Organised structure, Convenient interaction, Noticeable information, Creating focus and Instant feedback.

Combined with the insights gained from the Ideal scenario discussion session with two product owners from Macomi, I generated two initial concepts: EXPLICIT and AUTOMATIC. These two concepts were demonstrated as low-fi prototype and tested with 6 participants to get feedback on the experience, functions and workflow.

Based on the results of the iteration tests, the idea of the Homepage and the independent result view got positive feedback from the participants, which could be remained in the final design. Concept AUTOMATIC provided more intuitive interaction and performed better in organising information/data, which would be the base of the final design. But some aspects should be taken into account and improved. For instance, the flow of 'Input' needs more concrete design and more explicit and clear feedback is needed for the users to understand and interact with the prototype more confidently.

In the next chapter, I would introduce and explain the final design and prototype, which were developed based on the insights from the above research and design activities.

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06
FINAL DESIGN

After the conceptualisation phase, an iterated concept was generated based on the insights I got from the previous tests. This chapter explains the final concept, highlights, and the prototype made for evaluation.

Overview

6.1 Final concept: MACOMI Maintenance

6.1.1 Concept introduction

Macomi Maintenance is a data-analytic platform for railway maintenance planning optimisation, which was generated based on the user-centric research and insights from concept iteration tests. It consists of four main functional pages: Homepage, Input, Analysis and Result, which support the main scenarios for the railway maintenance planning optimisation discussed in 4.2. In Figure 56, it summarises the main functions of each page. Orange represents the four main functional pages and the purple blocks after each orange block are the functions and operations in that page.

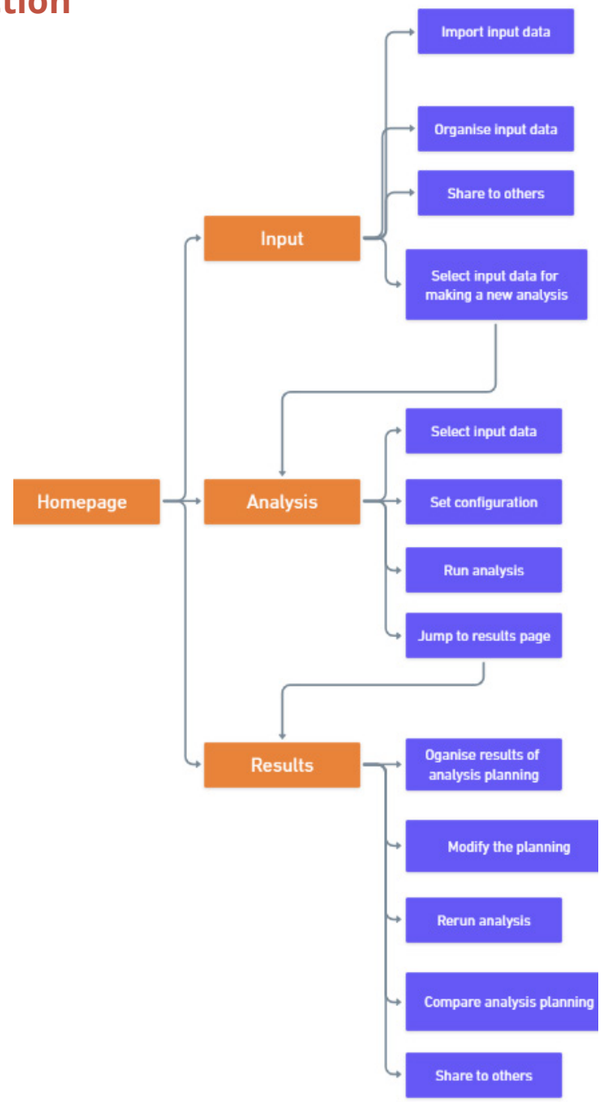


Figure 56. *Main Functions of Macomi Maintenance*

6.1.2 Highlights of the concept

01 Customisable Homepage

In the current PRM, there are a lot of data and buttons listed on the first page, which makes it looks too complex(a lot of functions and information) and overwhelming (Figure 57). Thus, a customisable Homepage was introduced in this concept to help to organise this complex system (Figure 58). It enables the user to customise (add/delete what they would like/dislike to see on the homepage). By default, the home page shows the Recent analysis and Analysis Progress as these are two elements the planners care a lot based on previous research.

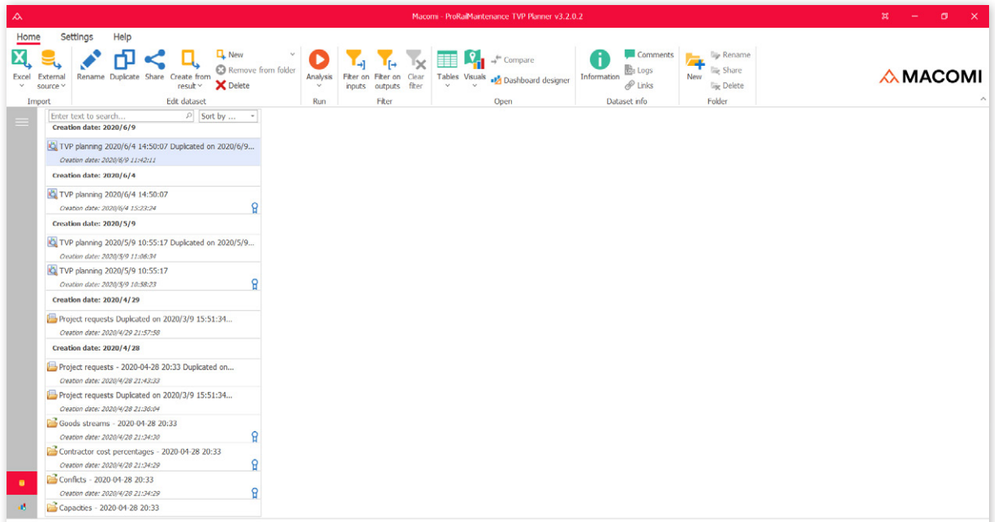


Figure 57. *First page of PRM*

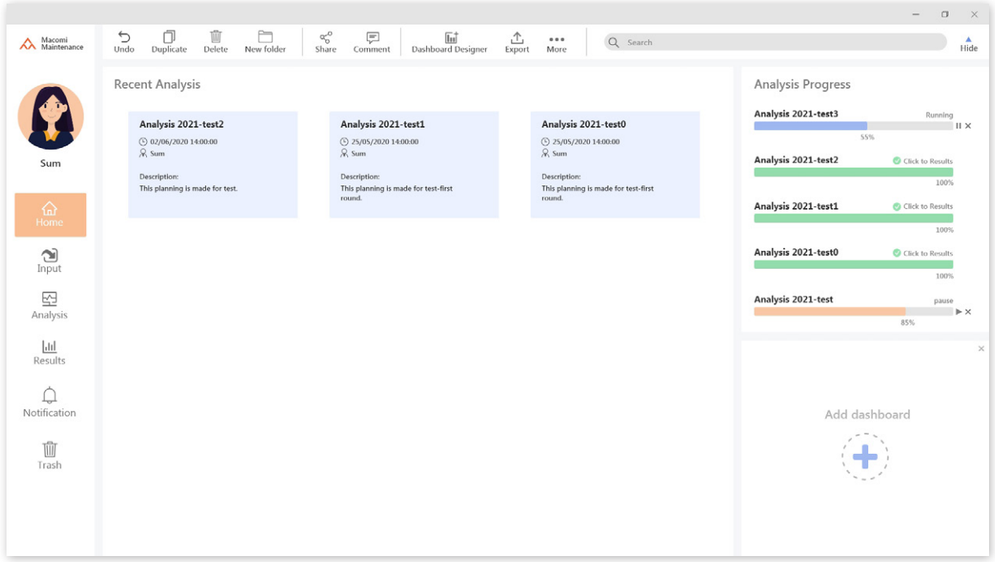


Figure 58. *Homepage of Macomi Maintenance*

02 Clearer function division

In the PRM, all data (input data, results of the analysis) is regarded as the same type of data and put together in a data-set list (Figure 59). This makes it difficult for users to organise data and understand the flow of making use of data.

In this concept, separated function pages were designed for different tasks. The user can visit different functional pages through the navigation bar(Figure 60). For instance, the user can go to Input, to import data and organise input data, or check the results of the analysis in the Result page. Each page has its main function so that the user can clearly understand what they should do on that page.

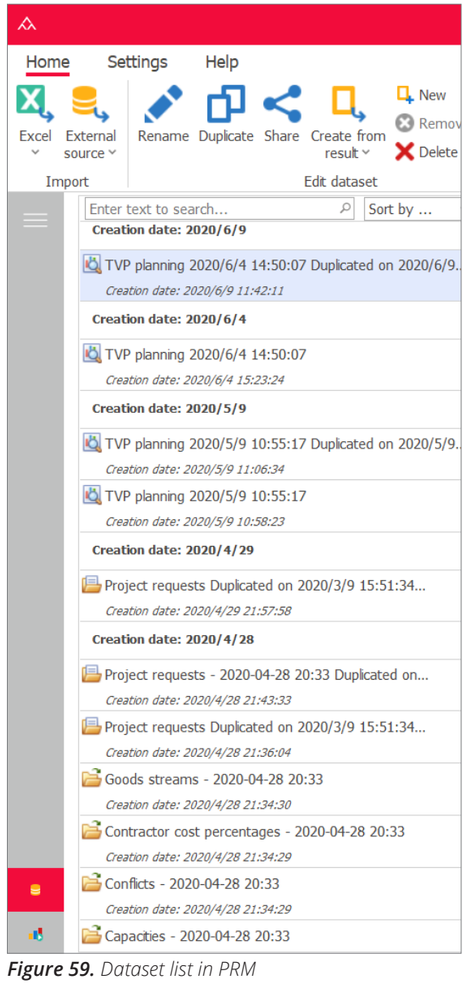


Figure 59. *Dataset list in PRM*

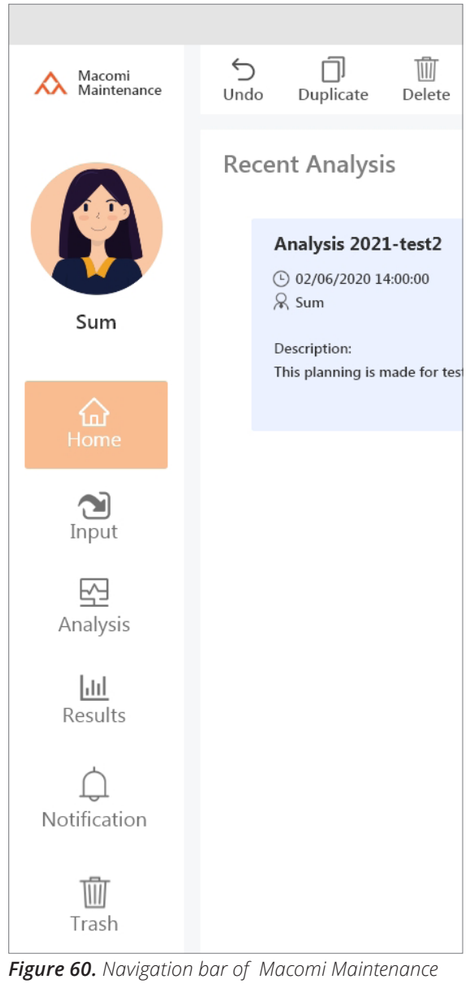


Figure 60. *Navigation bar of Macomi Maintenance*

03 Folders for organising data

In the Macomi Maintenance, users can easily create folders to organise either input data or the results of analyses. Whenever the user importing input data from the external environment, it would automatically group all the imported data into a folder(Figure 61). In this case, the user can either select individual input data or a folder for making a new analysis.

This idea can help to organise data especially for input data and requires less effort for users to select input data for making an analysis.

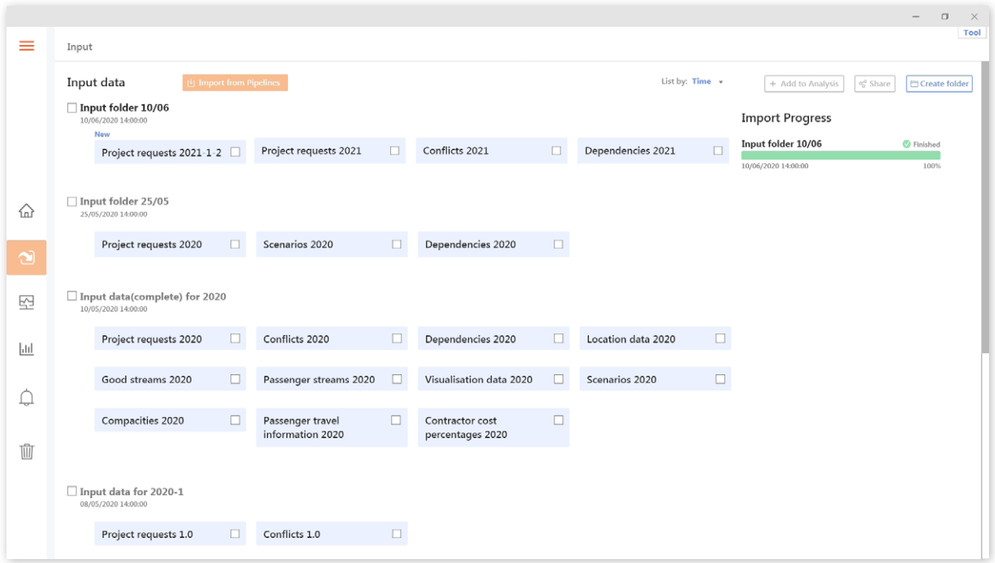


Figure 61. *Input data is organised by folders in the Macomi Maintenance*

04 Cards for information demonstration

In this concept, input data and the results of analyses are demonstrated on cards instead of a long list (Figure 62). For the results of analyses, there are short descriptions and information(e.g. name, time and editing person) on each card for users to quickly distinguish and identify the result. According to the feedback from the iteration test, showing data in this way makes it less crowded and more organised.

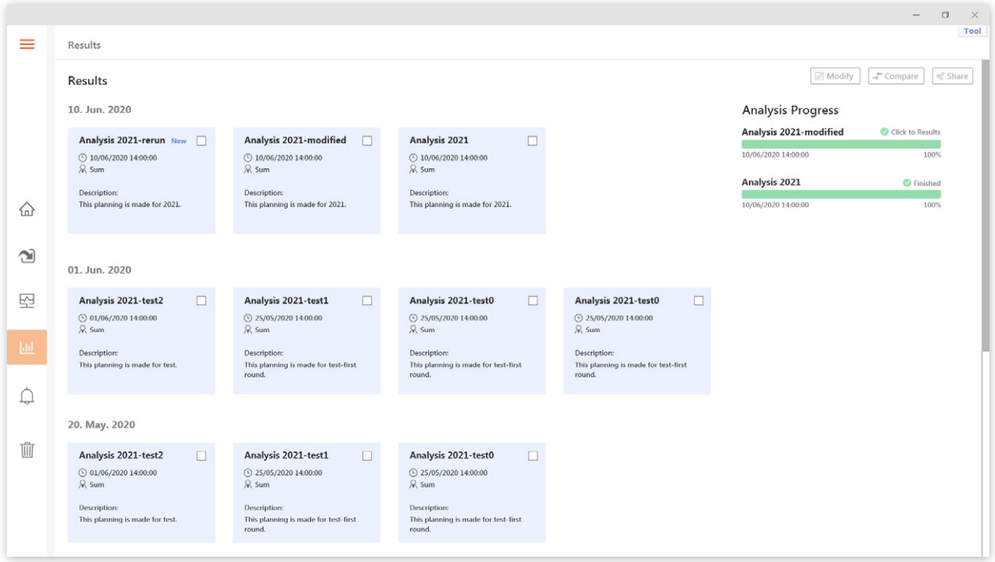


Figure 62. *Macomi Maintenance use cards to organise results of the analses*

05 Organising results in a more professional way

Currently, the results of the analysis in PRM are displayed in a way that is not well-organised enough. When the user chose a result from the list on the left, there was an overview of all the results on the right (Figure 63). The information on the right was a bit cluttered which made the results less trustworthy to the new users.

In the new design, various types of information of the analysis planning are organised by tabs(Figure 64). The overview of the scores and the Gantt chart is the first thing that comes into view after the user selects the planning, as it is one of the most important and interesting information for the planners. This idea helps to create focus and a special space for all the information about the results of the planning. By tapping the tabs, the users can check different information and enlarge to full screen for better manipulation and review.

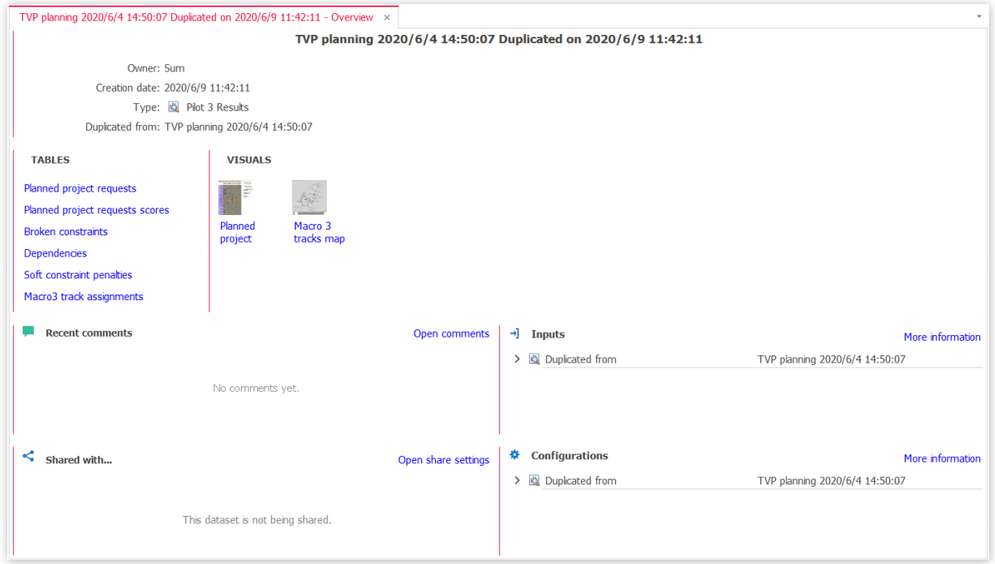


Figure 63. *Overview of the results of an analysis in PRM*

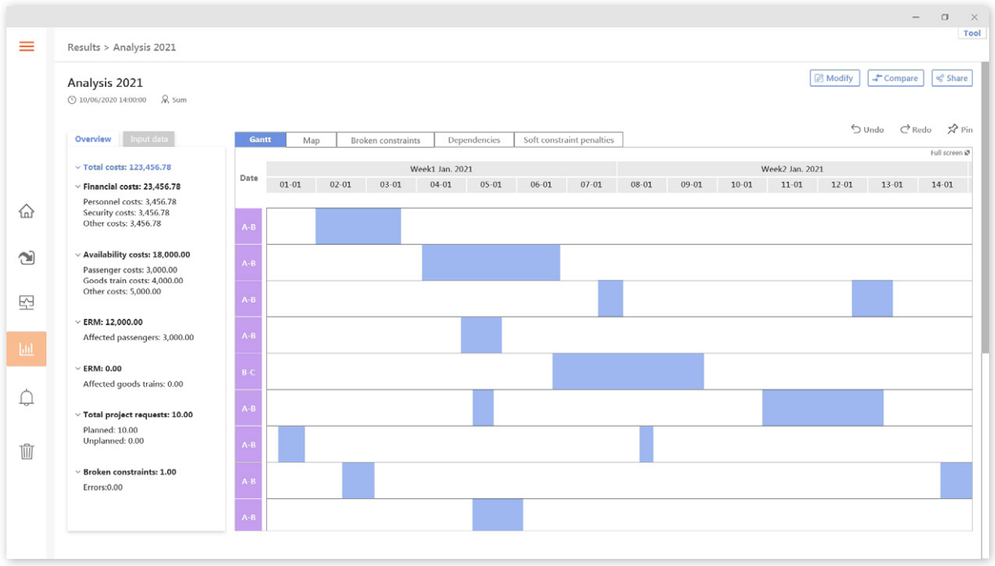


Figure 64. *Results of the Analysis 2021 in Macomi Maintenance*

6.2 Prototype

In order to demonstrate and evaluate the design in the evaluation test phase, I developed a high fidelity prototype with the prototyping software Adobe XD.

A high fidelity prototype mimics the actual interaction as real as possible and requires less effort than building a functional software by coding. By using a high fidelity prototype, the user can experience the interaction more immersively and the experience would be closer to using the actual software compared to testing with a low fidelity prototype or watching a demonstration video/ storyboard.

The following pages demonstrate the prototype of the final design and explain the key functions and interaction flows. As shown in Figure 65, the user needs to log in his/her personal account in order to get access to the Macomi Maintenance. After logging in, the user can start using the tool.

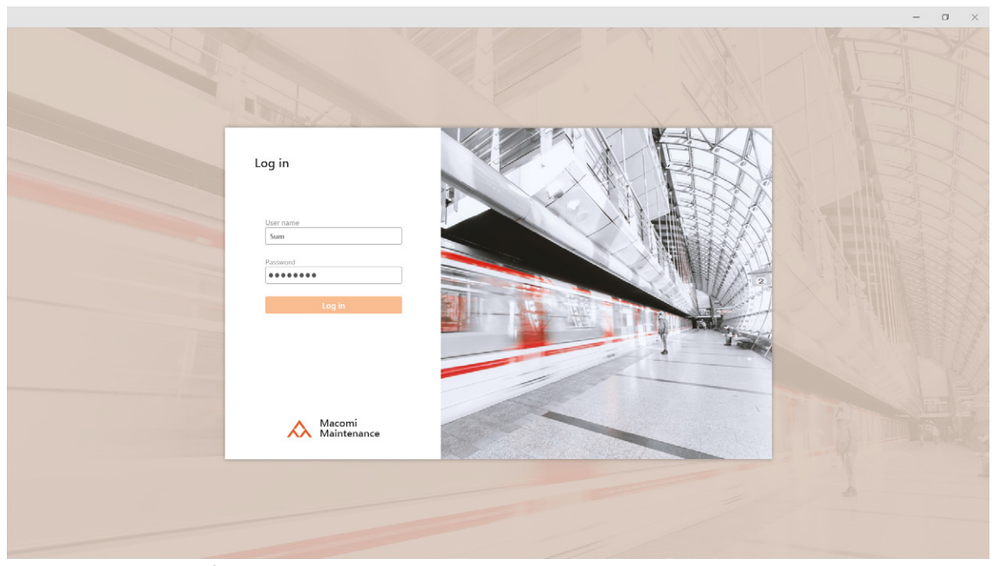
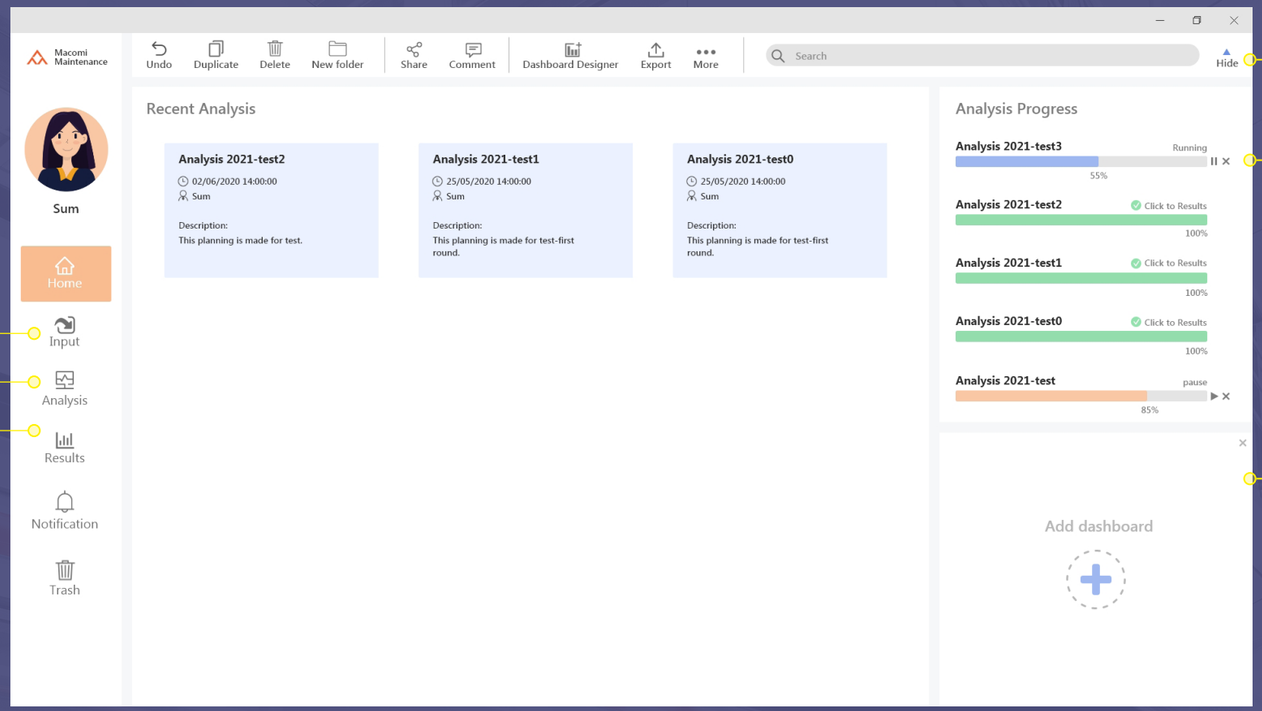


Figure 65. *Login page of Macomi Maintenance*

HOME PAGE



Toolbar

Users can hide the toolbar to keep a clean and 'minimalist' work space and use context menu(right click) to activate functions

Progress and shortcuts

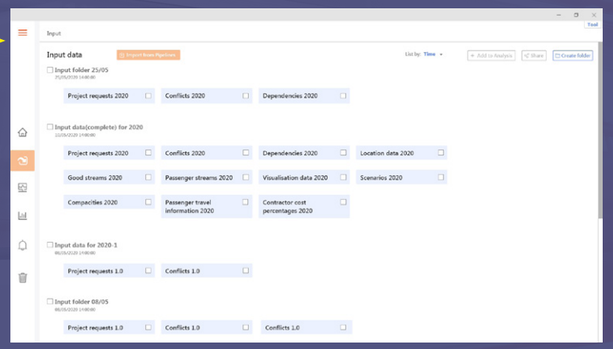
Support quick access to the analysis planning and check the progress of the analysis

Customisable dashboard

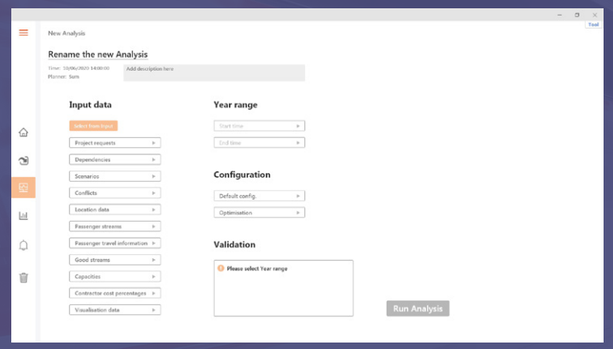
Different users might have different working habits and care about different information due to different responsibility. The Home page supports customising dashboard and the users can put the most relevant information for them on the homepage.

Navigation bar

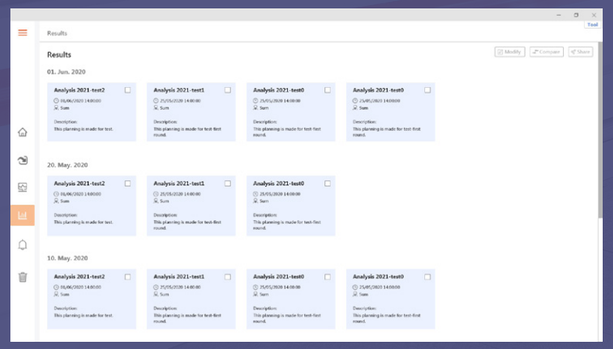
Show clear structure of the tool and the users can easily switch between various pages to conduct different operations



INPUT



ANALYSIS



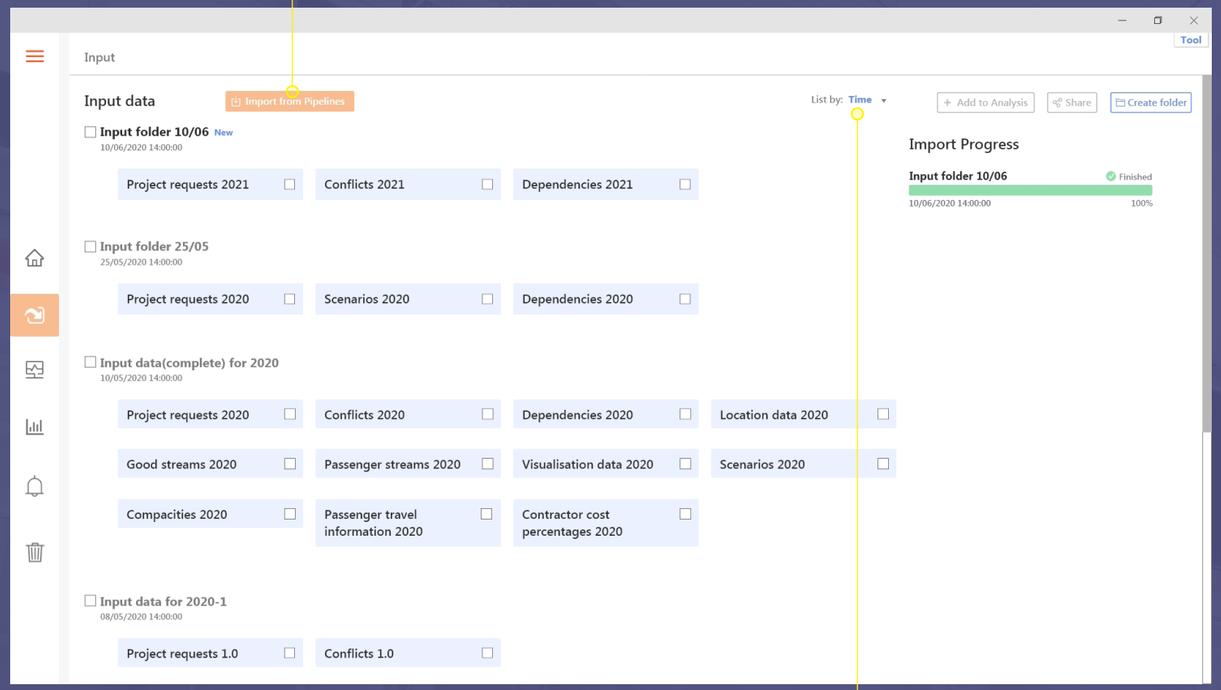
RESULTS

Figure 66. *Macomi Maintenacne: Home page*

INPUT

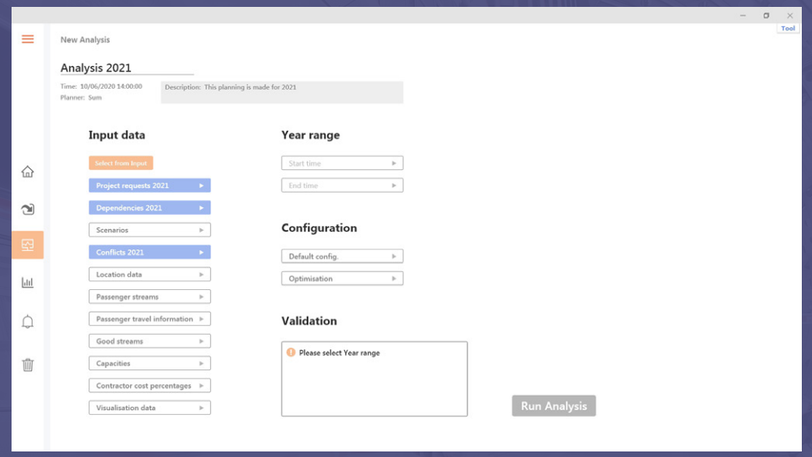
Import from Pipelines

External data(e.g. Excel form, visuals of the tracks etc.) can be transmitted and imported into the Macomi Maintenance



Select input data for making a new analysis

The user can directly select input data and add to the new analysis he/she wants to make.



Different types of view

The user can choose viewing input data by types or by folders. It helps the user to organise the data and select based on different needs

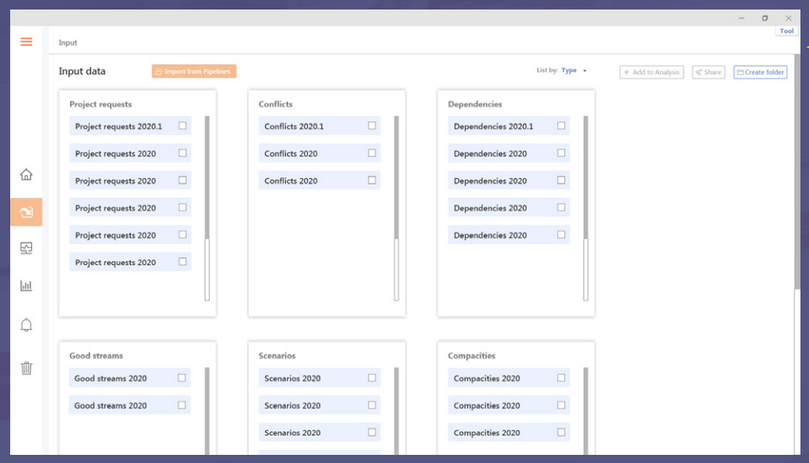
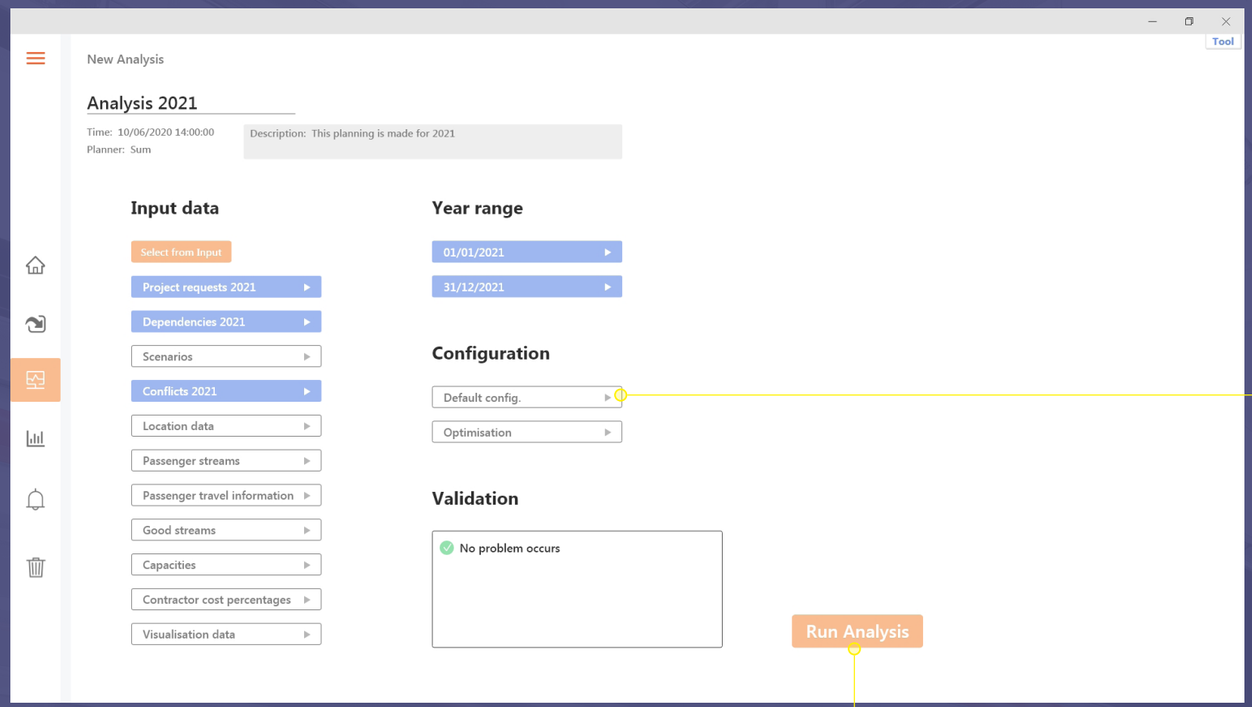


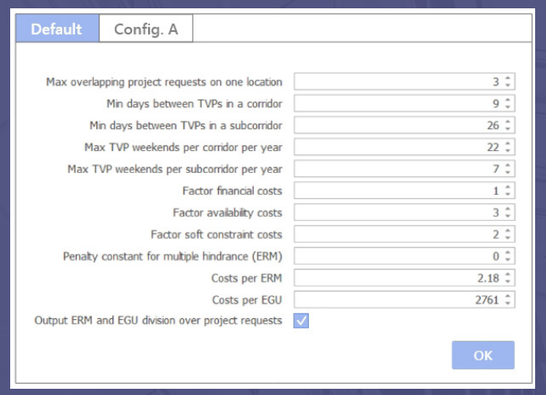
Figure 67. *Macomi Maintenacne: Input page*

ANALYSIS

INPUT

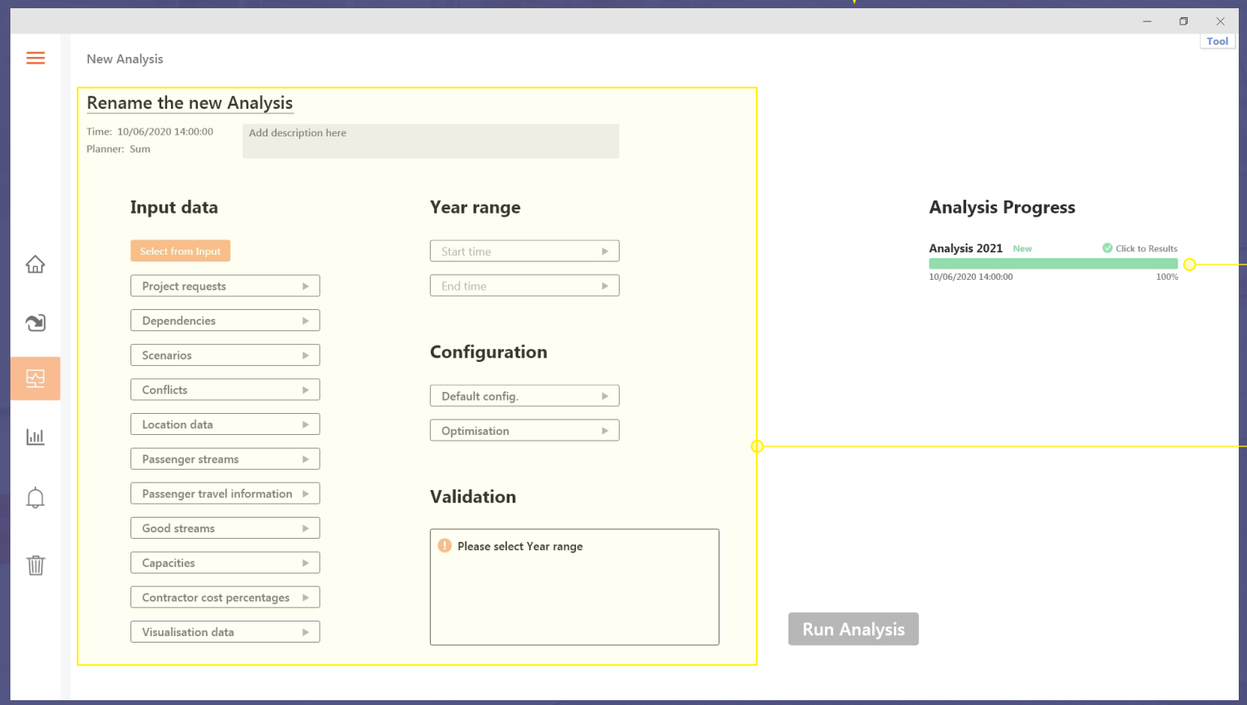


ANALYSIS

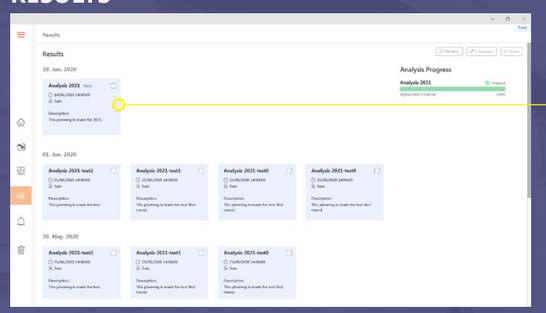


Configuration settings

Besides the default configurations, the user can also save his/her own configuration settings, so that they can have several 'default' and just select based on different scenarios.



RESULTS



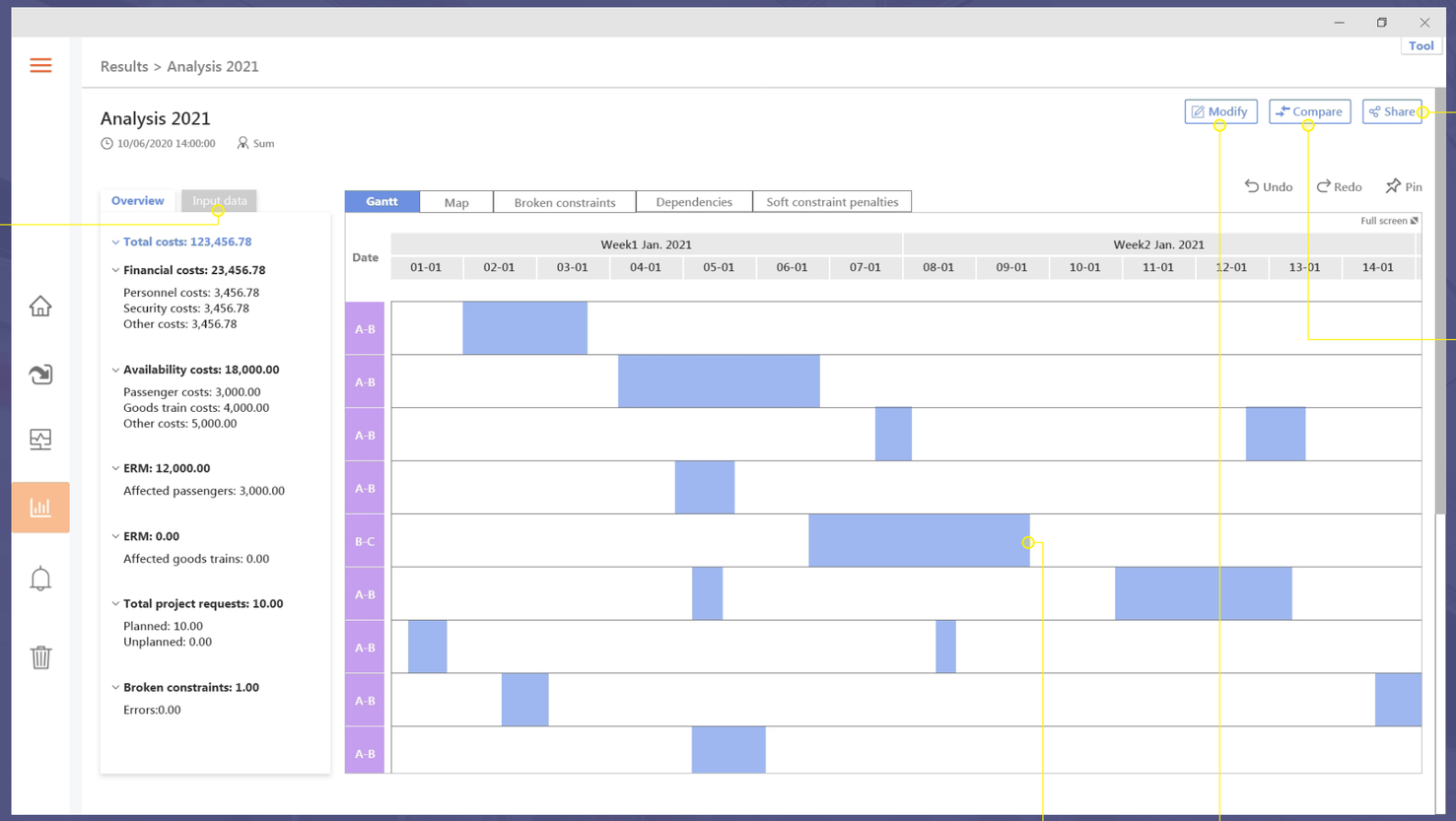
Quick access to results

After clicking 'Run Analysis', a progress bar would appears, through which the user can quickly check the results/go to the Results page.

After putting an analysis in progress, the user can immediately start planning another analysis.

ANALYSIS

Figure 68. *Macomi Maintenacne: Analysis page*

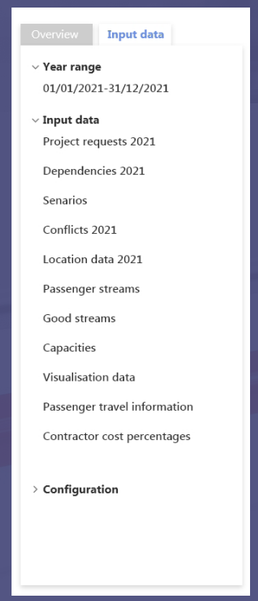


Share

The user can directly share the results of the analysis planning to others on this page. This flow will be explained in the 'SHARE' page.

Compare

This function supports comparing different analysis plannings in order for the users to define the optimal one. This will be explainted in the 'COMPARE' page.



Switch tabs to check various information

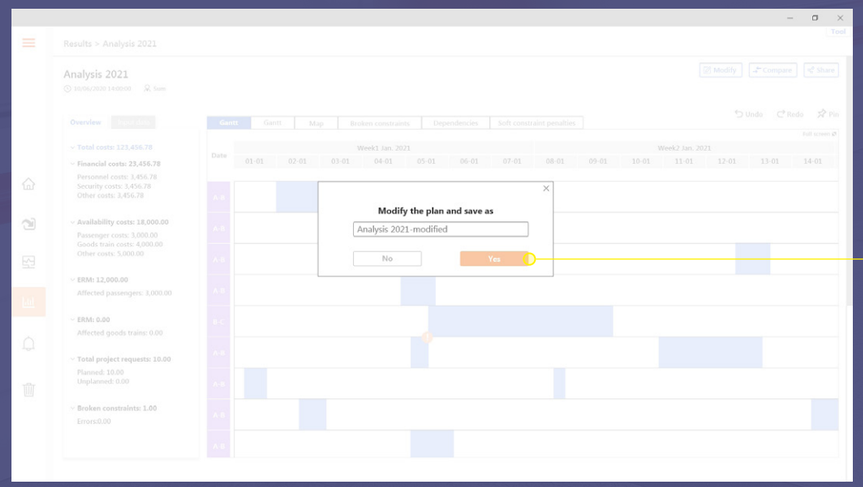
By switching tabs, the user can also check the input data used for making this analysis planning. This helps to distinguish between various plannings especially when the user run serveral analyses at once.

Modify the planning#1

The user can directly drag & drop the project requests to modify the plan.

Modify the planning#2

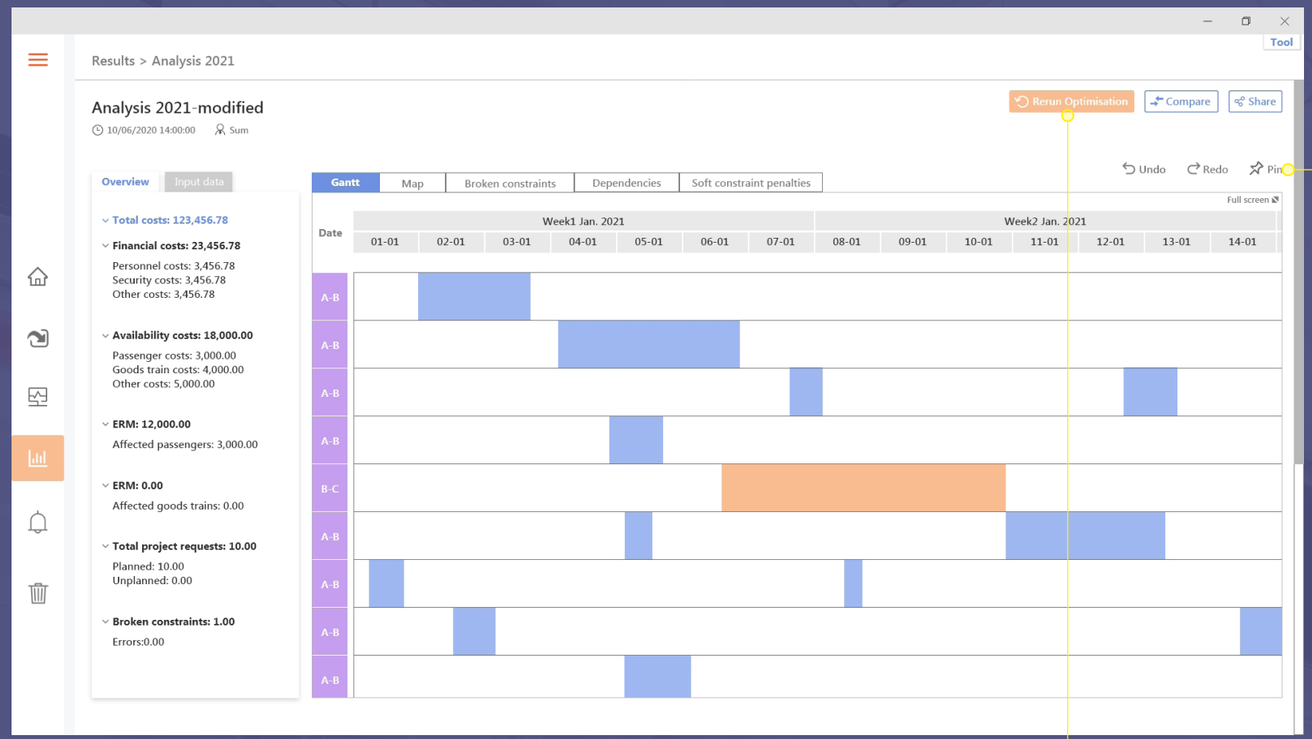
Or by clicking the 'Modify' button to create a copy of this planning in order to modify it.



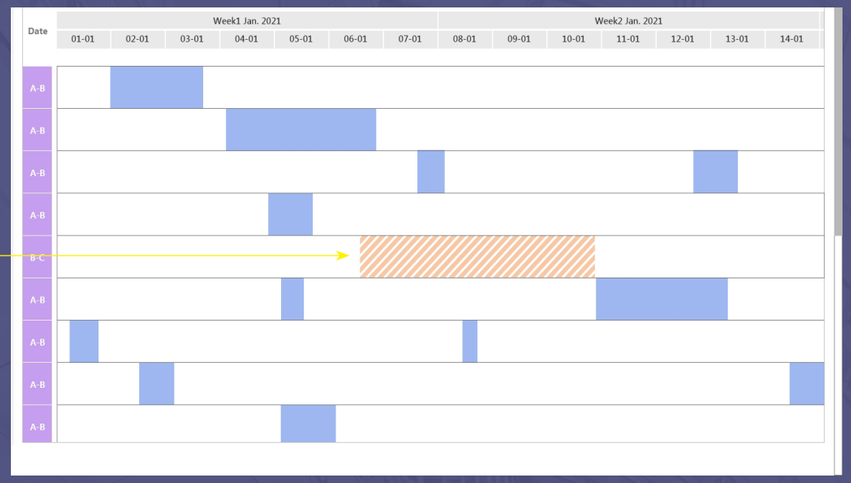
Duplicate and modify

By default, the original results of the analysis planning can not be changed(as reference). Thus, the tool will automatically duplicate it so that the user can directly modify the planning whenever they want to.

Figure 69. *Macomi Maintenacne: Results page*



MODIFIED ANALYSIS PLANNING



Pin

'Pin' is a function that enable the user to pin specific project requests. A pinned project request will be fixed and can not be modified until you unpin it. Usually it will be used for pinned big project or important projects that is hard to rearrange.

Rerun optimisation

After pinning some project requests, the user can rerun the analysis to optimise the plan based on the modification he/she just made.

In other words, all the other project requests might be arranged again around the pinned ones, and the algorithms will automatically optimise a planning based on the modified project requests.

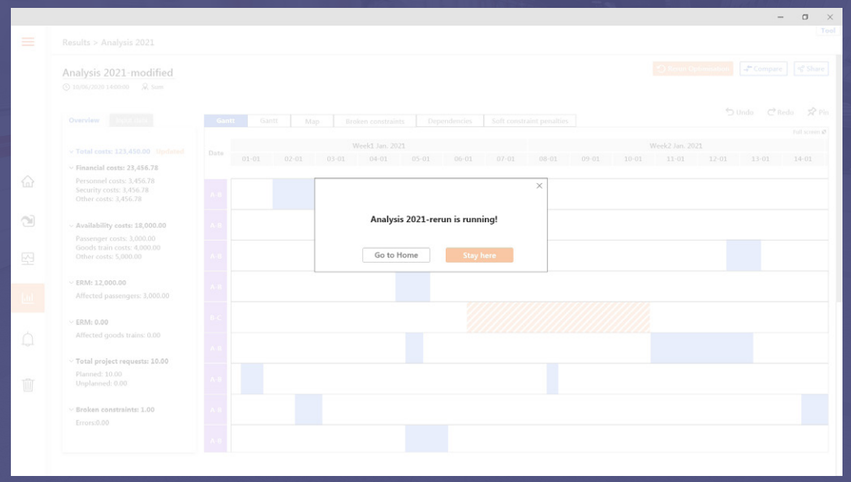
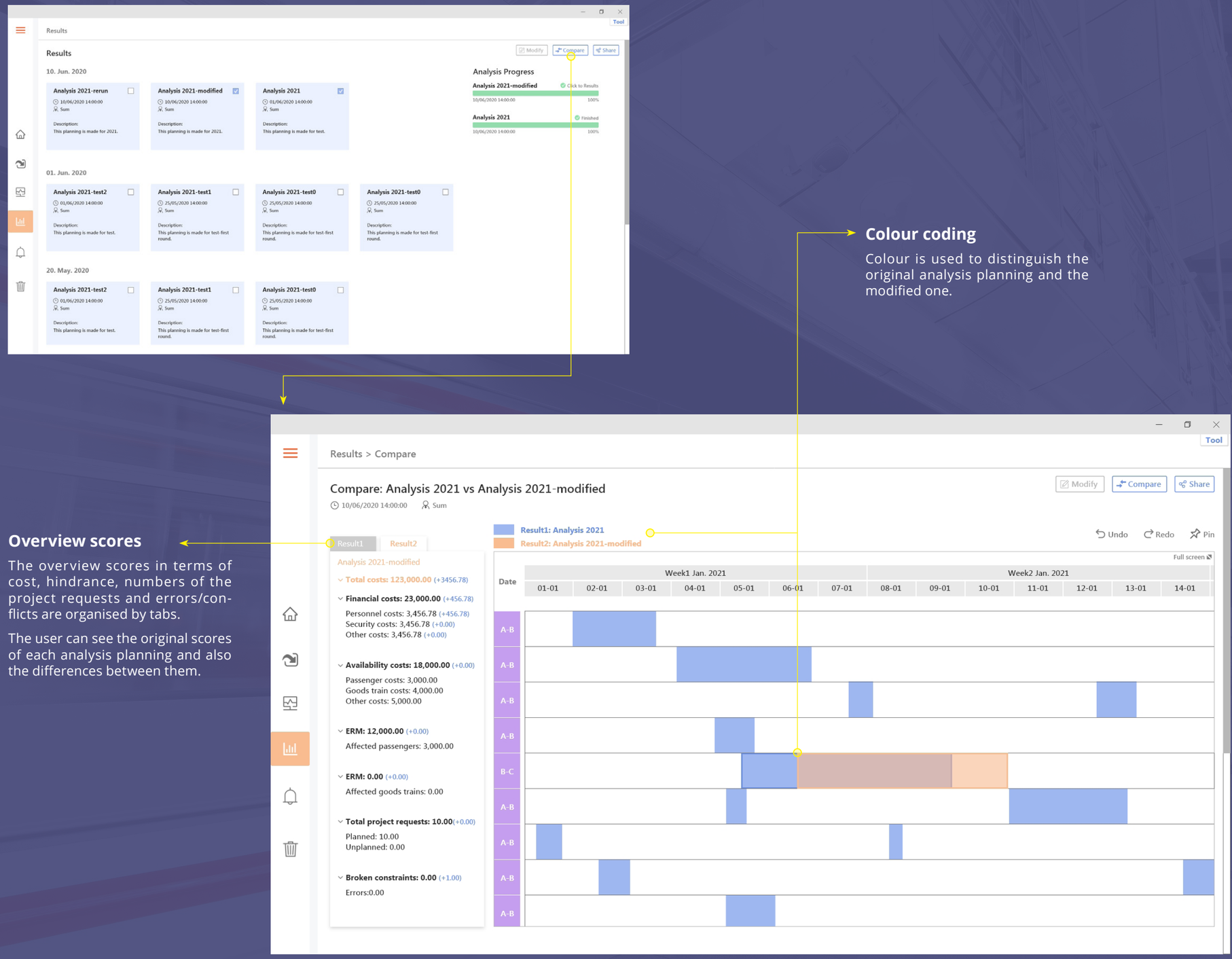


Figure 70. *Macomi Maintenacne: Modify and rerun optimisation planning*

MODIFY & RERUN



Overview scores

The overview scores in terms of cost, hindrance, numbers of the project requests and errors/conflicts are organised by tabs.

The user can see the original scores of each analysis planning and also the differences between them.

Colour coding

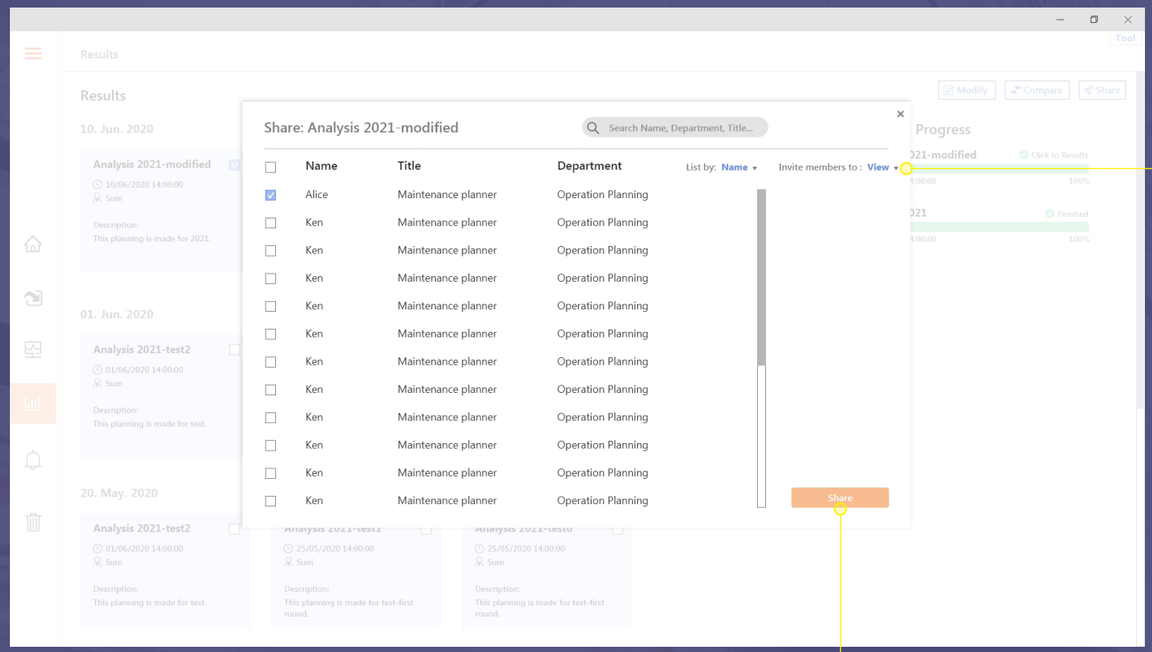
Colour is used to distinguish the original analysis planning and the modified one.

Figure 71. *Macomi Maintenacne: Compare planning*

COMPARE

Search

The user can search name or department in the search bar on top to quickly search for the person or select list by: Name/ department etc. and choose the person he/she would like to share the results with.



SHARE

Permission settings

When sharing the results/data to others, the user can set which type of premission(view only, can comment, can edit) he/she would like to give.

Share icon

After sharing the results, a share icon will appear on the card indicating to whom did the user just shared the results.

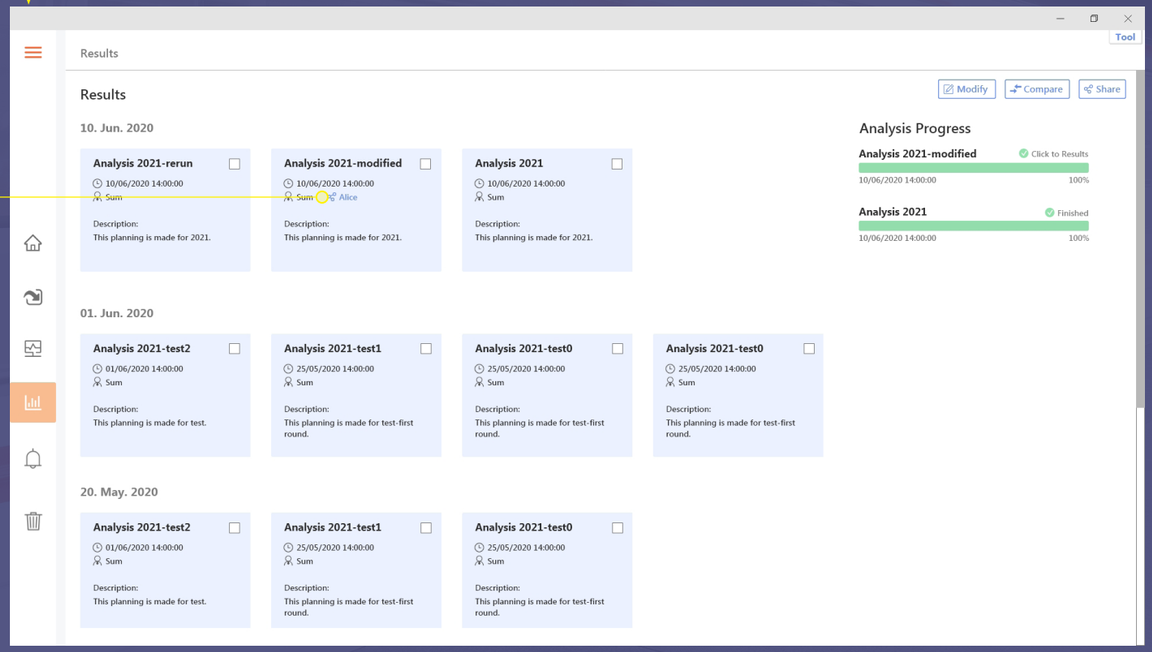


Figure 72. *Macomi Maintenacne: Share*

SHARE

07
Evaluation & Recommendations

This chapter is about the evaluation of the final concept. In this part, evaluation tests were conducted to see if the final concept has met the design goal and requirements. After that a discussion recommendations for futrue developments will be elaborated

Overview

7.1 Evaluation test

7.1.1 Goal and approach

The evaluation test aimed at evaluating the overall experience of the design and assess if it has met the design goal and requirements. Thus, the goal was to find the answers to the following questions:

1. ***How is the usability of the design?***
2. ***How is the aesthetics of the design?***
3. ***To what extent does the design achieve the design goal and requirements?***
4. ***What are the limitations and recommendations?***

The initial goal of this project was to improve the UX of PRM, therefore, it is crucial to evaluate the usability. Besides, the aesthetics of the interface can affect the actual perception of the overall experience such as usability (Moshagen et al., 2009), satisfaction (Cyr et al., 2008; Lindgaard and Dudek, 2003), preference (Schenkman and Jönsson, 2000), and intention of revisit (Mahlke, 2002). Thus, it is also valuable to assess the aesthetics of the prototype.

To evaluate the aforementioned aspects, there were two main tools used during the online prototype tests combined with qualitative interviews: System Usability Scale(SUS) and Visual Aesthetics of Websites Inventory-Short(VIsAWI-S).

System Usability Scale(SUS)

System Usability Scale(SUS) is a reliable tool for measuring the usability of various products and system, including software, hardware, website etc. SUS has become a standard with references in over 1300 articles and publications. (Usability.gov, n.d.-b) SUS consists of 10 statements with rankings from 1 to 5 representing 'Strongly disagree' to 'Strongly agree' (Figure 73) This scale can be used on small sample sizes with reliable results, which can effectively distinguish whether the prototype is usable or not.

	The System Usability Scale Standard Version	Strongly Disagree					Strongly Agree
			1	2	3	4	5
1	I think that I would like to use this system frequently.		o	o	o	o	o
2	I found the system unnecessarily complex.		o	o	o	o	o
3	I thought the system was easy to use.		o	o	o	o	o
4	I think that I would need the support of a technical person to be able to use this system.		o	o	o	o	o
5	I found the various functions in this system were well integrated.		o	o	o	o	o
6	I thought there was too much inconsistency in this system.		o	o	o	o	o
7	I would imagine that most people would learn to use this system very quickly.		o	o	o	o	o
8	I found the system very awkward to use.		o	o	o	o	o
9	I felt very confident using the system.		o	o	o	o	o
10	I needed to learn a lot of things before I could get going with this system.		o	o	o	o	o

Figure 73. *System Usability Scale (Brooke, 1986)*

Visual Aesthetics of Websites Inventory-Short(VisAWI-S)

VisAWI-S is the short version of VisAWI, an assessment tool for evaluating how users perceive the aesthetics of the graphical interface (e.g. website, prototype or even an online report) subjectively (Moshagen, & Thielsch, 2013). The full version of VisAWI has 18 items while the short version has 4, aiming to evaluating the general aesthetics, with answers from 'strongly disagree' to 'strongly agree' ranging from 1 to 7 (Figure 74).

	Strongly disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Strongly agree
1. Everything goes together on this site.	①	②	③	④	⑤	⑥	⑦
2. The layout is pleasantly varied.	①	②	③	④	⑤	⑥	⑦
3. The color composition is attractive.	①	②	③	④	⑤	⑥	⑦
4. The layout appears professionally designed.	①	②	③	④	⑤	⑥	⑦

Figure 74. *VisAWI-S (www.visawi.de)*

VisAWI-S has been evaluated in three studies including 1,673 participants and was proved to be reliable for measuring the four key aspects of the aesthetics: ***Simplicity, Diversity, Colourfulness*** and ***Craftsmanship***.

Simplicity measures how structured and clear the layout is and Diversity assesses the dynamic and originality of the prototype. Colourfulness investigates the choice and combination of colours while the craftsmanship indicates how professional and thoughtful is the design.

In this evaluation test, VisAWI-S is suitable for evaluating the general aesthetics of the prototype combined with interviews, as the full version could be too lengthy and time-consuming especially when SUS was also used for assessment.

Design goal and requirements

The design goal of this project is "To redesign an interface and user experience for the ProRail Maintenance that provides clear structure and instruction for the users to finish the tasks intuitively and confidently." After analysing, both quantitative and qualitative (e.g. observation, interview, etc.) results, would be evaluated and see if the prototype has achieved the Design goal and requirements.

7.1.2 Participants

The prototype was tested by 8 participants online through Zoom. The participants consisted of 5 experienced users (4 had experienced with PRM and 1 has used Railgenie) and 3 new users (2 Design students and 1 Electrical engineering student from TU Delft).

7.1.3 Materials and preparation

Before the evaluation, various materials were needed to support the tests: a clickable prototype, scripts (Appendix I), introduction slides to the railway maintenance context for new users (Appendix D), task list(Appendix J) and a Google form to record the SUS and VisAWI scores (Appendix K).

Before the actual evaluation tests started, I conducted a pilot test with a student from TUD as a rehearsal to find out bugs in the prototype, improve the test procedure and schedule. After the pilot test, I fixed some bugs and improve the test plan. This pilot test was only for precheck and the results were not included in the evaluation test results.

7.1.4 Procedure

The link of the prototype has been sent to the participants in advance via email and they were asked not to open it before the test. A test lasted for around 1-1.5 hours, the process was illustrated in Figure 75.

The whole session was held online through Zoom, and the participants were asked to share their screen during the test so that I could record and observe how they interacted with the prototype (Figure 76).

The evaluation session started with a brief introduction about the intention and procedure of this session and the consensus for recording (Appendix H). A general scenario was introduced to the participant:

- ***Imagine you have been working in ProRail for a year, now you are working on planning the maintenance of railway for 2021.***
- ***Data for 2020 is already there, only a few input data need to be updated for the Analysis 2021.***

Then the participant would share the screen and use the prototype to finish the following tasks:

1. ***Import new input data to Macomi Maintenance and make a new Analysis for 2021*** (New input data: Project requests 2021, Dependencies 2021, Conflicts 2021)
2. ***Check the Result of Analysis 2021*** (Gantt and Score)
3. ***Modify the project request of loca-***

tion B-C and pin it

4. ***Rerun optimisation based on the modified project request***
5. ***Share 'Analysis 2021-modified' to Alice***
6. ***Compare two plans*** (Analysis 2021 vs Analysis 2021-modified)

When the testee finished all the tasks, they would evaluate the usability and aesthetics of the prototype. In this part, I presented the statements one by one from SUS and VisAWI and then asked the participant to tell me the scores to show how much he/she agreed or disagreed with each statement. I decided to combine the SUS and VisAWI with interviews instead of merely using online questionnaires to record the scores. Because the participant could explain and show me which features or flow they were talking about through screen sharing during the assessment process, while they might too focus on filling in the form if I just asked them to fill in the SUS and VisAWI form.

At the end of the evaluation, I invited the participant to share their experience about the test in general and their demographic information (e.g. age, occupation, study background) for categorising participants(Appendix L).

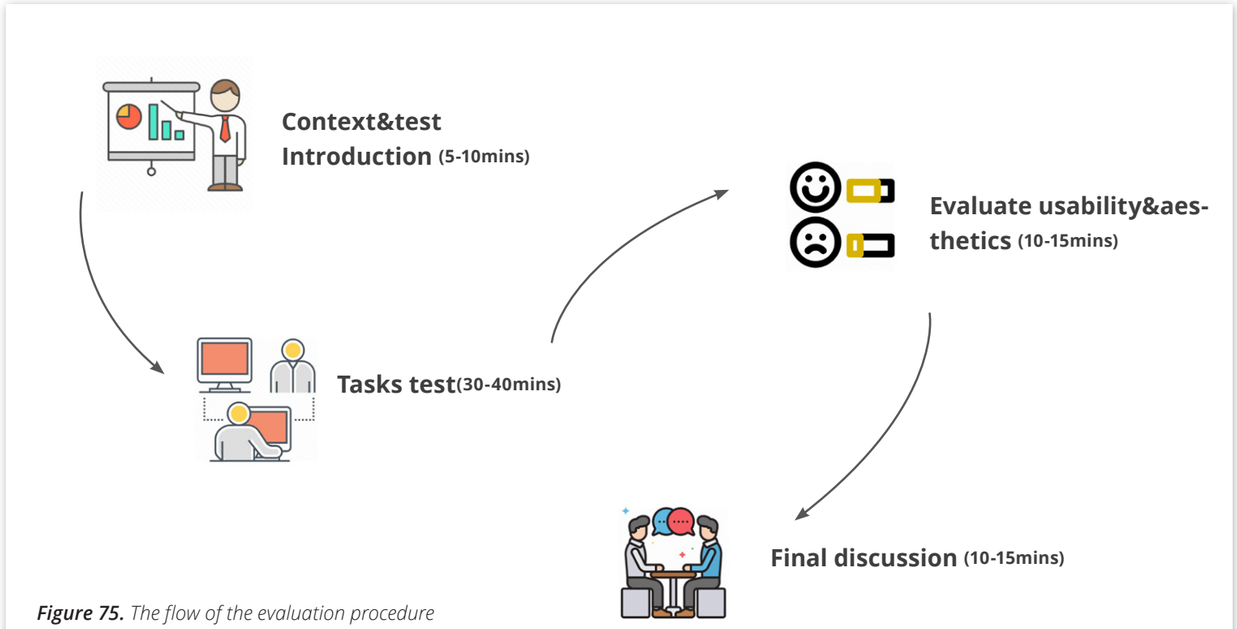


Figure 75. *The flow of the evaluation procedure*

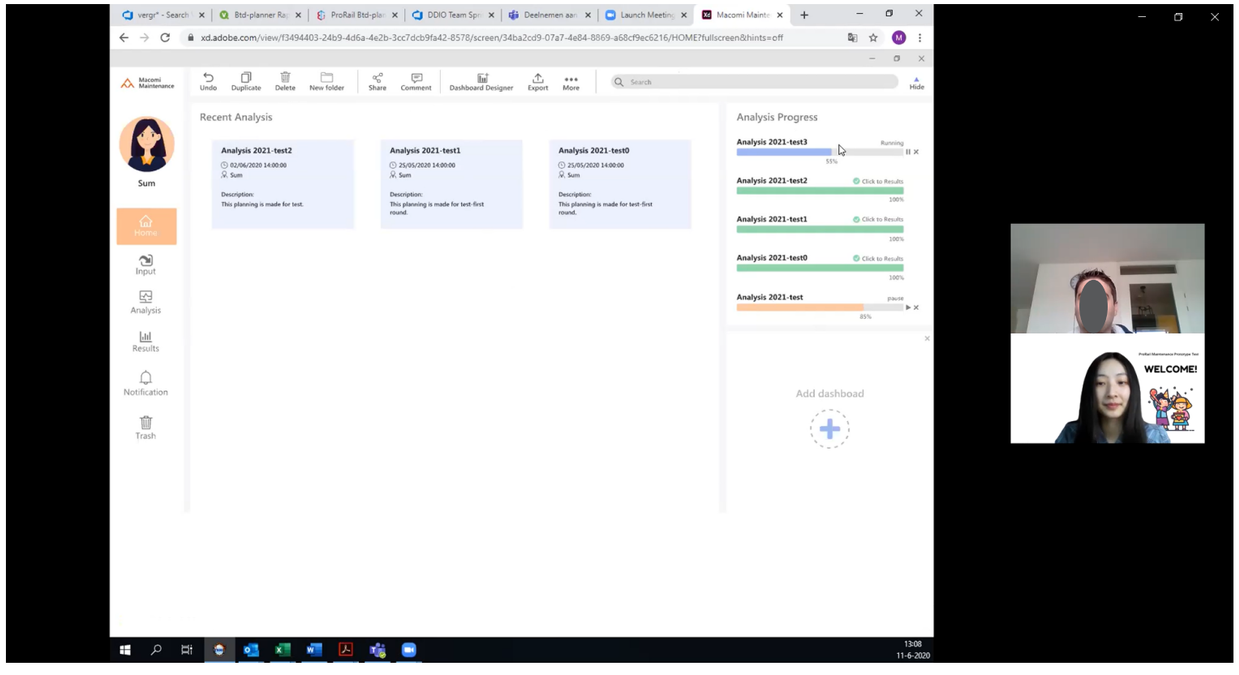


Figure 76. *Screenshot: Setup of the online evaluation test via Zoom*

7.2 Quantitative results

The quantitative results consist of two parts: the SUS score and VisAWI-S respectively representing the usability and aesthetics of the prototype in the evaluation test.

7.2.1 Analysis methods

During the evaluation, participants assess the usability and aesthetics of the prototype based on the SUS and VisAWI-S metric. The scores were recorded in a google form by me (Appendix M), and calculated and interpreted in the analysis phase.

SUS

In the SUS, all the odd-numbered statements are positive while the even-numbered ones are negative. According to (Usability.gov, 2020), the scores for each statement can be converted from 1-5 to 0-10. The formula of calculation of the overall SUS score for each participant can be summarised as below (T, 2020):

- X = Sum of the points for all odd-numbered questions – 5
- Y = 25 – Sum of the points for all even-numbered questions
- SUS Score = (X + Y) x 2.5

The SUS scores for the prototype in this evaluation would be the average score of the sum of the SUS score of each participant.

VisAWI-S

The four statements of VisAWI-S respectively evaluate the ***Simplicity, Diversity, Colourfulness*** and ***Craftsmanship*** from the first statement to the last. To get the score for each aspect, the average score of each statement was calculated. The general aesthetics of the prototype was shown by the average score of all four aspects.

7.2.2 SUS results

After calculation, the SUS score of the prototype was 85.625 on average. The average SUS score of the experienced users(n=5) is 90.5 while the new users(n=3) gave it a 77.5 on average (Figure 77)

According to a research project in which 500 different evaluations involving over 5000 participants have been analysed, the average SUS score is 68(Sauro, 2011). A score higher than 80.3 is regarded as 'grade A' and has an excellent performance in terms of usability (Figure 78)

Figure 77. *SUS scores of Macomi Maintenance*

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

85.625 (n=8)
(Average SUS score of Macomi Maintenance)

Experienced users: 90.5 (average)
New users: 77.5 (average)

Figure 78. *Interpretation of the SUS scores (UIUXTrend, 2020)*

VisAWI-S

The full score of this assessment is 7 and the Macomi Maintenance got 6.03 in general. The score of each aspect is shown in Figure 79, with Simplicity got the highest score (6.38/7) while Colourfulness scored the lowest (5.5/7).

According to the interviews related to this assessment, the prototype provided a clear structure and flow which helped to simplify the tool and increase the usability and improve the UX. For the Colorfulness, the participants thought that the colour was comfortable but the looks and feels could be more business-looking and fit the Macomi branding.

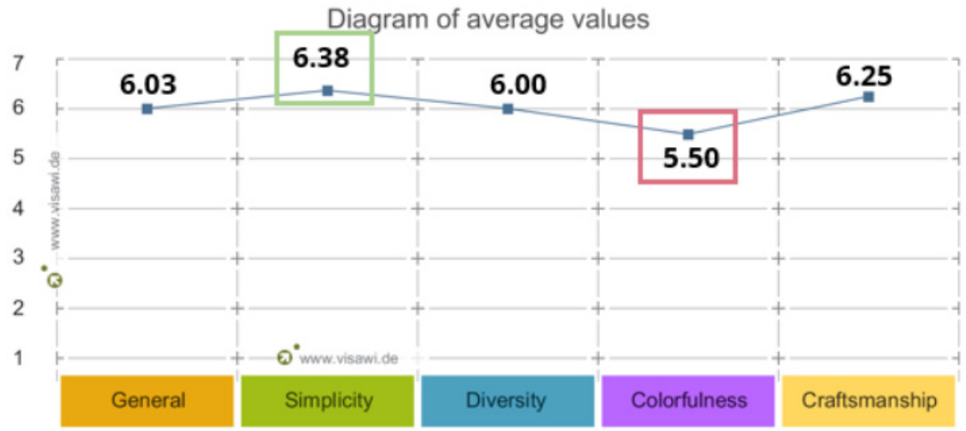


Figure 79. *Results of the VisAWI-S of Macomi Maintenance (www.visawi.de)*

7.3 Qualitative results

Besides quantitative data, qualitative data was also recorded and analysed in order to better understand what the participants were thinking and the reasons behind.

7.3.1 Analysis methods

To extract insights from the recorded videos, I created an Excel form based on the evaluation tasks. This form was for quickly noting down the insights and observation when reviewing the videos. It mainly recorded the user flow and their interpretation of the prototype, negative aspects (mistakes, hints did they need to continue the task and where they did not get enough feedback), positive elements and expectation (Table 2). Those were elements that could help to evaluate the experience of the test.

When reviewing the videos, I would extract and note down insights/quotes quickly in the Excel form (see recorded insights in Appendix N). Then I analysed the insights recorded for each task by comparing participants' feedback to find commons and differences, pros and cons. The results of the analysis are summarised and elaborated in 6.3.2.

Demographic	Age	Occupation	Study background			
Task	Description/flow	Problems/mistakes	Need hints	Lack of feedback	Positive elements	Expectation
First impresssion						
Import new input data from data Pipelines						
make a new Analysis for 2021						
Check the Result of Analysis 2021						
Modify the project request of location B-C and pin it						
Rerun optimisation based on the modified project request						
Share 'Analysis 2021-modified' to Alice						
Compare two plans (Analysis 2021 vs Analysis 2021-modified)						

Table 2. *A form for noting insights from the evaluation tests*

7.3.2 Qualitative results

After analysing data, I summarised the main feedback and insights combined with figures to indicate related features or flows. The numbers in the bracket at the end of each insight represent how many participants shared the same opinion. For instance, (see Figure 80) (2/8P) means the total number of participants is 8, and two of them have acknowledged the positive element “Quick selection”; (P2) represents “Participant No.2” in the orange text.

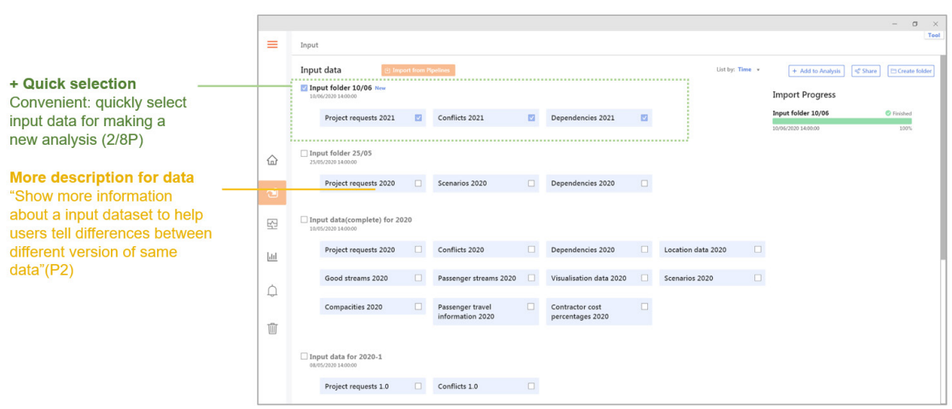


Figure 80. *An example of the qualitative insights*

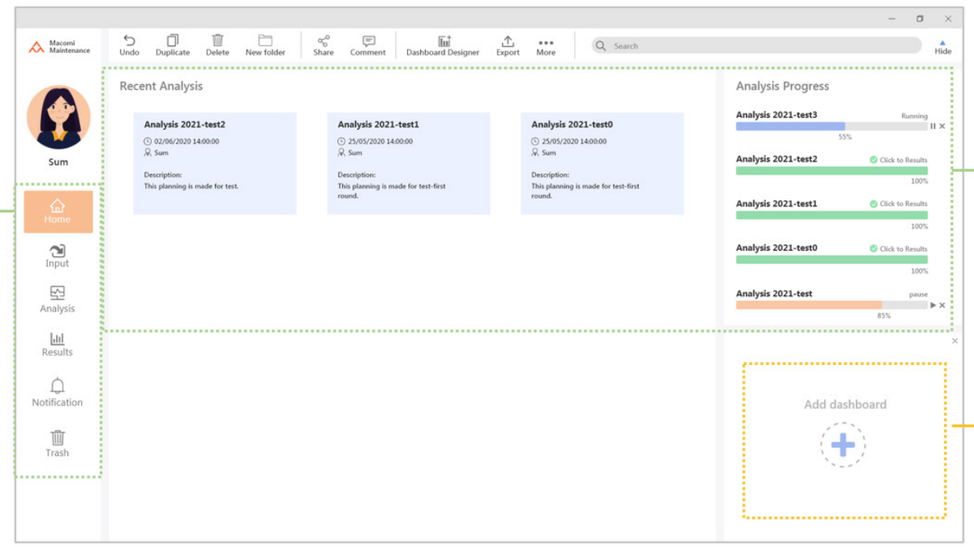


Figure 81. *Qualitative insights for Homepage*

Homepage

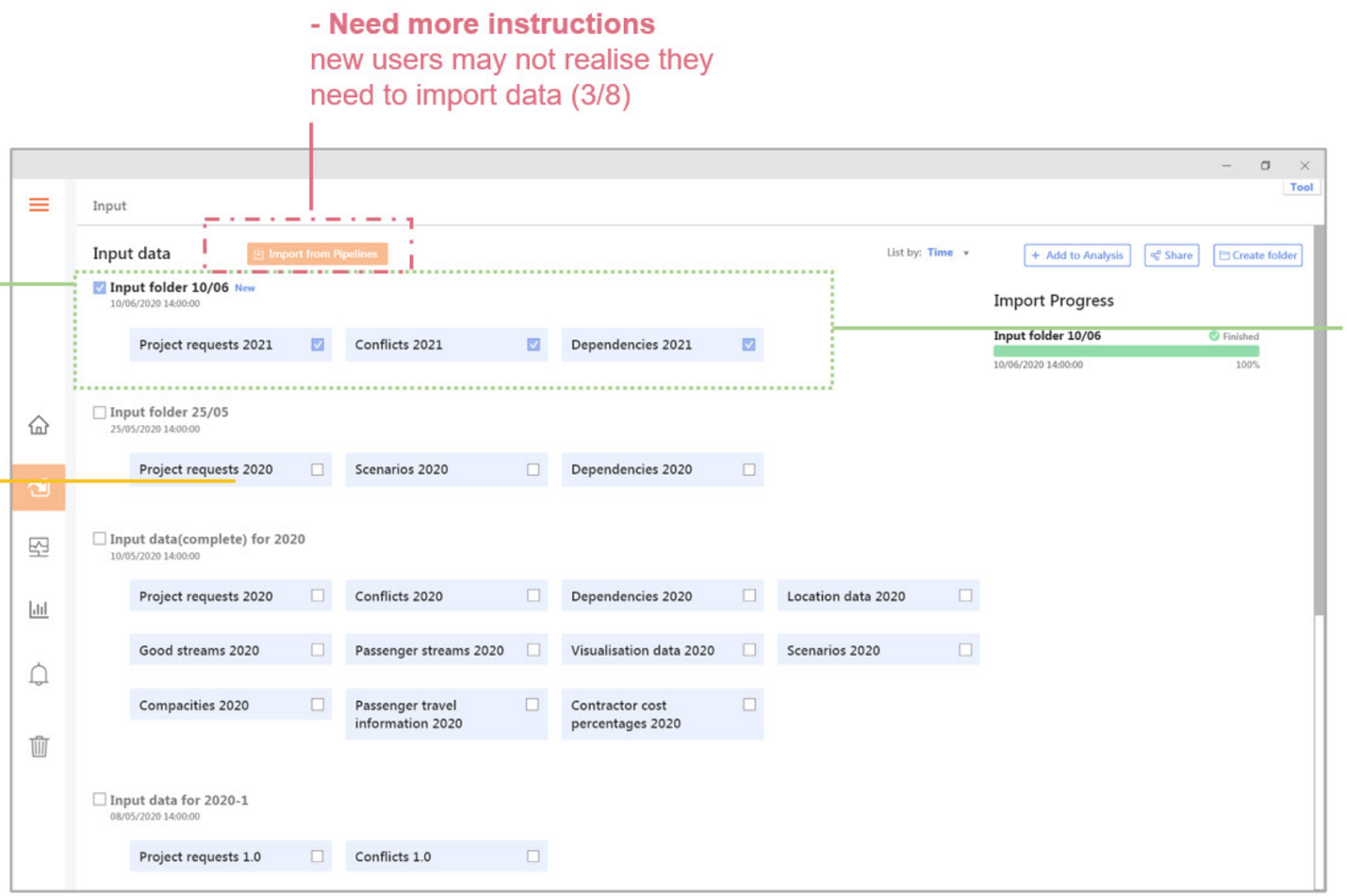
According to the participants, the Homepage helped them to focus on the Recent analysis and the progress of the Analysis, and quickly check them (Figure 81). Those two elements are the most vital for them and it was convenient that they could directly go to relevant pages by simply clicking them.

But for some participants, especially for new users, they might need more guidance for them to start confidently when they first open the prototype. As a participant(experienced users) mentioned: “It’s quite clear for me, but I can imagine that for those who did not know a lot about PRM, might find it less confident to do so.”

Input

As Figure 82 shows, the concept of using folders to organise input data was acknowledged by the participants. It helped to organise data in a structured way and it was convenient for the users to select individual input data or a series of data.

A participant mentioned that he would like to know more information about the data besides the name to distinguish different version of a type of input data. Also, more hints might be needed to guide new users to first import data.



+ Quick selection
Convenient: quickly select input data for making a new analysis (2/8P)

- **More description for data**
  "Show more information about a input dataset to help users tell differences between different version of same data"(P2)

- **Label or filter for selection**
  "I expected something like labels that can quickly filter the latest version of each type of input data" (P5)

+ Well organised data
folders help to organise data and show clear structure (4/8P)

Figure 82. *Qualitative insights for Input*

Make a new analysis

The highlights and the structure of the layout helped the users to identify what they need to fill in this page in order to make a new analysis (Figure 83). However, 3 participants thought the flow of selecting input data was a bit interrupted because the prototype would guide the user to the Input page instead of selecting on this page. It made them feel they were jumping to another flow and they would expect to select in a pop-up window/list without leaving this page.

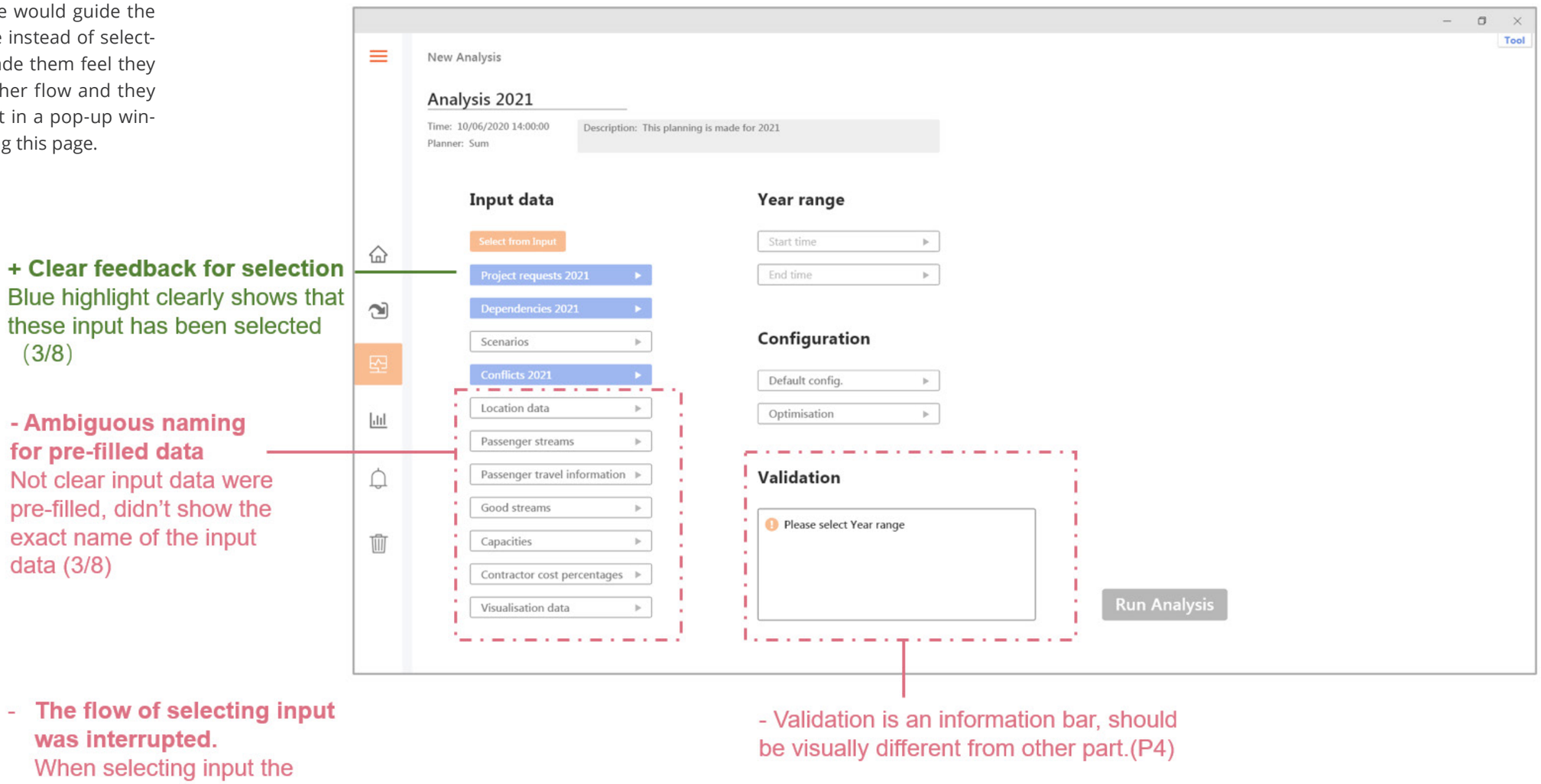


Figure 83. *Qualitative insights for Making a new analysis*

Results and Modify the plan

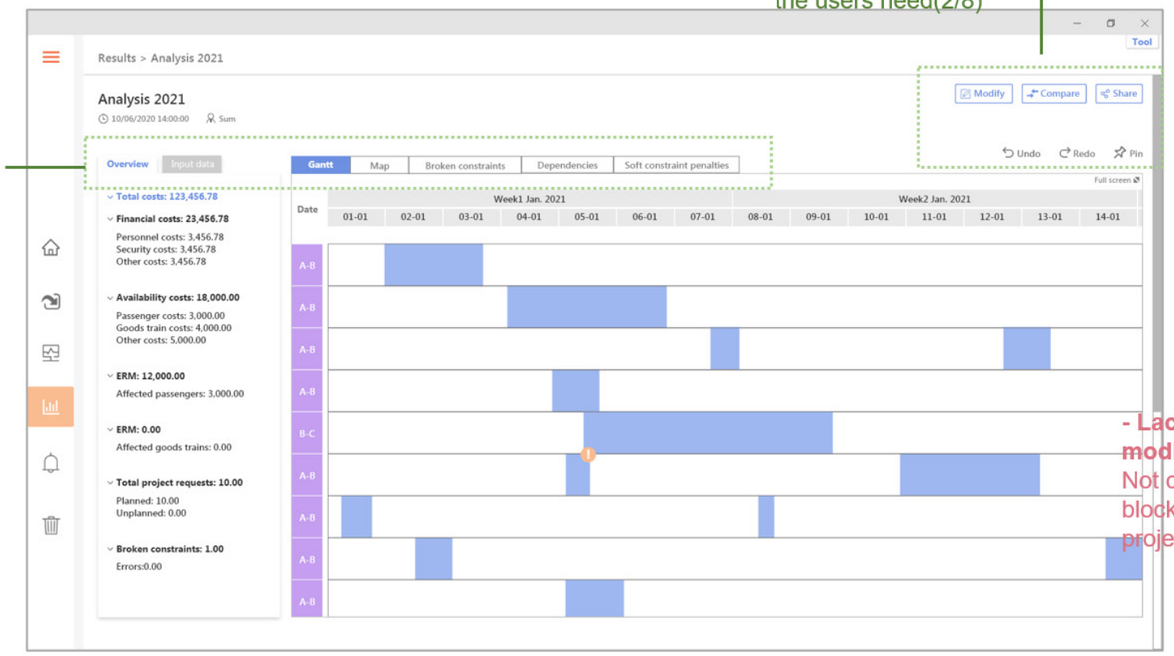
Based on the feedback from the participants, tabs helped to organise the results of the analysis. The most often used buttons are on the top right (see Figure 84) which is noticeable and easy to find.

When modifying the plan, new users tended to click the 'Modify' button while the experienced users would directly drag the 'block'(project requests) to modify the time slot of a project. It was because the drag & drop interaction was too implicit for new users so that they might not notice that they can edit the plan directly.

When the participant tried to modify the plan(either through clicking 'modify' or drag & drop interaction), a notification for renaming the duplicated plan would pop up (Figure 85). This feature was good but the narrative was confusing that some participants were not sure if they have already modified it.

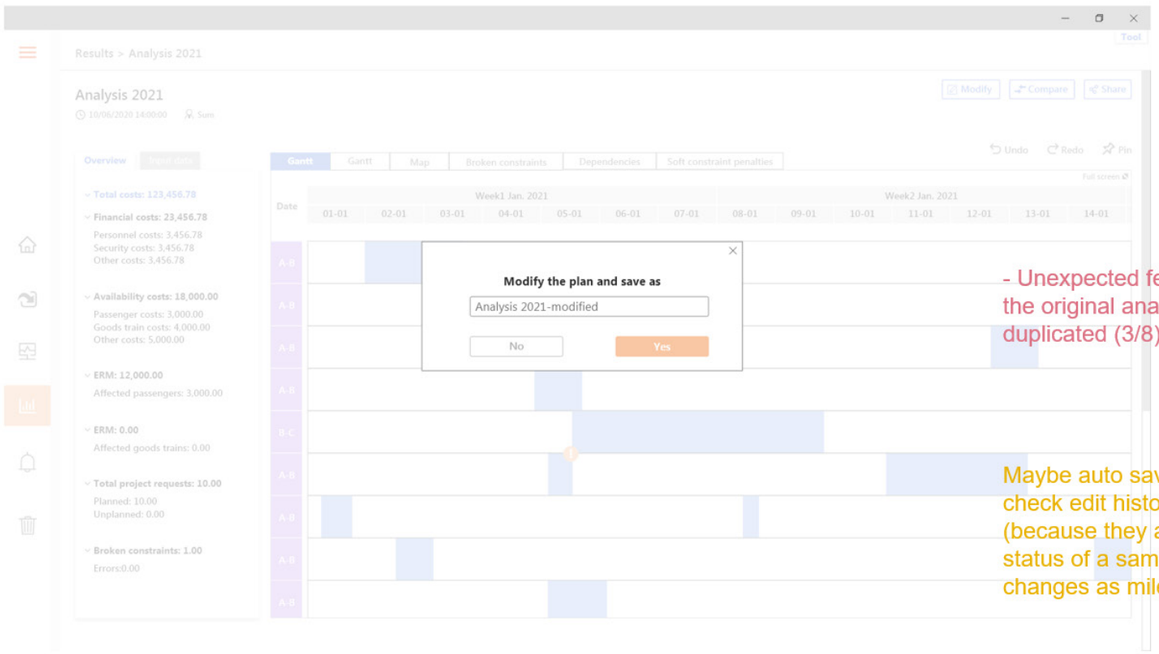
+ Convenient operation
Buttons were easy to find indicating main operations that the users need(2/8)

+ Clear main focuses for the users(Overview, Input data, Gantt) (2/8)



- Lack of indications about modifying.
Not clear they could drag the blocks directly to modify the project requests (2/8)

Figure 84. *Qualitative insights for Results*



- Unexpected feedback: not clear the original analysis would be duplicated (3/8)

Maybe auto save and I can check edit history/milestones (because they are different status of a same file) I can save changes as milestone/mark.

Figure 85. *Qualitative insights for Results*

Compare two results

Providing overview scores of both analyses was acknowledged by some participants, as they could switch the base and compare to the other one(Figure 86).

Using colour coding worked for many participants while some have mentioned that more connection between the original and the modified ones is needed(e.g. an arrow to show which block was originally from which one).

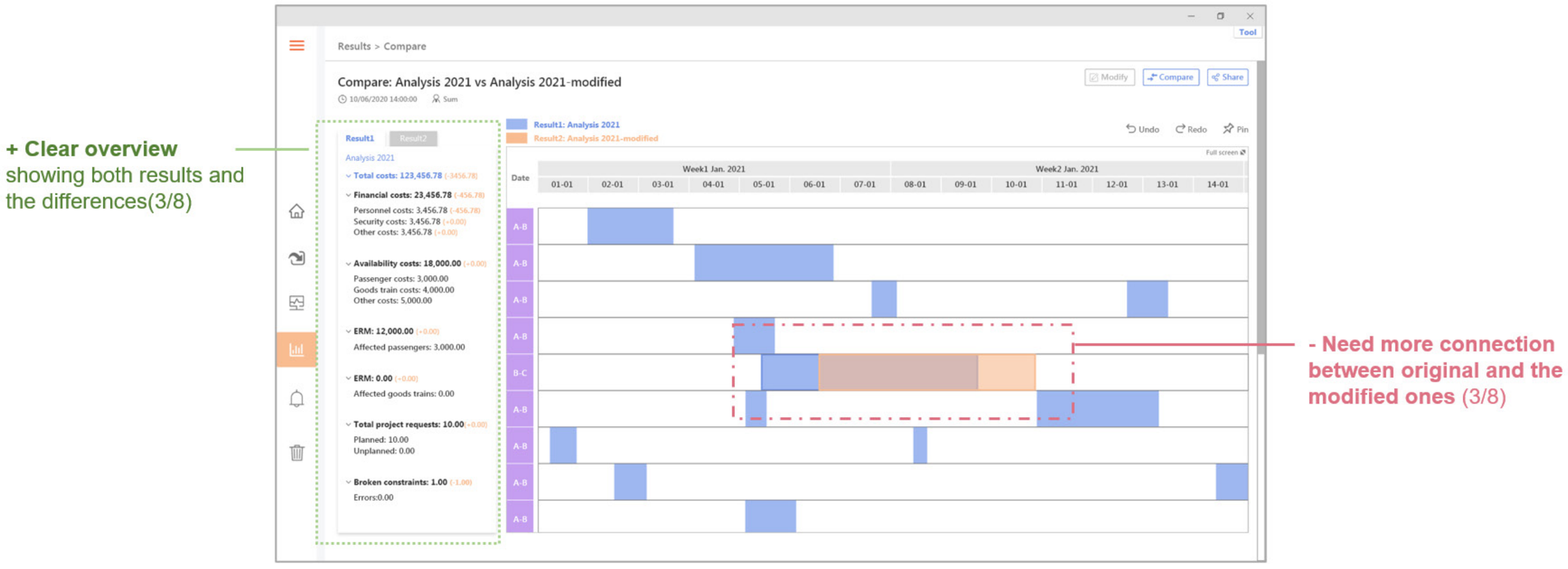
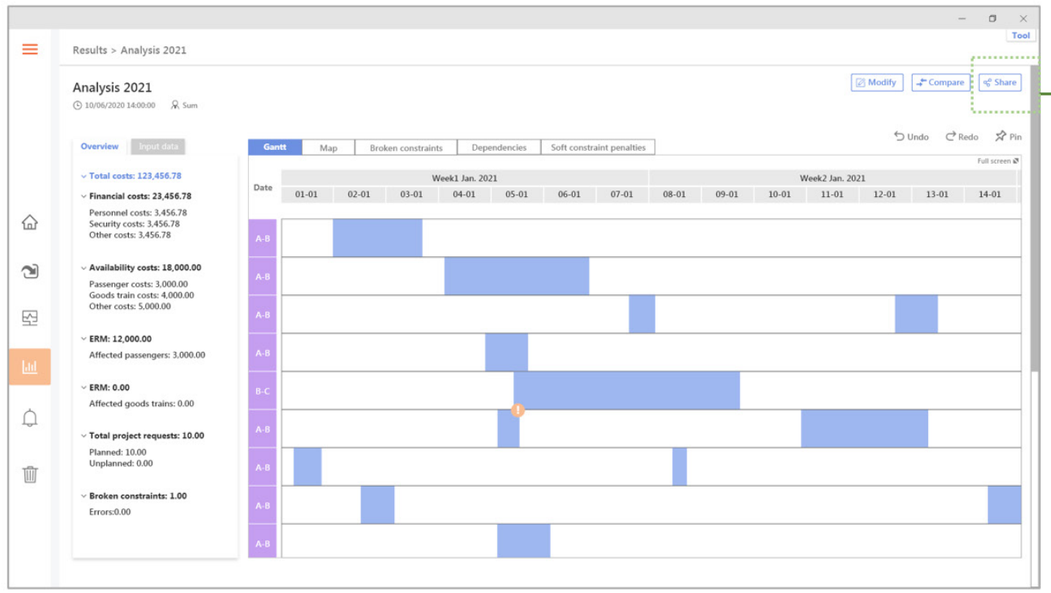


Figure 86. *Qualitative insights for Comparing two analysis planning*

Share to others

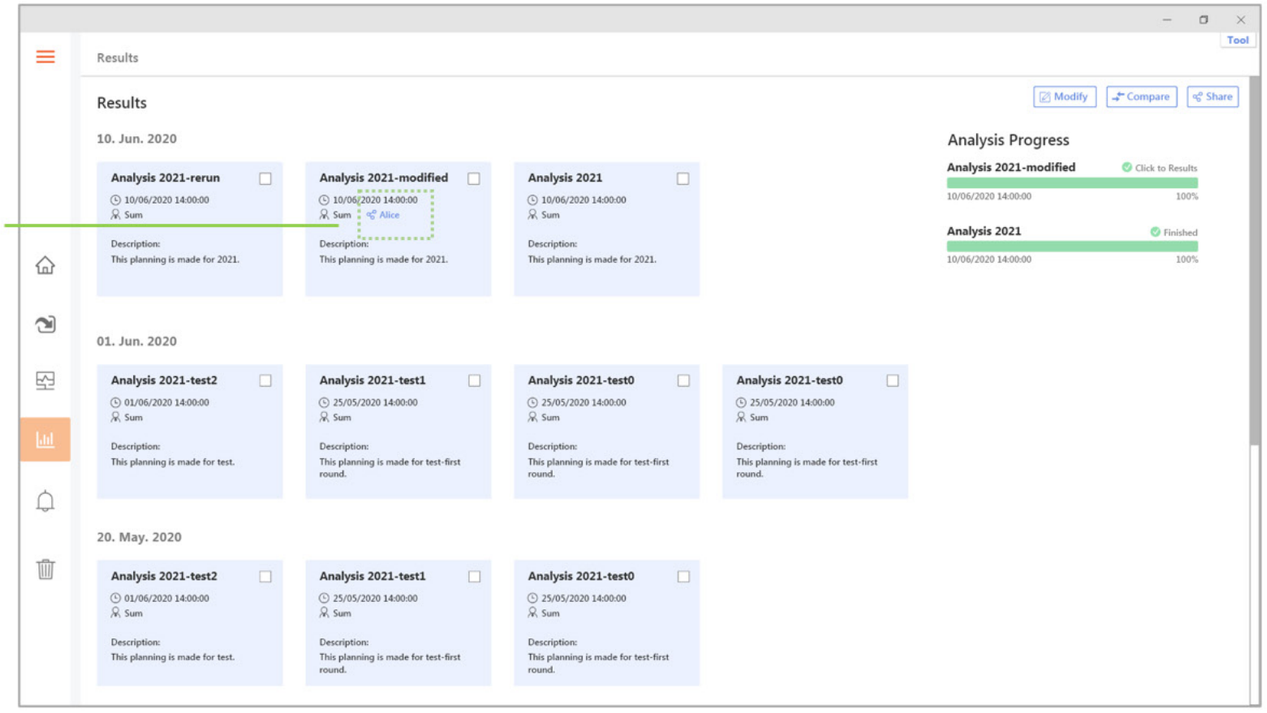
A participant explicitly expressed that he liked the fact that he can not only select the analysis on the Results page but also share it directly when checking a specific result (Figure 87).

Although the icon was clear for the participants that they have shared the analysis (Figure 88), 4 participants expected more explicit notification (e.g. a pop-up) to indicate they have successfully shared to others.



+ Convenient operation
"When checking the results of this Analysis, I like that I can share it with someone directly on this page. Because I'm sure this is what I want to share" (P5)

Figure 87. *Qualitative insights for Sharing*



+ Clear demonstration
The icon clearly show to whom the analysis was shared(5/8)

- Not enough feedback after sharing (expect a pop-up) (4/8)

Figure 88. *After sharing, an icon would indicate to whom did you share*

7.3 Discussion

According to the results of the evaluation, Macomi Maintenance had an excellent performance in terms of usability and succeed in simplifying the user flow of this complex system. However, it was found that experienced users and new users might have different opinions on some parts of the concept and the experienced users gave much higher scores than the new users did in the SUS evaluation. Therefore, it is also interesting to have a discussion based on this.

It was acknowledged that the concept provides a clear overview and structure in general, and all the participants were quite confident that they could use the tool individually after the first try. For experienced users, the flows were quite clear and they rarely had difficulties with finishing the tasks. This might because the concept was designed basically based on the TVP planning process and gained insights more from the professional side (e.g. from ProRail and Macomi, who are experienced with this type of analysis). Therefore, experienced users might be more familiar with the workflow and have a better experience than the new users did.

However, new users had no experience with PRM or TVP planning and they explicitly mentioned that they thought a quick tutorial before they started or more instructions could help them confidently use the tool. Although all the new users in the evaluation session succeed in finishing all the tasks, they felt a bit uncertain or neglected some steps sometimes. For example,2/3 new users forgot to import input data first and they did not notice that they could directly drag the 'block'(project request) to modify the time slot for the project request. They sometimes used their 'gut feelings' or explored a little bit then successfully achieved the goal. In short, the tool provides enough instruction or guidance for new users to finish the tasks and it is easy to learn, but the users expected more guidance at the beginning for them to use the tool ***more confidently***.

Generally speaking, the design has provided a more intuitive and user-friendly experience compared to the PRM and it helps to organise data and information more clearly. The Macomi Maintenance offers a more convenient and intuitive interaction, which helps to simplify and improve the TVP planning process, but more instructions or quick tutorials might be needed. Therefore, it would be also interesting to investigate more about how to help new users quickly understand the TVP planning process and make the flow more integrated in the future.

7.4 Limitations

Although the final design got positive feedback in general in the evaluation tests, there were still some limitations that should be taken into account.

Participants

There were 8 participants including two types of users invited to the evaluation: Experienced users and new users. 8 participants are good enough for qualitative feedback, but it might be a bit too few for quantitative evaluation(ideally should have at least 20 participants for quantitative assessment). Due to time limitations and the COVID-19 situation, I failed to find new users with study background related to railway maintenance planning. Instead, I found 3 students that know nothing about railway maintenance planning, and I gave them an introduction about this context before the evaluation. Basically, this plan could help to make the participants fit the persona and they also provided very valuable insights and feedback. But I would assume that it is still valuable to test with new users that have a background related to this domain, as they know better about the decision-making process and relevant knowledge.

Prototype

A prototype was developed as close as possible to the final effect of the design. However, it was not fully functionally working as intended and some interaction was hard to implement, which might have impacts on the user experience. For example, when making a new analysis, the ideal situation was that the default name of the analysis would become editable when the user put the mouse on it. But this was not able to achieve in the prototype which made the user thought they could not change it. Thus, during the evaluation, I would verbally explain to the participants and need to give hints to them sometimes.

Functions

The current PRM is a complex software including a lot of functions that support various activities for railway maintenance planning optimisation. With limited time and in order to gain deeper insights, I decided to mainly design for the main scenarios and left some functions in the toolbar (e.g. export results with Dashboard designer). Therefore, the participants did not experience all the functions that the current PRM have in this design. In this case, I spent more effort into designing the main structure and functions and got valuable insights, but the experience of other functions still need to be designed and evaluated, and I would recommend this to be a part of the future improvements.

7.5 Recommendations

During the whole process especially in the final evaluation, I discovered some potential design opportunities and things that can be improved in the future.

Test with more participants

As mentioned in the limitations, more participants might be needed for quantitative evaluation(e.g. SUS and VisAWI-S). For the types of participants, I would recommend having some new users with relevant background knowledge(railway maintenance planning) and some experienced users experiencing with other railway maintenance or operation planning software. Because in the evaluation, most of the experienced users are familiar with PRM and only one participant experienced with another railway operation optimisation software(Railgenie), and it might be also valuable to see if the Macomi Maintenance also perform excellently for experienced planners who did not use PRM before.

Explore potentials for the Macomi platform

Due to the scope of the thesis and time limitation, I did not dive deep into how this design can be used for other analytic tools in the Macomi platform or make a plan for that. But I saw the potential of some features especially the structure in general and the methodology that can help to improve the overall Macomi platform and be applied to other tools in it. Thus, it would be valuable to investigate how to make use of this concept to improve the overall Macomi platform in details.

Adjust the UI style in order to fit the Macomi branding

According to some participants, the looks and feels and the layout of the design is good, but the colour composition can be more business-looking and fit the Macomi branding. Although I have considered some features, for instance, use the orange(the colour of the Macomi icon) to highlight important buttons, it might be not enough to create more professional branding for Macomi. Therefore, I would recommend improving the colour by using a darker vibe and a bit higher colour contrast in general to create a more professional and business style.

7.6 Conclusion

This chapter introduces the evaluation process, results of the final concept Macomi Maintenance, after which a discussion and limitations is discussed. Based on the above insights, recommendations are proposed for improving the design and future development.

The final evaluation tests were conducted online with 8 participants to assess the usability, aesthetics of the prototype and get qualitative feedback on it.

Macomi Maintenance got 85.625 on average in the SUS assessment which represents an excellent performance in usability. The general aesthetics scores a 6.03 out of 7 in the VisAWI-S evaluation and it was acknowledged that the layout and helps to simplify the tool in a positive way while the colour style of the final concept could be more business-looing and fit the Macomi branding.

Based on the quantitative and qualitative results from the final evaluation, Macomi maintenance has achieved to provide a more clear structure of information and intuitive experience that the participants could make a maintenance planning, modify and compare planning confidently.

The final design provides enough instructions for users to finish the tasks successfully, while there could be more for new users to quickly and confidently understand the planning process. This was mainly discussed in the discussion section, discussing the differences feedback from experienced uses and new users.

Limitations about participants, prototype and functions of the final design were elaborated. At the end of this chapter, three recommendations are proposed for future improvement and development: ***Test with more participants, Explore potentials for the Macomi platform and Adjust the UI style in order to fit the Macomi branding.***

Reflection

Now I have already reached the last phase of my thesis project and I can confidently say that I have learnt a lot of things and achieved the goal I set at the beginning of the project.

It is my first time to individually manage a project as complex as this one which is a completely new domain for me that involved many stakeholders. I can still remember the first two weeks I worked at Macomi when I knew nothing about data analytics or railway maintenance and had to learn and digest lots of knowledge in a short time. I also had a struggling time trying to narrow down the scope and the focus of my thesis, as I always wanted to cover everything before. Through this thesis, I have learned how to make decisions and sometimes it is important to leave out something to ensure I could focus on the most important part and create valuable output within a limited time. I would say this is one of the most crucial lessons I learned from this project which will benefit me in the rest of my life.

Another objective I have achieved through this thesis is to improve my project management and planning skills. Before this project, I used to rely on my groupmates to contact companies or look for participants as I was not confident enough and thought they might do better than me. Thus, I decided to work with an external company as I wanted to challenge myself to manage a project that has more stakeholders which would push me to communicate with others and plan in advance.

During this process, I made long-term and short-term plans and tried to actively contact people and conduct research and tests at Macomi and ProRail. I also managed to quickly adjust the plan to adapt to the COVID-19 situation and move activities online to reduce the negative impact on the progress. After this project, I would proudly say that I am more confident now and I realised that planning is important while immediate action is also vital. What could be improved in terms of planning is that I should have started writing the report even earlier so that I could have more time to iterate and improve it.

Last but not least, I have integrated and used what I have learned in this project, tried some new methods/tools(e. g. mouse tracking heatmap, online user testing, etc.) and improved my research and design skills. I am so glad that Macomi and planners at ProRail were very interested in my research and design methods and acknowledged my outputs. I was invited to share my findings and the research methods at Macomi and participate in workshops to discuss how my ideas can be implemented to improve not only PRM but also other tools in the Macomi platform. This thesis will be an unforgettable experience for me, from which I saw the value of design and gained confidence and knowledge.

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Sum Yuet Leung
Master thesis / Design for Interaction

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