Graduation Project Report

European train travel

5th of July 2024

Daan Doeleman (S2709465)

Bachelor Creative Technology

Table of content

1. Acknowledgement

I would like to thank all organisations involved in the preceding field study for their contribution. Without the organisations displayed below, the foundation for this research would not be as strong as it is now. I also want to thank all interviewees who made some time available for me and for being able to provide me with the answers I needed. Additionally, I want to give a special thanks to Torben Holvad, my supervisor from the European Union Agency for Railways (ERA) who together with Idriss Pagand, Mitchell van Balen and Stefan Jugelt provided me with many background information and useful insights for my research. Many thanks for that! In general, I am really thankful that ERA was willing to be my client for this Graduation Project.

Besides them, I also really want to thank Martin Stienstra and Katarzyna Zalewska, my supervisors from the University of Twente. They were a big guiding factor in shaping my graduation project and provided me with a lot of feedback during the research process. Without their help this Graduation Project would have never become such a great success.

2. Abstract

Research has shown that for almost 20% of all European short haul flights, rail offers a faster or similarly fast alternative compared to taking the plane. Just to give an example, short haul flights between Frankfurt<>Duesseldorf and Frankfurt<>Stuttgart all have a train connection of under 1,5 hour. Still up to 10 flights a day are being operated on both of these routes. So even though fast rail alternatives exist, many passengers still prefer to take the plane. When looking at the current state of our climate this clearly is a very urgent problem which needs to be tackled. Besides that, shifting passengers from air to rail is not only more sustainable it can also increase the passenger's comfort and bring extra economic wealth to the regions which become better connected by high speed rail. Putting more passengers from flights on trains is therefore an important issue which this research project will try to address.

In order to prevent the usage of short haul flights, first of all a literature research has been conducted. During this literature study it was found that travel time and price are the most important variables in passenger's travel mode decision making. Additionally literature stated that in order to change travel behaviour, the creation of a win-win situation is key. Therefore it could be concluded that in order to persuade short haul flight passengers to take the train, it is important that they become aware of the win-win situation associated with taking the train instead of flying. This includes for example a reduction of price and travel time, while also cutting carbon emissions.

Since there currently exist no travel platforms which communicate such a persuasive win-win situation and also none which make an unbiased comparison on price and travel time, the need for an informative and efficient intermodal platform which persuades more passengers to take the train was indicated. Therefore, this Graduation Project has investigated the best possible design and implementation of such a multimodal travel platform. During this investigation the Creative Technology design process was followed, which eventually resulted in a final travel planner design.

As part of this process, the final travel planner prototype was evaluated by means of a small user study. The user study indicated that the suggested platform design facilitated a behaviour changing win-win situation by better informing passengers about the total price, travel time and emissions associated with each mode of transport. This resulted in the successful persuasion of short haul flight passengers to take the train. The suggested travel planner design can therefore be considered as a potential solution addressing the issue of unnecessary short haul flight usage.

3. Introduction

The European transport sector is the second sector in terms of emissions, representing 25% of the total EU GHG emissions, after the energy supply sector [41]. Looking at the current state of our climate and the set targets in the European Green Deal as well as the SDGs there clearly is a strong urge make the European transport sector more sustainable [23][24]. One of the most effective ways of cutting these GHG emissions is replacing more unnecessary short haul flights by rail [2]. Research by Doeleman [7] showed that for almost 20% of all European short haul flights, rail already offers a faster or similarly fast alternative. Just to give an example, short haul flights between Frankfurt<>Duesseldorf and Frankfurt<>Stuttgart all have train connections of under 1,5 hour. Still up to 10 flights a day are being operated on both of these routes [7]. So even though fast rail alternatives exist, many passengers still prefer to take these up to 120 times more polluting flights [7][21].

One would think that replacing such flights by rail would be easy since travel time is short and prices are low, however literature suggests that there still remain many challenges in this field [2][7]. One of the key reasons why it remains difficult to convince such passengers to take the train are among others [7][26]:

- Poor multimodal air-rail connectivity;
- Bad reputations of railways (especially in Germany);
- Strong airline competition on price resulting in a loss of passengers to the competition once removing these flights;
- The lack of an efficient intermodal product which informs passengers that rail is in these cases the faster, cheaper and more sustainable alternative.

Even though some of these challenges are already well known, there has not been done much research on potential solutions which can overcome these challenges. Therefore, the main objective of this paper, is to investigate the best possible design and implementation of an intermodal platform which persuades more passengers to take the train instead of the plane. This is because almost all current travel planners contain a strong bias towards flying. To tackle climate change it is important to provide passengers with unbiased information. That is why the following main research question has been formulated as follows:

How to develop an online platform that persuades passengers to take the train instead of short haul flights by informing them about the different modes of transport (including price, climate impact and travel time)?

In order to come up with a final answer to this question, the following sub research questions have been identified:

- *What are for passengers' important factors in deciding which mode of transport to travel with?*
- *How to influence the travel behaviour of passengers?*
- *What are the benefits of a modal share shift from air to rail?*
- *Which alternative platforms currently exist?*
- *What kind of elements should the new platform have?*

All in all, it is expected that by answering the sub research questions above a well-supported final conclusion can be drawn on the main research question. This includes a well-tested and evaluated final design of a persuasive platform.

4. Background Research

Before a solution is developed to address the challenge of persuading short haul flight passengers to take the train, it is important to conduct research that helps define the exact problem at the root of the challenges. Furthermore, it is beneficial to explore the psychology behind passenger's travel mode decision making for an effective design process. All in all, this background research will provide an overview of existing research as well as current similar interventions, which will eventually contribute to the development of my own persuasive platform.

Literature research

The literature research chapter will dive into the topic of how passengers' behaviour can be influenced and how more passengers can be persuaded to take the train instead of the plane. The first section of this chapter will try to get a better understanding of passengers' travel mode decision making as well as reasons why passengers still opt to take these unnecessary flights. Afterwards it will be investigated how travel behaviour can be influenced and what the benefits are of doing this. Altogether, these findings will later be utilised in the successful development of a persuasive online travel platform.

Passengers travel mode decision making

There are many different important factors for passengers to decide with which mode of transport (either air or rail) to travel with. According to Nikolic et al. [2] environmentally related factors such as air quality impact and CO2 emissions are of secondary importance for travel mode decision making. They indicated that non-environmental travel factors such as flexibility, comfort, safety, reliability, availability and travel time are one of the most important. Clewlow et al. [6] agree with the importance of rail travel time in reducing short-haul air traffic in Europe. However, they also found important additional other factors such as Gross Domestic Product, fuel price, hub status and population density. Still travel time seems to be a frequently reoccurring factor. Sun et al. [8] also proved that travel time is most critical in determining the competitiveness between High Speed Rail (HSR) and air transport. They state that shorter travel time will attract more passengers. So all in all, travel time indeed seems to be one of the most important factors for passengers to choose between taking the train or the plane.

However, price also seems to play an important role. Nurhidayat et al. [13] also showed that for HSR and airplane competition speed and with that travel time seems to be one of the most important factors. But they also highlighted that additional factors such as ticket price, travel habits and service frequency/convenience are the important factors for passengers. Also Pagliara et al. [9] found prices and service frequency to be the most important variables in competing with aviation. But also the rapidness and smoothness of check-in and security controls at the airport are crucial as well. Other research projects from both Shi et al. [17] and Xu et al. [19] also proved that transportation cost and transportation time are the most important decision making

factors for passengers. Therefore it can be concluded that both travel time as well as ticket price seems to be one of the most important factors for passengers to decide with which mode transport to travel with.

Several other studies focussed more on the influence of social-demographic factors on passenger's travel mode decision making. The following important social-demographic factors have been identified:

- Business vs Leisure travel: A study from Min et al. [14] indicated that whether someone is travelling for Business or Leisure plays an important role in their travel mode decision. Business passengers found safety and private spaces important regardless of the fare, while for leisure passengers price and the possibility to travel in groups is more important. Also Shi et al. [17] proved that the person accompanying the traveller is important in their travel mode decision making. It was seen that when people travel together, they are more likely to choose for HSR, as was also indicated by Min et al.
- Income: Another research project from Min et al. [14] indicated that the preference for air transport becomes stronger when income increases. Shi et al. [17] also found that when people are on a tight budget, they rather choose for rail, since it is often the cheapest option. Another study from Chan and Yuan [15] agrees with the statement from Min et al. and Shi et al. that income is an important factor. However, their research indicated that people with a higher income did more often chose for rail alternatives, contradicting the findings of Min et al. and Shi et al.
- Gender: Research by Min et al. [14] indicated that gender also seemed to play an important role in travel mode decision making. Males were proven to prefer HSR, while women usually prefer to fly. Also Shi et al. [17] found gender as one of the most important decision making factors. "Males are found to be more inclined to travel on the HSR as compared to females [17]."

All in all, one can conclude that social-demographic characteristics such as gender and income as well as travel time and price are one of the most important factors of passengers to decide with which mode of transport (either air or rail) to travel with. However, it does have to be noted that these are just general factors, which might vary for each individual. Therefore these principles should only be considered as some important decision making factors, but it is not limited to only these.

Influencing passengers travel behaviour

With this deeper understanding about important factors in travel decision making of passengers, it is time to go one step further and see how passengers' behaviour can be influenced. Literature suggests that there are many different techniques that could lead to changed behaviour. According to Cialdini [1] there are seven main principles of influence:

- Scarcity: make people aware of the limited availability of a product or service could influence their behaviour;
- Authority: experts recommending a certain type of behaviour could make it more likely that other will follow as well;
- Social proof: once certain behaviour is proven to be good by a large audience, it is more likely that others will follow as well;
- Sympathy: people are also likely to change their behaviour when they feel a kind of personal bonding with a person or organisation;

- Reciprocity: as one might expect, people also expect to get something back when they change their behaviour. This indicates the importance of creating a win-win situation. One gives some, one should also get some;
- Consistency: people also often have the tendency to stick to their previously chosen behaviour. People do not like to see that their past behaviour was bad and that they should therefore change. People will try to defend themselves in such situations;
- Unity: the pressure from a group or society is also a large factor which influences behaviour.

Cialdini indicated that the human brain can generally be influenced by making use of these principles. However, the personal characteristics of an individual also play a large role in to what extent these principles can be successful. For example some people are very likely to change their behaviour when the authorities tell you to do so, while for others this might not work. Therefore these principles should again be considered as general influencing factors, but it is not limited to only these.

Cialdini is not the only academic who highlighted the importance of reciprocity. Hogan [18] also agrees with Cialdini that reciprocity is an important principle for influencing behaviour. Hogan also indicated that creating a win-win psychology is key in order to achieve persuasion. Additionally, Ajzen [12] highlights that behavioural intentions are the key determinants of actual behaviour. This might sound like a contradiction to what has been found by Hogan and Cialdini, however also his findings show similarities with the Unity principle of Cialdini. Ajzen namely found that behavioural intentions are to a large extent influenced by three main factors. First of all, subjective norms play a large role, relating to the pressure from a certain group. Especially the specific norms in a certain group, about what one should or should not do, determine to a large extent the behaviour of its members. Secondly, also perceived behavioural control seems to be important. This relates to an individual's perceived ease or difficulty of performing a certain behaviour. The level of self-confidence and self-efficacy play a large role in this as well. Thirdly, attitudes are important. This relates to an individual's readiness to perform a given behaviour. It can also relate to whether their behaviour and its outcome is being desired in relation to existing norms and behavioural control.

All in all, the findings of Ajzen seem to overlap to a large extent with the unity factor according to Cialdini. From both papers it becomes clear that the pressure and norms from a certain group influence to a large extent one's behaviour. Therefore it can be concluded that the main factors which can influence behaviour are creating a win-win situation, the reciprocity principle as well as the feeling of pressure from a specific group or society, the unity principle.

Benefits of replacing air by rail

The previous section highlighted the great importance of reciprocity, so creating a win-win situation when passengers decide to shift from air to rail. Therefore, it is now important to investigate what the potential benefits are for both passengers as well as the climate when shifting from air to rail transport. Literature generally agrees on the climate benefits HSR has. According to Prussi and Laura [11] HSR is clearly beneficial for the climate. Their results indicate several clear advantages that high speed trains have over planes, especially in terms of direct emissions per passenger km. "Compared to a neutral scenario, with an annual passenger increment of 3.5%, the

HSR substitution of the 5% and the 25% of this increment allow a GHG saving of 4% and 20%, respectively [11].” Sun et al. [8] agree with the fact that the introduction of HSR is beneficial for the climate. Their study also proved that shifting passenger from air to rail has induced additional rail demand. “After the introduction of HSR, the alternative aircrafts have reduced in size and number of seats, resulting in a reduction of emissions per passenger km [8].” Also Clewlow et al. [6] did find similar results. They came to the same conclusion that improvements in rail travel times have resulted in reductions in short-haul air travel demand.

Although, not all literature agrees with the climate benefits of HSR. Dobruszkes et al. [3] state that the positive impact of HSR is limited. They showed that HSR frequency is found to have only a weak impact on air services. Besides that, they even found that multimodality, thus the introduction of HSR connections to airports, could contribute to feeding more passengers on long haul flights. Not to mention that replacing short haul flights might free up slots for longer haul flights, increasing the total emissions.
However, Albalate et al. [4] proved the complete opposite and state that multimodality is the key to success. They proved that the overall consumer surplus always rises from the reduction in air-rail connecting time, reflecting that an integrated hub with seamless transfer between air and rail services is always preferred by passengers.

When not looking at emissions, but at the economic and passenger side of HSR, literature clearly agrees on the benefits of HSR. According to Adler et al. [5] it is always worthwhile upgrading to high-speed rail infrastructure. They proved that the increase in consumer, producer and government surpluses are sufficient to cover the daily cost. Also the additional tax income coming from HSR would be sufficient to cover the infrastructural cost. Also on the passenger side, HSR has many benefits. According to Pagliara et al. [9] the introduction of HSR results in travel time savings, better quality of supplied services, greater comfort for users, and improved accessibility.

Therefore it can be concluded that even though large climate benefits were not found in all case studies, literature generally agrees that HSR itself is more sustainable, more comfortable, profitable, and therefore beneficial for both the climate, passengers and the economy. With this proof that a modal share shift from air to rail is beneficial for both passengers and the climate, we indicated the possibility of developing a behaviour changing win-win situation.

The demand for an unbiased travel platform
Since rail has many benefits over flying, it is important to also make passengers aware of these advantages. Many studies have indicated the relevance of better informing passengers by providing them accurate and unbiased travel information, but unfortunately such a platform does not exist yet. According to Worth and Dalunde [31]:

> *“Often a route cannot be easily planned. If it can be planned, a ticket or tickets cannot be bought for it in one transaction. Even if it can be purchased, real-time data is not available or passenger rights are unclear in the case of something going wrong. These problems particularly affect the greenest long distance public transport modes, railways and long distance buses, where combining modes and operators presents more difficulties than in air transport, especially if you want to travel across one or more border.*

The climate change imperative is obvious here. Transport is the only sector of Europe's economy where carbon emissions are today above 1990s levels, and where emissions continue to rise. At the very least the EU needs to make sure a greener alternative to a car journey or a flight is as simple to plan and book as possible, yet we are a long way away from that reality currently. Passengers choosing multimodal or multi-operator trips should not be disadvantaged in terms of the quality of information about disruptions to their journey, or in terms of their passenger rights, in comparison to those making single mode and single operator journeys [31]."

Another research project which compared all the currently existing travel planners, also came to the following shocking conclusion [44]:

"It has to also be stated that even the best journey planner did receive only 63% of all possible points, and on average the journey planners received 44%, which implies that there is still much development opportunity for the operators of journey planners [44]."

The relevance of improved intermodal travel planners has also been highlighted by the European Commission, who expressed the strong need for comprehensive door-to-door information allowing for well-informed travel decisions [32]:

"The development of multimodal journey planners will enable the development of a more efficient transport system; it will widely benefit citizens, as, for example, it is not always easy to get the right information about cross-border transport and connections; it should also allow for the possibility to go for a journey that least affects the environment [32]."

The EU also supports several improved travel planner initiatives such as MultiModX [33], Bonvoyage [34][36] and several projects within their Innovation Program 4 [35]. The goal of MultiModX is to deliver a set of innovative multimodal solutions and decision support tools for the coordinated planning and management of multimodal transport networks. Unfortunately, the scope and outcome of this project is limited, because only a hand full of European countries (5 in total) are participating [33]. The more promising Bonvoyage project unfortunately only resulted in a small demo platform which was released in 2018, but currently not available anymore [37]. To conclude, despite the development of several multimodal travel platform initiatives, there currently is no unbiased travel planner available which informs passengers about the benefits of train travel over flying.

Conclusion

The extensive literature analysis brought to light that short haul flight passengers are mainly driven by travel time as well as price in their travel mode decision making. It has also been seen that HSR has plenty of benefits over flying. Not only for the climate, but also for passengers as well as the economy. Additionally, it was also proven that passenger's behaviour can be influenced the most successfully once a win-win situation is created.

All in all, this suggest that in order to successfully persuade short haul flight passengers to take the train, they need to become aware of the travel time and price savings of taking the train as well as the large number of environmental advantages of using HSR. Altogether, this could make more passengers aware of the win-win situation of changing from air to rail and with that it will very likely influence the travel behaviour of short haul flight passengers.

State of the art

Before starting the development of my own persuasive platform, it is important to first investigate further what kind of similar platforms already exist. Therefore this section will provide an overview of the state of the art in the field of multimodal travel platforms.

From private to public transport

There currently exist several alternative platforms which do not focus on putting air passengers on rail, but their focus is mainly on persuading car travellers to make more use of public transport. This includes for example a mobile navigation application that has been developed with the goal to encourage multimodal (public and private) transport. The app guides users to their destination by integrating the use of both private and public transport options [10]. The goal is to persuade more travellers from private cars to take public transport or at least combine both modes. All in all, this platform was mainly successful because it could result in a total reduction of travel time as well as climate impact. Another similar personalized multimodal travel service provides multimodal route recommendations considering the individual preferences [19]. By further improving the service quality of existing travel apps it managed to attract more travellers from private cars and optimize the transport resources for sustainable intercity transport. A third platform also successfully managed to encouraging individuals to reduce car use and mitigating global greenhouse gas emissions [16]. The layout of this platform can be seen in figure 1 below.

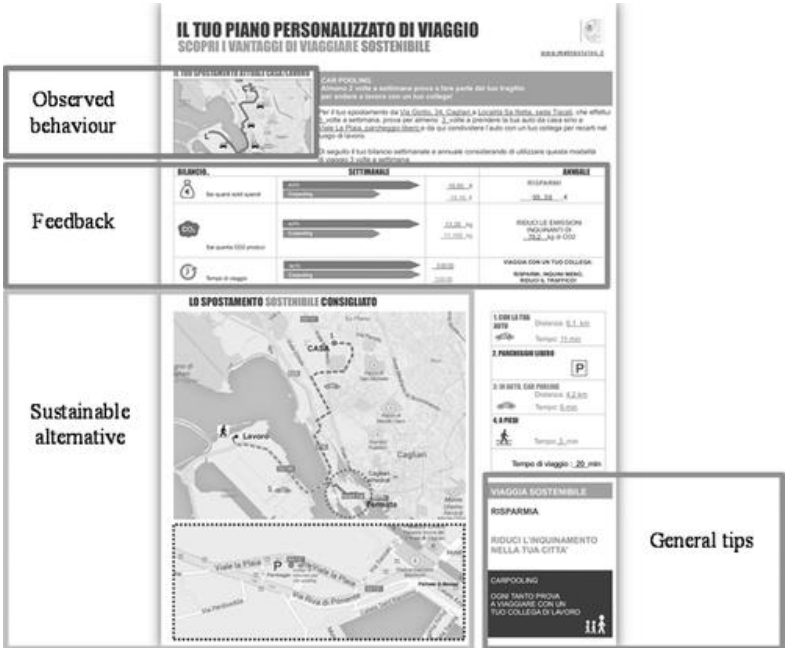


Figure 1: An example of a multimodal travel platform [16]

Another initiative called Transit+ combines public transport such as buses, rail and ferries with private transport such as personal or shared scooters and bikes. Its main goal is to provide better multimodal trip planner results which can result in a shorter travel time [22]. An example of this travel platform put into use can be seen in figure 2 below.

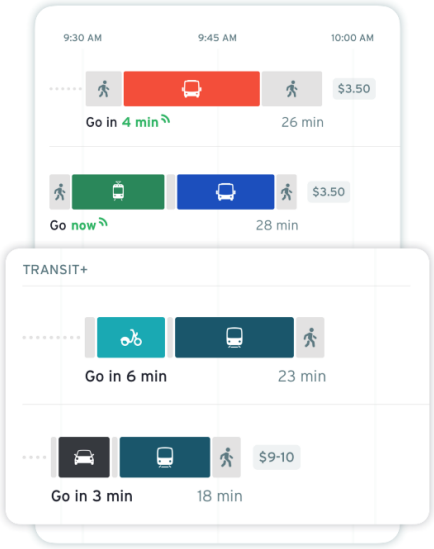


Figure 2: The Transit+ multimodal travel platform [22]

Besides, that there also exist several smaller pilot platforms which aim to facilitate efficient intermodal private and public transport. One example is the Rail2Ride pilot which tries to combine ridesharing with scheduled transport services such as bus and rail [27]. Another platform called “Citymapper” has proven to be very good at short distance within city travel. It integrates different options such as walking, cycling, cabs and public transport. The user can then compare the best multimodal travel option (see figure 3).

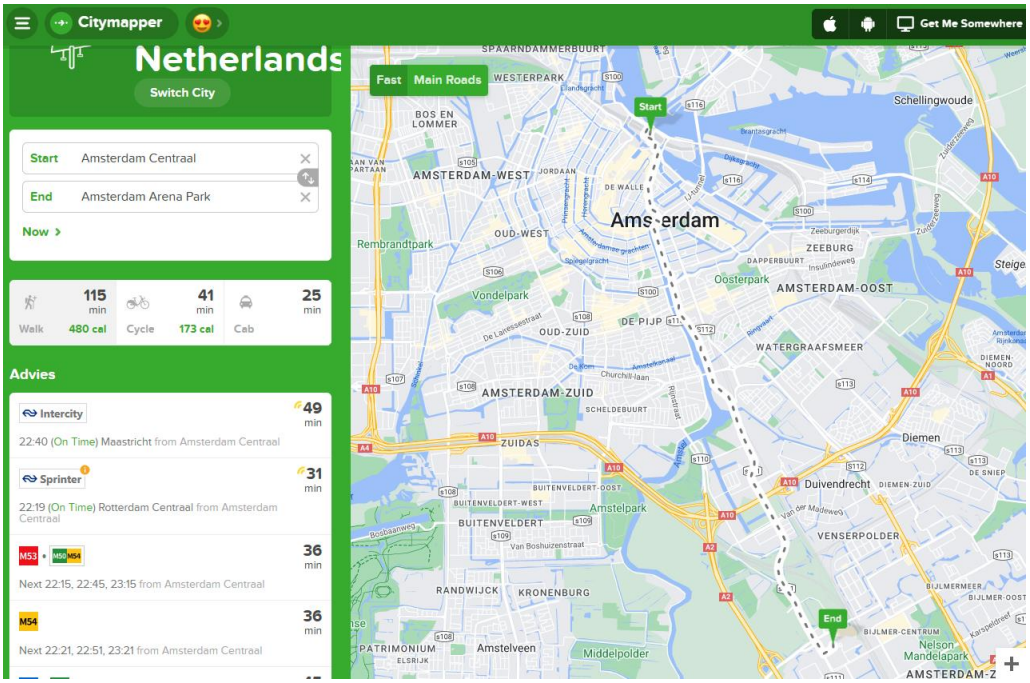


Figure 3: The Citymapper travel platform [42]

All in all, it can be concluded that in order to encourage more sustainable multimodal public and private transport, one should take individual preferences into account as well as make users aware a win-win situation. An example of such a win-win situation could for example be a faster travel time as well as reduced emissions for a specific journey. Eventually this could successfully put passengers on the fastest and most sustainable modes of transport.

From air to rail transport

The previous section indicated that currently many multimodal platforms aim to put more passengers from private transport on public transport. However, there seem to be very few multimodal air-rail travel planners. Travel planners such as Google Maps do have the option to compare both air and rail journeys, but this comparison does not give clear information on total travel time as well as price associated with each mode of transport [28]. As can also be seen in figure 4 below, Google Maps does only show very biased information towards flying. Pretending that flying is much shorter than it actually is.

Figure 4: The bias in current travel planner such as Google Maps [28]

As can be seen in figure 4 above, it seems like flying is the much better option to travel between Frankfurt and Groningen, since flying only takes 1 hour and 5 minutes while the train seems to take 10+ hours. However the fastest door to door train journey from Groningen to Frankfurt is only 5 hours and 13 minutes. While for flying only the flight time from Amsterdam to Frankfurt is shown, excluding the waiting time at the airport, security checks, getting from and to the airport etc. Therefore taking the train might actually be the much faster option. Especially when knowing that getting from Groningen to Amsterdam Schiphol Airport takes more than 2 hours by car and train. Unfortunately Google maps only shows the short flying time from the closest airport (in this case Amsterdam) and does show the total travel time for flying. To better inform passengers about the benefits of train travel, it is suggested that travel platforms do show the total travel time instead so that a more objective comparison can be made (see figure 5).

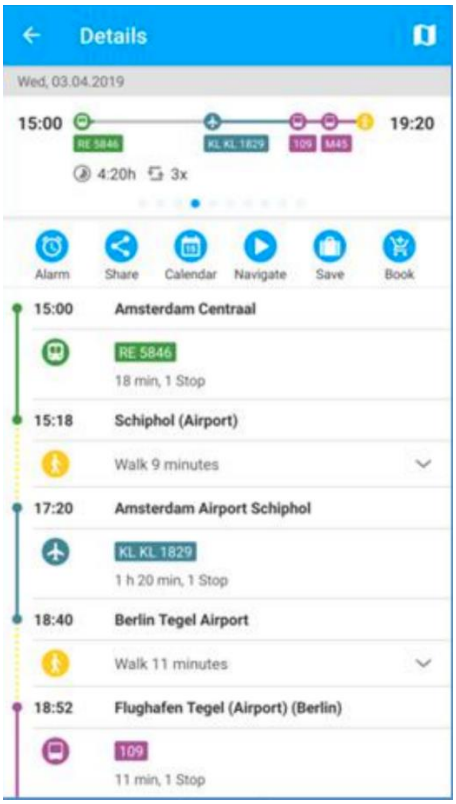


Figure 5: The suggested information a travel platform should provide [27]

Other multimodal travel planners, such as Omio [29] and Rome2Rio [30] face the same issue as Google Maps. They do compare both trains, busses and planes for worldwide journeys. However, Omio does not show any multimodal air-rail combinations and both Omio and Rome2Rio do not display the total city to city travel cost and travel time for air journeys (see figure 6 and 7).

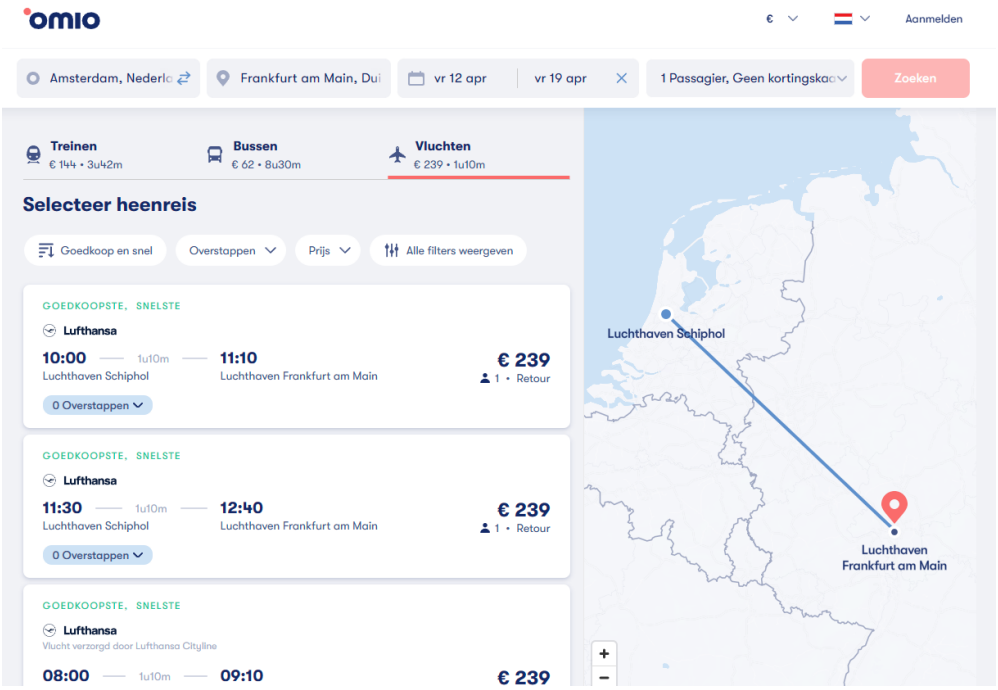


Figure 6: The information provided by the Omio travel platform [29]

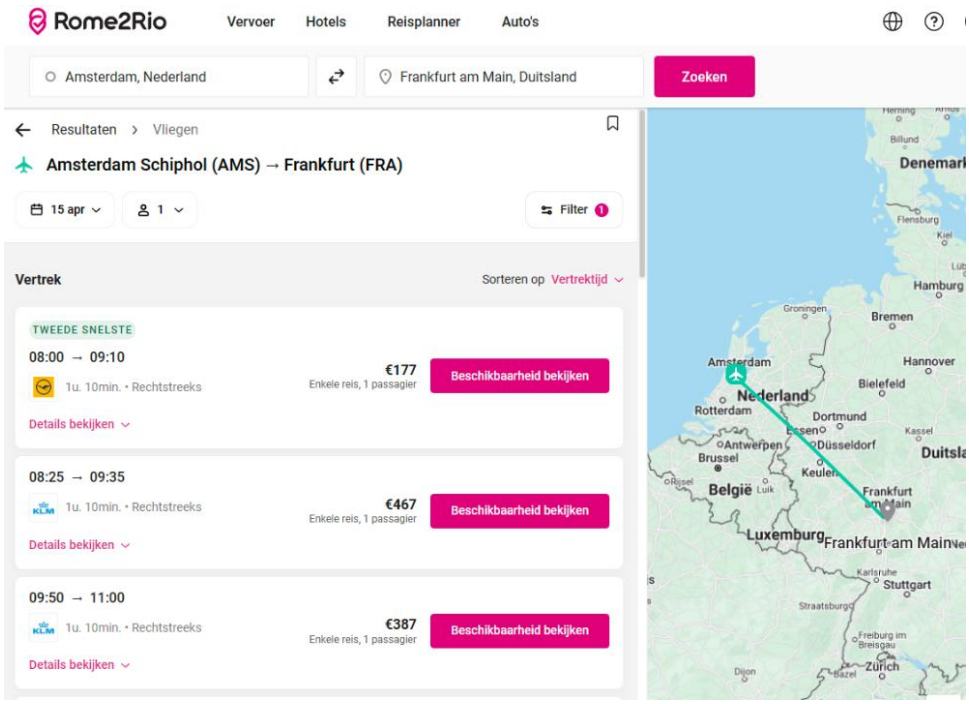


Figure 7: The information provided by the Rome2Rio travel platform [30]

Since only the flight time and ticket price is displayed on both of these platforms, flying usually seems faster and cheaper, thus more attractive. Making these travel planners generally biased towards flying as well. When incorporating the total picture, including among others the travel time and costs of going from and to the airport as well as waiting times at airports, passengers would get a fairer comparison between both modes of transport. This is mainly because the rail journeys do show the total city to city travel time as well as its total price while air journeys only show the time you are inside the airplane.

The design of travel platforms

Knowing that there is a strong need for a true unbiased multimodal travel platform, it is time to take a look at how such platforms are usually designed. This section will analyse different studies on the design and functionalities of such persuasive travel platforms.

Research by Cheung and Sengupta [43] identified specific steps passengers go through when planning their journey. As can be seen in figure 8, a user usually starts with defining their origin and destination location. This could be either inputted as a POI (for example a train station) or the current location of the user. In most travel planners, one should fist select a mode of transport and after that it will show its specific travel time and costs. The user could then analyse these results and compare by selecting other modes of transport. Dependent on the availability of data, usually real time travel data is preferred to provide the most accurate travel information for passengers.

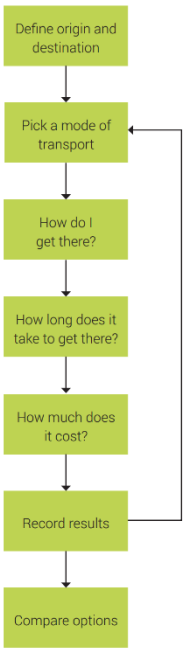


Figure 8: The process of planning a journey [43]

Cheung and Sengupta also indicated the importance of crowdsourcing, relating to users who can contribute information to a system. This includes for example, accidents on the lines, delays of trains, crowdedness in certain coaches etc. Incorporating such functionalities could provide users with more up to date information. Besides that, their research highlighted that personalisation is important in travel planners, meaning that specific travel behaviour or preferences of users should be stored and used in a relevant way. This includes storing frequently visited locations (such as your home and work location), to make it easier to navigate. Also customisation was found to be important when planning a journey. “Travel planners should provide users the option to select preferred modes of transport [43].”

All in all, Cheung and Sengupta suggest that travel platforms should be designed in such a wat that it at least shows information on journey time and mode of transport used for each leg of the journey. Secondly, information such as cost, fuel use, CO2 emission and burned calories can be included as well. Besides that, this study has identified a number of desirable functionalities which could help improve usability [43]:

- Ease of data input:
  - Auto completion;
  - Reduced textual input;
  - UI elements follow the platform convention;
  - Providing user feedback to validate input.
- Customisations:
  - Options are clearly visible;
  - The buttons of the option menu adhere to the platform convention.
- Results display:
  - Information appears in a natural and logical order;
  - Additional information should be relevant to the user’s needs only.

But one might wonder now how such functionalities are put into practice in current travel planners. According to another comparative travel planner study by Esztergár-Kiss [44]: “The journey planner of DB provides the best services and widest range of information for passengers. This system is especially outstanding in the main aspects of booking and payment and supplementary information, but its dynamic information is also very detailed (e.g., environmental impacts and services at the station) [44].” Therefore the DB travel planner can be taken as potential inspiration for the design of my own travel platform (see figure 9).

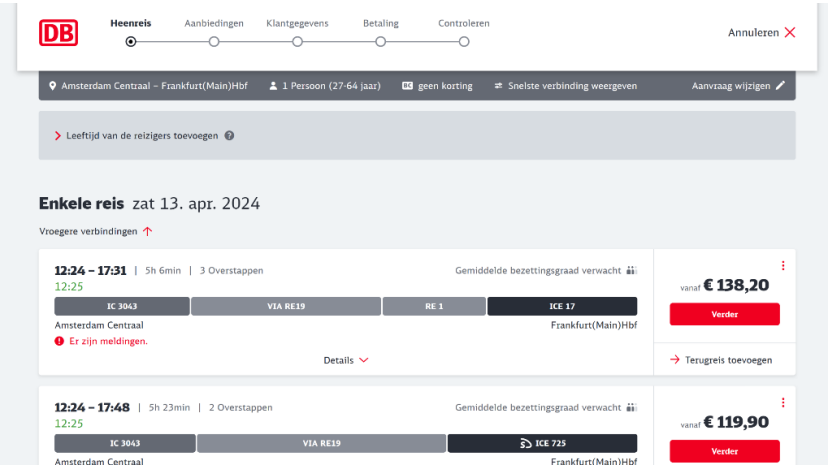


Figure 9: The DB travel planner [45]

Another research project conducted a survey amongst a diverse group of passengers. It investigated the important elements a travel platform should have and ranked which elements are the most important. Their key findings can be seen below (see figure 10 till 13).

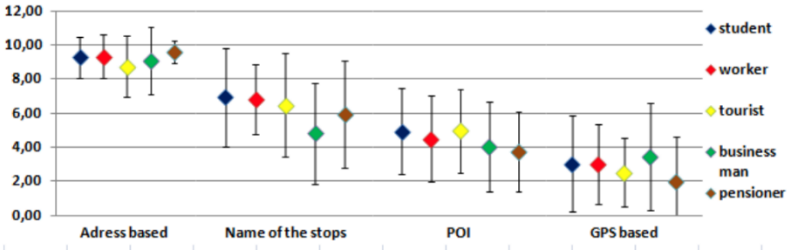


Figure 10: The preferred input modes [46]

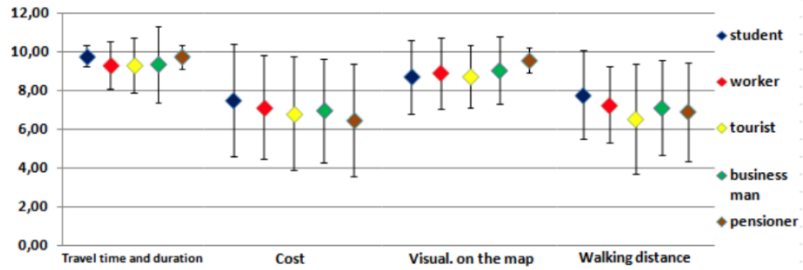


Figure 11: The preferred route planning information [46]

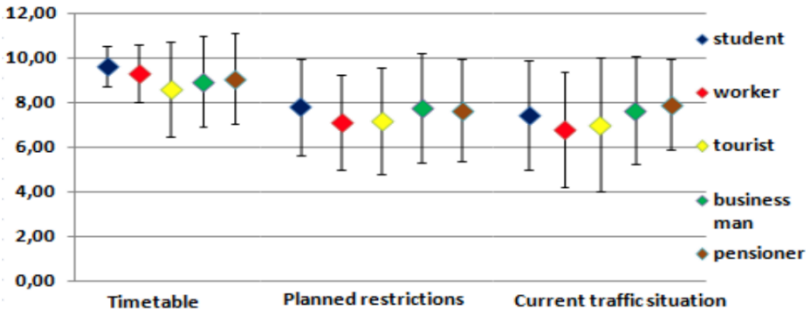


Figure 12: The preferred operational features [46]

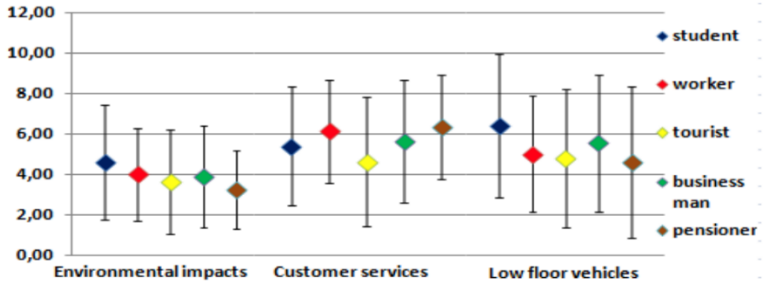


Figure 13: The preferred supplementary information [46]

All in all, it can be seen that address based input is the most frequently used by all respondents. Besides that, travel time information as well as visualizations on maps are important characteristics of a good travel planner according to the participants. Also additional information on the timetable as well as customer service and low floor vehicles was appreciated by the respondents.

Conclusion

The background research provided extensive information on possible design elements and features of a successful multimodal travel platform. Even though no unbiased multimodal air-rail platforms currently exist, the importance of such a platform was clearly indicated. With this conclusion as well as the important decision making factors of passengers and the proof of a persuasive win-win situation in mind, it is now time to go one step further. In the further sections it will be investigated how such a well needed persuasive informing platform could be designed. This background research provided enough convincing support for the effectiveness of such a multimodal platform as well as important factors to keep in mind during the design process of such a platform. All in all, this background research can therefore be considered as the stepping stone for a successful Graduation Project.

5. Methods and Techniques

The development of this GP's multimodal travel platform will follow the Creative Technology Design method from Mader and Eggink [25]. This approach provides a guideline for creating a well-supported design. It is an iterative process that allows for a cyclic design approach, creating the opportunity to come back to earlier stages when a design is iterated. It also consists of among others divergence and convergence, which forms a spiral model including different phases. The entire process can be seen in figure 14a below. The Creative Technology design process can help combining literature-based knowledge with expert feedback to create an optimal product that encapsulates the user needs and stakeholder requirements. The first phase of this process is Ideation, the second Specification, the third Realisation and lastly the Evaluation phase. Before starting the ideation phase, a design question has to be formulated. In this Graduation Project the design question is also the main research question and therefore formulated as follows:

How to develop an online platform that persuades passengers to take the train instead of short haul flights by informing them about the different modes of transport (including price, climate impact and travel time)?

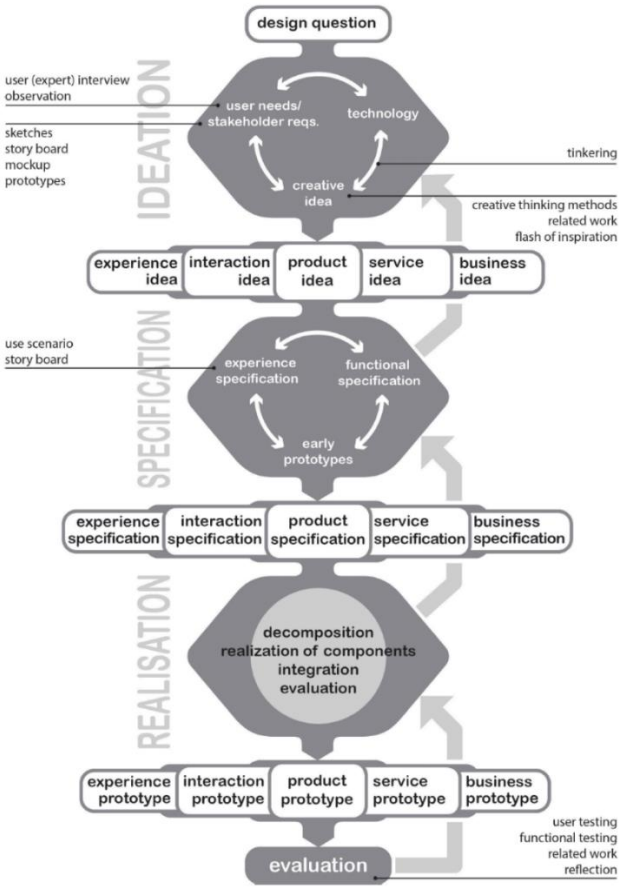


Figure 14a: The Creative Technology design process [25]

Ideation

The first phase in the Creative Technology design process is called ideation. During this phase a broad range of domains will be explored in order to define a design space. After defining this design space one would converge towards one specific solution. The ideation phase can have three different starting points [25]:

- User needs or a stakeholder request
- Technology itself
- A creative idea

Since this GP followed from a request of my client the category “User needs and stakeholder requirements” were chosen as a starting point. The whole design process will therefore also be executed in close cooperation with my client, the European Union Agency for Railways.

Before coming up with the first product idea, a semi-structured expert interview will be conducted with the client to define their product requirements. This approach is also suggested by the Creative Design Process (see figure 14a). Semi-structured interviews do not have a fixed amount of questions that are asked a particular order. In such interviews the interviewer presents a list of questions, but they can be seen as guiding questions to direct the conversation a little bit [40]. The semi-structured approach has been chosen to create opportunities for the interviewer and interviewees to discuss more than might be suggested by the interview questions. The list of requirements following from this interview will be categorized based on the MoSCoW methodology [20]. This means that the requirements will be assigned to one of the following four categories: a requirement the system Must, Should, Could or Would Have. The same will be done for the requirements following from the background research chapter.

Once a clear list of preliminary product requirements has been identified, the next step can be taken towards coming up with the first product idea. From this point onwards, a user-centred design approach will be implemented. User-centered design [39] is an approach in which the designer focuses on the users and their needs within each phase of the design process. Keeping this in mind, the designer will brainstorm and design new concepts.

The mind mapping method will be used as a brainstorming technique to come up with the first product idea. The central point of the mind map will describe the main problem. Around this problem description, several solutions will be described. It is suggested that solutions with similarities will be bundled on the same branches of the mind map. Once moving further along these branches, the ideas will become more detailed and specific. In order to efficiently develop a mind map, the online Excalidraw tool will be used [38].

Once the mind map has been finished, the different ideas will be validated in terms of suitability by laying them next to the product requirements. The ideas which are contractionary to the requirements will be dropped. The remaining ideas will be ranked by giving them a score from 1 (least complex, accessible etc) till 5 (most complex, accessible etc) on the following topics:

- Complexity: “How difficult is it to build and implement the idea?”
- Accessibility: “How big is the audience that can be reached with this idea? And how easy is it to reach this audience?”
- Effectiveness: “How effective is the idea in realizing a modal share shift from air to rail?”
- Uniqueness: “How unique is the idea? Do similar solutions exist already?”

By ranking the ideas on these topics, the best possible idea can be selected. This initial idea will be presented to the client and supervisors for feedback. The idea will be iterated based on this feedback. Once this is completed, the final idea can be worked out further during the next specification phase.

Specification

During the specification phase, the product idea following from the ideation phase will be worked out in more detail. This includes the following elements [25]:

- About the system:
  - (Non-)functional requirements and system specification;
  - Design specification;
  - System architecture.
- About the user:
  - Persona;
  - Scenario;
  - Storyboard.

First of all, the functional requirements will to a large extent follow from the earlier set product requirements of the expert interview. Even though, the product requirements might not directly describe functional requirements, they can often easily be deducted from them. Also, additional suggested functionalities following from literature might be considered. The functional specification will also include an architecture design of the platform on different levels. This is because the final online platform might need access to external servers. To make the realisation easier, it is important to further specify the system’s architecture and describe its functionality in detail.

Secondly, the design will be to a large extent be based on existing literature as well as similar other travel platforms. By basing my platform on these existing systems, one could create a thrusted and recognisable design that frequently used travel platforms communicate. It that way, the step of going from current travel platforms to my travel platform will not be too big.

To also get a better understanding about the potential users of my product a persona, scenario and storyboard will be created. These will describe in detail who the potential user is and when/how they will use my travel planner. This will result in a better and more specified understanding about the different stakeholders involved and what their relation is to my product.

Altogether this could guide my initial idea towards a more specified first prototype and a better understanding about the potential users. This better specified idea will be presented again to the client and supervisors for feedback. The idea will be iterated based on this feedback. Once this is completed, the idea can be realised during the next realization phase.

Realisation

During the realisation phase, the final detailed idea from the speciation phase will be converted into a first prototype of the actual platform. The realisation of such a prototype mainly includes programming the travel planner and setting up the environment of the online platform. The specified design, (non-)functional requirements and system architecture of the specification phase will be used as a starting point for the realisation of the travel planner.

The envisioned platform will be decomposed into different sub-components which will all build one after each other. It is expected that this will make the realisation more efficient because the sub-components can all be tested and debugged separately. Eventually the combination of all sub-components should provide us with a full functioning system.

Once the prototype of the system has been finished, a small evaluation will be conducted. During this evaluation the prototype will be compared to the (non-)functional requirements to see if all necessary elements (the must have requirements from the MoSCoW method) of the system are successfully incorporated. Based on this evaluation, changes were suggested to improve the system during future development.

Evaluation

The last phase of this GP is the evaluation phase. This phase focusses among others on the intuitiveness, content, usability and effectiveness of the travel planner. During the evaluation phase a small user test will be executed of roughly 20-30 minutes. The aim to test the travel planner with roughly 10 to 15 participants of different ages and backgrounds. The user test will start with a short introduction explaining the background of this GP as well as an explanation of the travel planner prototype. Also the structure of the user test and the rights of the participants will be mentioned. This includes signing a short consent form which can be found in Appendix 1.

After the introduction, a semi-structured introductory interview will be held regarding the current travel behaviour of the participant. This includes questions on how often they travel, which modes of transport they prefer and how they currently plan their journeys. A semi-structured approach has been chosen, because this provides some guidance during the interview but also allows for additional elaboration, more than the questions might suggest [57]. Altogether this could provide useful in depth insight in the decision making process of the participant.

Once this introductory interview has been finished a small user test will be conducted in which the user executes three tasks within the travel planner. All three tasks involve planning a journey with my travel planner. The first task will include a journey in which taking the train is faster and cheaper. The second task will include a journey in which taking the train is similarly fast and expensive. The third task will include a journey in

which taking the train takes significantly longer and is similar in price. For all three tasks the rail emissions will be much lower as compared to the flight alternatives. The combination of these three tasks is expected to provide a clear insight into what extend people are willing to travel by train and why they chose for either flying or taking the train. This includes insight in the most important decision making factors or passengers (either travel time, price, emissions or something else).

During this user test the “think aloud” procedure will be used. “A think-aloud protocol is the process of having participants speak what they are thinking as they complete a task [58].” This could provide detailed feedback on the travel planner, including confusing design elements, struggles and other issues which might arise while interacting with the platform. Additionally, an in-depth insight in the decision making process of the participant can be gotten. This includes the reasoning behind why one would choose for a specific mode of transport.

After the user test a short semi-structured interview will be conducted. This interview will dive into the intuitiveness, content and usability of the travel planner. Potential design, layout and functional improvements will be discussed. Besides that, questions will be asked about whether the participant is more likely going to take the train and what the most important factors are for choosing a certain mode of transport.

The user test will conclude with a short survey which includes the System Usability Scale and some demographic questions (see Appendix 2). “The System Usability Scale is a simple, ten-item Likert scale giving a global view of subjective assessments of usability [59].” All questions of the System Usability Scale use a 5 point scale ranging from completely agree to completely disagree. The outcome of the System Usability Scale is a score ranging from 0 to 100 assessing the overall usability of my system. This score is calculated as follows [62]:

- Step 1: Convert Responses to Numbers:
  - Strongly Disagree: 1 point
  - Disagree: 2 points
  - Neutral: 3 points
  - Agree: 4 points
  - Strongly Agree: 5 points
- Step 2: Calculate X and Y:
  - X = Subtract the sum of all points of odd-numbered questions by 5.
  - Y = Subtract 25 from the sum of points from all even numbered questions.
- Step 3: Calculate the SUS Score:
  - SUS Score = (X + Y) * 2.5

The average SUS is around 68 [62]. This means that a system with a SUS of 68 can be interpreted as a system with an okay overall usability. Systems with a SUS score above this average are considered to have a good or even excellent usability. Systems with a SUS below this average can be seen as systems with a poor or even awful usability. The distinction between whether a system has an excellent, good, okay, poor or awful usability according to the SUS can be seen in figure 32 below.

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

Figure 32: Assessing the System Usability Scale [62]

Next to usability, the demographic questions of the survey can provide insight in whether the influence of social-demographic factors on travel mode decision making (such as income, gender and business/leisure travel) following from the background research are also visible on in my sample.

An overview of the complete user test plan can be found in Appendix 3. The results which follow after the execution of the user test plan will be analysed afterwards. This will be done by combining the survey answers, observations and interview answers into three clear overviews:

- One clear table which combines the demographic questions of the survey with the travel behaviour questions of the first interview;
- One table which calculates the System Usability Score for each user dependent on their answers from the survey;
- One A4 sheet with written notes for each individual user describing the decision making process of each passengers as well as feedback points they mentioned during the user test and second interview.

If time allows it is suggested that the described evaluation process is repeated for each iteration of the travel planner. This means that after a first round of evaluation the travel planner might be improved based on the first feedback. A second round of evaluation can then be conducted with the improved travel planner to check if there are any remaining points of improvement. Such an iterative approach is also suggested by the Creative Technology design process and is expected to result in the most optimal outcome. Altogether it is also expected that the described evaluation methods and techniques in combination with this iterative approach will provide detailed insight in the effectiveness of my travel planner.

Summary
Figure 14b incorporates all used methods and techniques into the Creative Technology design process, providing a clear overview and summary of this section.

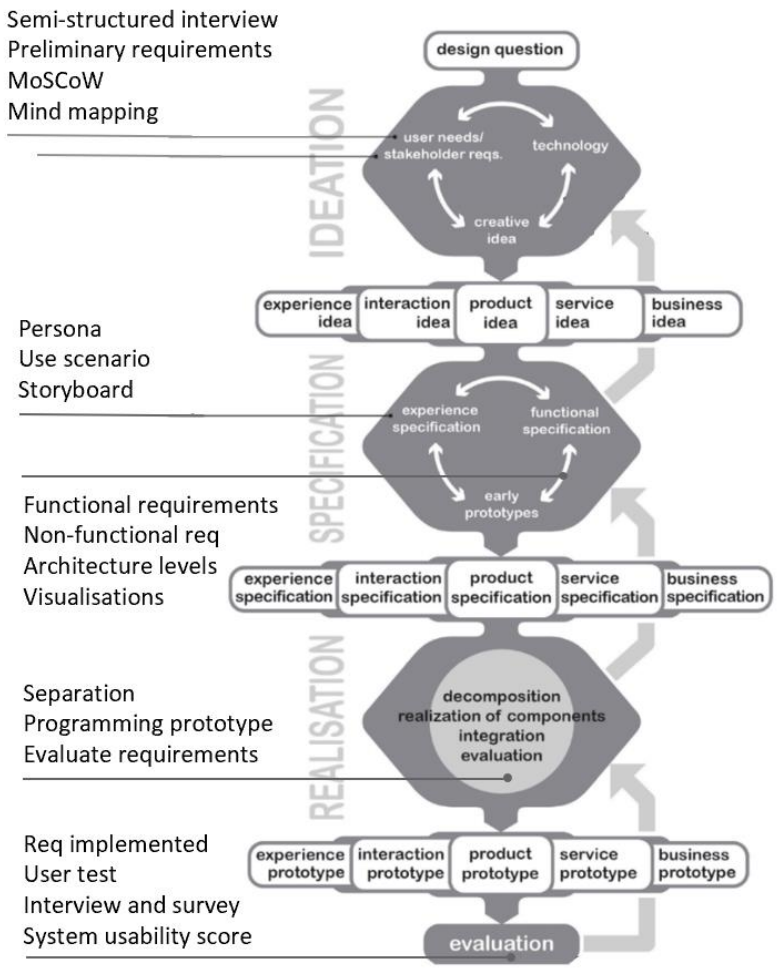


Figure 14b: The used methods and techniques of this GP incorporated into the Creative Technology design process [25]

The coming four chapters will dive into each distinct phase of the Creative Technology design process and execute the, in this chapter described, plan and methodology associated with each individual phase.

6. Ideation

The previous chapter highlighted that the first phase of the Creative Technology design process is ideation. During this phase the product requirements will be identified and based on that potential solutions will be brainstormed. After a process of iteration the final product idea will be described.

Expert's opinion

The interview with the client European Union Agency for railways identified several requirements the which the platform should fulfil. These requirements have been categories according to the earlier described MoSCoW method. The results of this can be found in figure 15 below, answering the sub research question "What kind of elements should the new platform have?".

Category	Requirement
Must have	The user must be able to provide the following input: departure city, destination city, departure or arrival time, date of travel.
	The platform must make a real multimodal comparison between air and rail which is unbiased towards any mode of transport.
	The platform must show total and broken down price, total and broken down travel time, total emissions, where to buy it.
Should have	The platform should incorporate the individual preferences of its users. This includes preferences such as, rather show: • The cheapest or fastest option • Journeys by train or train • Journeys with more or less transfers • Journeys with a lower carbon footprint
	It should be possible to incorporate multimodal car + train/plane combinations for some legs of the journey if they are very fast. Preferably only from departure and not going back, since then often no car is available.
Could have	The platform could incorporate train capacity/availability and show if tickets are available or not.
	The platform could also show long distance coaches and the total travel time, emissions and price for it.
Won't have	The platform will not make people change trains for only +/- 5 minutes of time gain. Fewer transfers should be preferred over insignificant time gain. Especially in night train this could be an issue.
	The user will not select a mode of transport beforehand. The platform should output any mode of transport.
	The platform will not show any car only journeys.
	The platform will not exclude night trains even though they might be significantly slower. When sleeping, longer travel times are less important. Therefore night trains should still be shown even though the day trains are significantly faster.

Figure 15: The solution requirements categorised according to the MoSCoW method

Suggestions by literature

Besides the requirements from the expert interview, it is also important to take into account the suggested requirements by literature. These requirements come from the background research chapter and are summarised in figure 16 below.

Category	Requirement
Must have	The travel platform must provide a clear overview of both travel time as well as ticket price, since these seem to be one of the most important decision making factors.
	In order to successfully persuade passengers to take the most sustainable mode of transport, they must be informed about the win-win situation associated with it.
Should have	The travel platform should provide information in a clear overview so that a good comparison can be made.
	The travel platform should make use of real time data if possible.
	The platform's UI elements should follow the platform convention and general process of journey planning.
	The platform should provide clear user feedback to validate the provided input.
	The information shown should appear in a natural and logical order.
Could have	The platform could incorporate data crowdsourcing to provide even more accurate and up to date data.
	The platform could provide a personalised experience by taking individual travel behaviour into account and store things such as frequently visited locations.
Won't have	The platform won't provide biased information towards any mode of transport. An objective comparison on travel time as well as price should be made.

Figure 16: The suggested platform requirements by literature categorised according to the MoSCoW method

The requirements from both figure 15 as well as 16 will provide guidance for the next section, the brainstorming phase. During the brainstorming phase, these requirements will be kept in mind and to a large extent shape the ideas. Especially the reoccurring requirements, such as making an unbiased comparison and doing this on both travel time as well as price, are very important to implement in the final solution. Therefore these two lists of requirements can be considered as a strong guiding factor for the brainstorming session which will follow next.

Brainstorming

With these requirements in mind, it is now time to start thinking about potential solutions. This raises the question: What different sorts of multimodal travel platforms can be developed? In order to answer that, the mind mapping technique will be used. Mind maps are a useful tool to generate, visualize, structure and classify ideas. It can help with solving problems and making decisions [47]. The centre point of the mind map describes the main topic of interest, in this case a persuasive multimodal travel platform. Around this bubble different ideas are ideated and potential solutions are discovered. The outcome of this brainstorming session can be seen in figure 17 below.

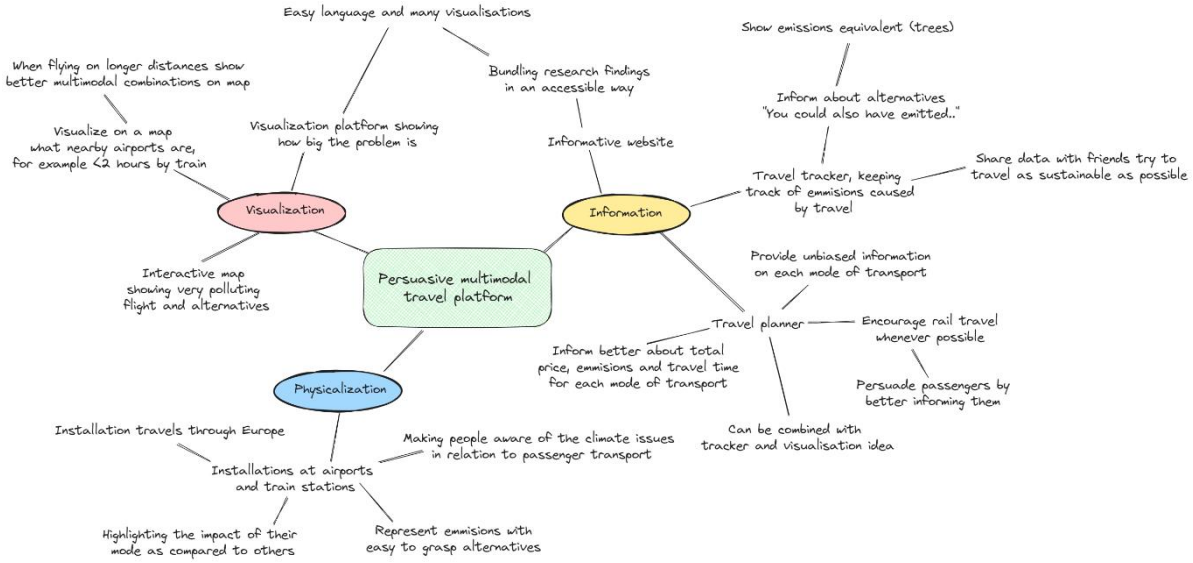


Figure 17: The outcome of the initial brainstorming session

This brainstorming session resulted in three main categories with ideas: physicalization, information and visualisation ideas. Each of these individual categories will be elaborated further below.

Physicalization

One of the ideas in the physicalization category was to put persuasive installations at trains stations and airports throughout the EU. These installations could highlight the environmental impact of the respective mode of transport the passenger has chosen as compared to other alternatives. In that way, people can reflect on their travel mode decision making and by doing that potentially change their behaviour. If possible such installations can even be placed at other public locations such as supermarkets or big shopping malls. Even though these are not transport locations, it could still inform a large audience about the climate impact of certain modes of transport. All in all, the main goal of such an installation is to try to persuade passengers to choose for most sustainable mode of transport.

Visualisation
Secondly, in the visualisation category I came up with the idea of building a persuasive and interactive map. This map could for example visualize nearby airports which you can reach within 2 hours by public transport. For each airport it could show the price, travel time and emissions of traveling to a certain destination. In that way sustainable multimodal travel could be encouraged. It is important for this idea, that not too much information is shown and that is presented in an accessible and easy to understand way. For example by using an approach which allows for simple information at first glance, but also enables digging deeper to get some more in depth knowledge. Altogether this could bundle significant amount of data and information into an understandable way.

Information
Thirdly, in the information category also different ideas have been developed. The first idea was to create an informative website which bundles all research findings on this topic in an accessible way. This could make the often hard to understand academic papers on this topic more accessible for a large audience. The second idea in this category was to create a travel tracker which keeps track of your travel emissions. This travel tracker can for example represent your total emissions with trees to make it easier to grasp. It could also highlight alternatives such as: “You could have saved X grams of CO2 by traveling with this mode of transport.” This data might also be shared with friends to give it a competitive element. The third idea in this category is the idea of building a travel planner which informs passengers better about the total price, emissions and travel time related to each mode of transport. Altogether, the main goal of these informative platform ideas is to make sustainable travel more attractive while not being biased towards any mode of transport.

Comparing the ideas

This brainstorm section explored different ideas for a persuasive travel platform. It is now time to compare these different ideas and try to come to the best final solution. This will be done by giving each idea a score from 1 till 5 on the following topics:

- Complexity
- Accessibility
- Effectiveness
- Uniqueness

A score of 1 means least complex, least accessible, least effective or least unique. And a score of 5 means most complex, most accessible, most effective or most unique. Raking the brainstorm ideas on these topics resulted in the following table below (see figure 18).

	Complexity	**Accessibility**	**Effectiveness**	**Uniqueness**
Physicalization	4	1	1	5
Visualisation	3	5	3	4
Information	2	5	5	4

Figure 18: The outcome of the idea comparison

As can be seen in figure 18, the physicalization ideas were found to be the most unique, but also the most complex, least accessible and least effective. The main reason why it was found to be inaccessible is because passengers have to physically go to a train station or airport in order to use it. They can for example not use it when planning their journey from home. At least putting such installations in each house can be considered unfeasible. Secondly, the physicalization ideas were also not found to be the most effective, because it lets people mainly reflect on their travel mode decision making instead of persuading them beforehand. Thirdly, it was expected that the physicalization ideas are the most cost intensive to implement European wide. This is because, it is very expensive to put such installation at each airport and train station throughout Europe. All in all, it has therefore been decided that the physicalization ideas will be dropped.

When looking at both the visualisation and information category it can be seen in figure 18 that these were found to be quite unique. This is because no direct alternative or competitor currently exists. Secondly, these ideas were expected to be very accessible since they are web based and therefore online accessible for a large audience. Thirdly, the visualisation and information ideas were also expected to be moderately complex to implement, since large amounts of data is available for such platforms. This includes for example large datasets of European short haul flights as well as their rail alternatives. Eventually, the travel planner idea of the information category was found to be the most effective since it directly tries to influence the decision making at the moment when different travel options are compared. However, since the visualisations also received a high score according to figure 18, they will not be fully dropped. It will still be tried to integrate those into the informing ideas if time allows for it.

Overall it can be concluded that the information idea of creating a travel planner seemed to be the most effective and most fitting with the requirements of the client as well as literature. Such a platform would namely easily facilitate the required unbiased travel mode comparison on both travel time, price and emissions. Travel planners usually also ask for input such as departure city, destination, travel date and time. This therefore nicely fits with the first requirement of figure 15 as well. All in all, the information idea seemed to clearly be the most effective and align the best with the suggested requirements by the client as well as literature. This idea was therefore chosen as the final idea for this Graduation Project.

The final idea

Since we now got to the final idea of building a persuasive travel planner which makes a fair comparison between travel modes, it is time to take a closer look at what sort of functionalities this final idea should have.

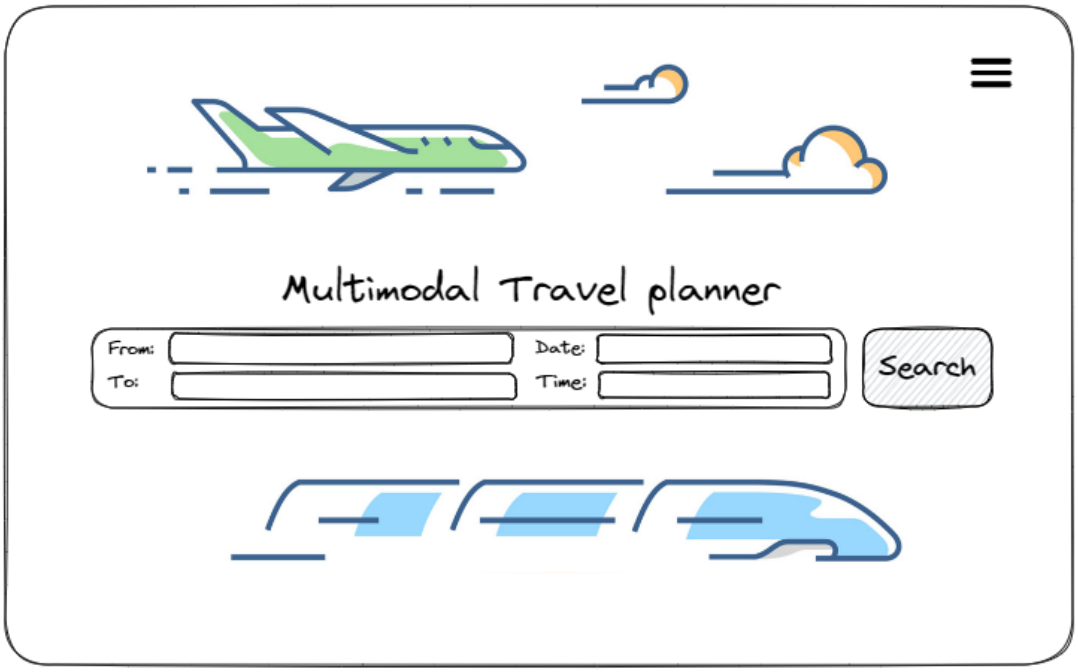


Figure 19: A first sketch of the final solution

As was suggested by both the client as well as the travel planning process of figure 8, it is important that a user can provide input about the journey they want to take. This includes the date of travel, preferred departure or arrival time, destination location and arrival location (see figure 19). Secondly, the background research highlighted that it is important to make an objective comparison between air and rail transport based on the provided input. This should primarily include the total door-to-door travel time as well as total costs (see figure 20). By providing this comparison in a fair way, it is expected that more people will be persuaded to take the train instead of the plane. Additionally, information such as emissions, where to buy it and number of transfers could contribute to this goal as well. Besides that, the background research also highlighted that it is important to make the general layout, structure and interactions of the travel planner similar to the current standards. In that way the platform will be easy to use for passengers. It is important that all the elements mentioned above, will be incorporated in the final idea as good as possible. Only then it is expected that passengers will successfully be persuaded to take the most sustainable modes of transport.

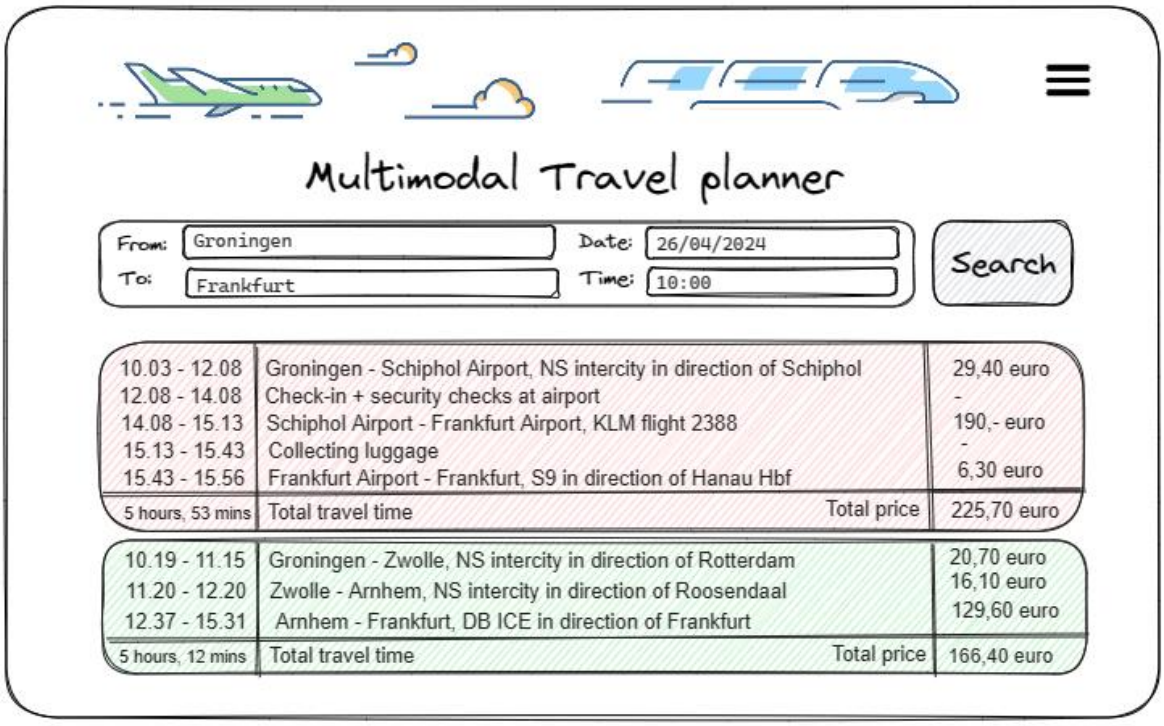


Figure 20: The potential functionalities and layout of the final solution

As was seen in chapter 4 background research, current travel planners usually do not show the total price and total travel time for air journeys. Figure 4, 6 and 7, highlighted that the journey from Groningen to Frankfurt by rail would take 10+ hours and 1 hour by plane according to Google Maps. However, this comparison seems to be strongly biased towards flying since a slow night train was selected and only the flight duration of 1 hour was shown. Once an unbiased comparison is being made (see figure 20), it can be seen that the total travel time by rail is actually shorter and much cheaper. Instead of 10+ hours, the day journey by rail actually is around 5 hours. And instead of 1 hour, it actually takes almost 6 hours from door to door to travel by plane. Therefore, travelling by rail is actually the best option once a clear and unbiased comparison is being made. Providing additional evidence for the large potential of this persuasive travel planner idea.

Once the basic functionalities of the travel platform are implemented, it would also be interesting to look at adding the additional interesting functionalities from the brainstorm. This includes among others an interactive map or a personalised experience. The different travel options can for example be visualised on a map, highlighting the different airports to depart from or different train routes to take. It would also be interesting to allow users to create their personal profile on the travel planner which keeps track of their travel behaviour and informs them about this. Besides that, also additional information on for example luggage check-in facilities at train stations and customer rights might be relevant to incorporate as well. Such functionalities could make the travel planner extra unique as compared to just implementing the functionalities which followed from the background research. The exact design of my travel planner as well as the final list of functionalities will be further explored in the next chapter, the specification phase.

7. Specification

The previous chapter provided a clear description of the final idea and some of its basic functionalities. This chapter will dive further into the detailed design and functionalities of this final idea as well as the systems architecture and target users. Altogether this will form a good foundation for the next chapters realisation phase in which the system itself will be build.

Persona

Before getting an understanding of the systems functionalities and architecture, it is first time to take a closer look at the users of my travel planner. In order to come up with a clear description of potential users of my system, a persona was created. Personas are fictional characters, who represent different types of users that might use your product in a similar way. This might help getting an understanding of the users' needs, experiences, behaviours and goals [52]. Based on the background research as well as the systems functionalities, the following persona has been created (see figure 28 below).

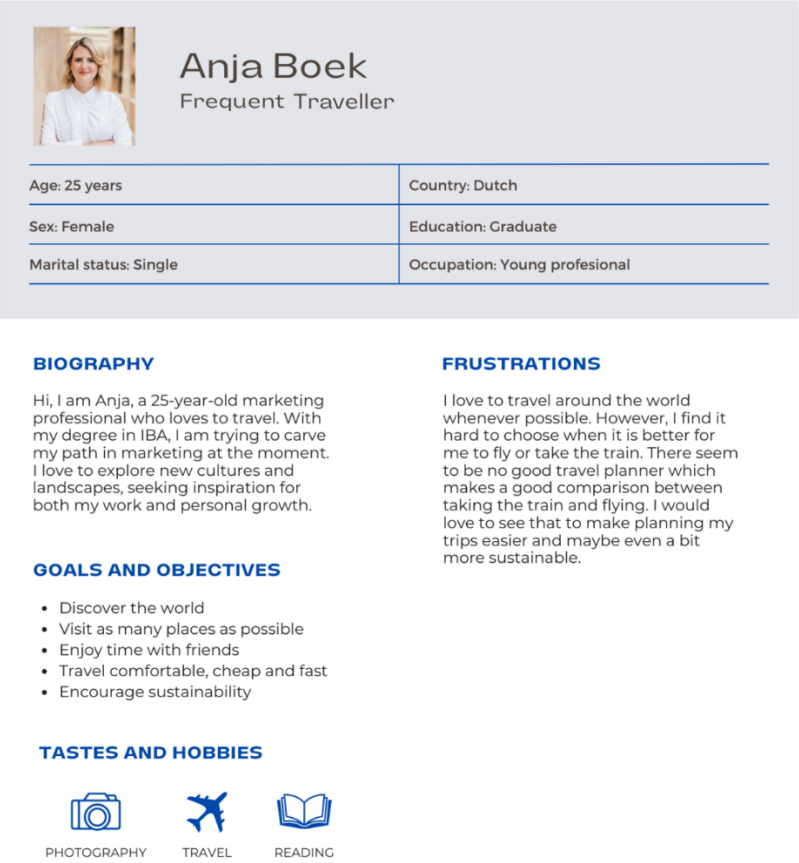


Figure 28: The persona of a potential user of my travel planner

The persona of figure 28 describes a frequent international traveller who wants to go from source to destination as fast and cheap as possible, but also tries to do it a bit sustainable if possible. This could clearly be a potential target user of my platform. For such people my platform could help make the right decision on when it is better to fly and when to take the train. However it does have to be mentioned that not only frequent leisure travellers are expected to use my travel planner. Even though they might be one of the most intensive users of the travel planner, also any other person traveling on longer distances within Europe is of interest. This includes business travellers and people with any age, gender and income. Besides individuals, my platform could also be helpful for people traveling together in pairs or groups. Therefore it is important to note that figure 28 only suggests one potential user but it is not limited to only these.

Scenario

The persona provided a clear understanding of the potential users of the persuasive travel platform, but it is also interesting to take a more detailed look at the context of use. Therefore this section will describe the scenario in which the platform is being used.

A scenario describes a basic story of an action or goal that a user wants to accomplish. It describes in detail the: who, what, when, where, why and how of the user's scenario [53]. In the context of this GP's persuasive multimodal travel planner, the following scenario of use has been described:

"*Anja Boek is a frequent traveller who loves to explore more of Europe. Since the summer break starts in a few weeks, Anja wants to plan a trip from her hometown close to Groningen to her grandmother in Frankfurt, Germany. She is still at home and doubts whether it would be the fastest and cheapest to fly or take the train. Therefore she decides to make use of a new kind of travel planner which compares both options. She first heard about this new travel planner in an online article and also got it as a recommendation from one of her friends. Therefore she descried to give it a try. She puts in here departure city, the destination and preferred date and time of travel. The travel planner provides here with an overview of the total travel time by plane and by train. She finds the information on the screen minimalistic and therefore easy to understand. She likes the clear symbols which visualise the provided information. Also the flight and train journey are clearly separated and easy to compare. To her surprise, it seems to be significantly faster and cheaper to take the train instead of flying from Amsterdam. She also sees that taking the train has a positive impact for the climate due to its lower emissions. Therefore she eventually decides to take the train and book the corresponding tickets. The travel planner provided her with a clear overview of the journey she needs to take and where she could buy the train tickets. Once she ordered here tickets online she was all set to visit her grandmother this summer and enjoy some time with her.*"

Storyboard

In order to get an even better and visual understanding of the context of use of my travel planner, it would be interesting to visualize the use scenario of the previous section into a storyboard. A storyboard is a visual representation of a user's journey through a product. It consists of a sequence of images outlining the user's actions, thoughts and emotions at each stage [55]. Converting the scenario of use from the previous section into a visual storyboard resulted in the following image below (see figure 29). Highlighting the process and steps a user takes when planning a journey with my travel planner.

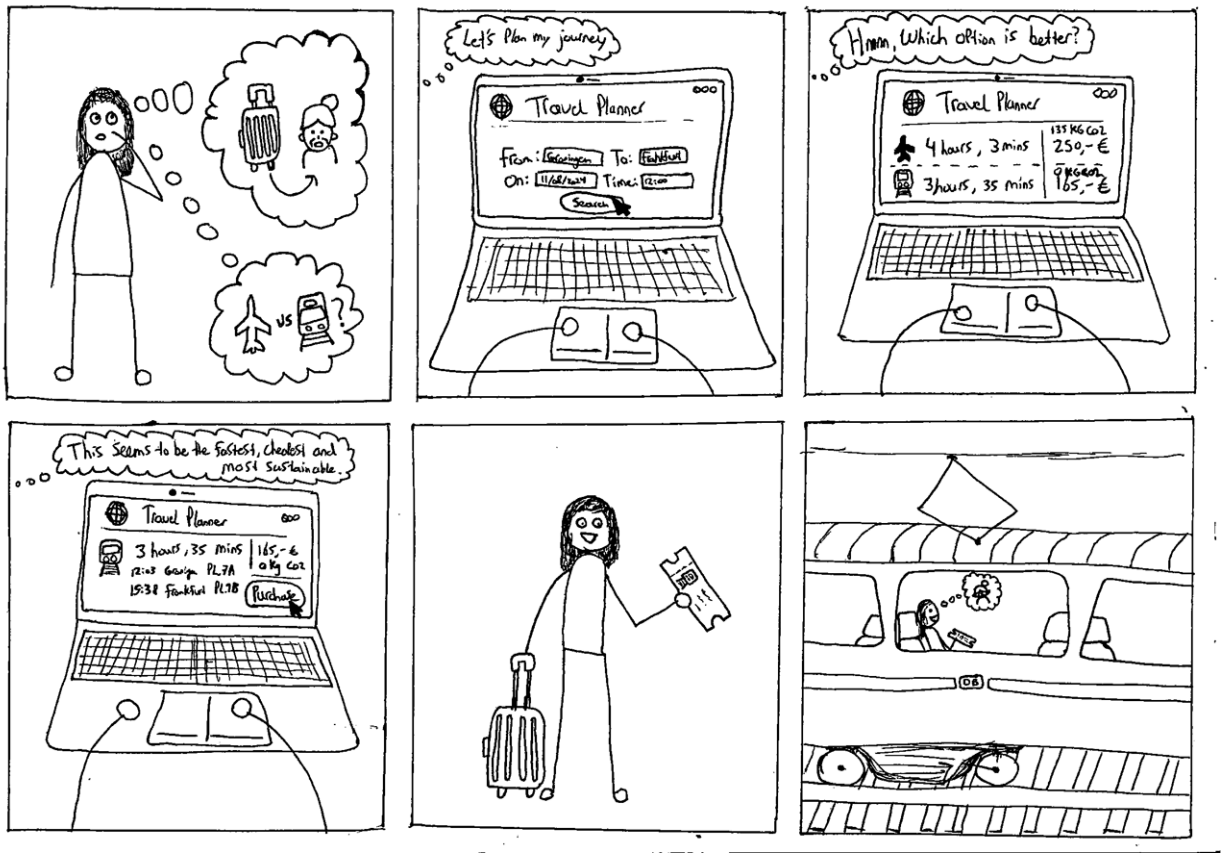


Figure 29: The storyboard visualising the use scenario

The first (top left) scene of figure 29 shows the initial idea of making the trip to grandma and the doubt of taking the train or plane. In the next scene the user puts in the details of the journey including the date, time, departure and arrival city. In the third scene different options are compared which eventually results in the fourth scene with taking the train as the fastest, cheapest and most sustainable option. Once the user has bought their ticket via the travel planner, they can print their ticket and make the actual journey. The last two scenes highlight the eventually train journey the user is going to take on the earlier planned date and time.

Functional and non-functional requirements

The second step in specifying the concept of a multimodal travel planner is describing the systems functional and non-functional requirements. Therefore the earlier described requirements from literature (figure 16) as well as the expert interview (figure 15) will be regrouped into either functional or non-functional requirements. Besides that, each requirement will be elaborated and further specified. This resulted in the following list of non-functional (figure 21) and functional (figure 22) requirements.

Category	Requirement
Must have	NF1: In order to successfully persuade passengers to take the most sustainable mode of transport, they must be informed about the win-win situation associated with taking the train instead of the plane. This could for example be realised by showing a reduction in price and travel time while also having a positive impact on the climate.
	NF2: The design should facilitate a clear overview of both travel time as well as ticket price, since these seem to be one of the most important decision making factors.
	NF3: The platform's design must visualise additional information such as total and broken down price, total and broken down travel time, total emissions, where to buy it. This information should be sufficient and clear for passengers to be able to execute the journey.
Should have	NF4: The information shown should appear in a natural and logical order, similar to the currently existing travel planners. A natural and logical order means that there should be a clear match between the information the system provides and how it can be used in the real world, while executing the journey. Also the information on the same train or flight should be grouped together to avoid confusing the user. To further achieve a natural and logical order, also different steps within each journey should be displayed chronologically in time. All in all, the platform's UI elements should follow the platform convention and general process of journey planning. This means that a similar layout, structure and interface design is suggested as currently existing planners. In that way a natural and logical order can be achieved.
	NF5: The travel platform should be designed in such a way that it provides a clear overview of information so that a good comparison can be made. This means that sufficient information should be shown to make a good comparison, but on the other hand the user must also not be overloaded with too much info.
Could have	NF6: The platform's design could incorporate train capacity/availability and show if tickets are available or not.
	NF7: The platform's design could visualise long distance coaches and the total travel time, emissions and price for it.
Won't have	NF8: The platform will not show any car only journeys.

Figure 21: The list of non-functional requirements

Category	Requirement
Must have	F1: The user must be able to provide the following input: departure city, destination city, departure or arrival time, date of travel.
	F2: The platform must make a real multimodal comparison between air and rail which is unbiased towards any mode of transport. This means that an objective comparison on travel time and price must be made.
Should have	F3: The platform should provide clear user feedback to validate the provided input. This includes for example correcting for misspelled city names or wrong date and time input.
	F4: The travel platform should make use of real time data if possible. For example live information should be shown on train delays, travel platforms etc.
	F5: It should be possible to incorporate multimodal car + train/plane combinations for some legs of the journey if they are very fast. Preferably only from departure and not going back, since then often no car is available. This would make the platform useful for an even larger audience of car owners.
Could have	F6: The platform could incorporate data crowdsourcing to provide even more accurate and up to date data. This means that it could be possible for users to provide input on for example occupancy, delays or other relevant information for their journey. Such information could be shown on the platform to be more up to date with the real life situation.
	F7: The platform could provide a personalised experience by taking individual travel behaviour into account and store things such as frequently visited locations and other travel patterns. This also includes incorporating individual preferences such as, rather show: • The cheapest or fastest option • Journeys by train or train • Journeys with more or less transfers • Journeys with a lower carbon footprint
Won't have	F8: The user will not select a mode of transport beforehand. The platform should output any mode of transport (in this case both air and rail options).
	F9: The platform will not make people change trains for only +/- 5 minutes of time gain. Fewer transfers should be preferred over insignificant time gain. Especially in night train this could be an issue.
	F10: The platform will not exclude night trains even though they might be significantly slower. When sleeping, longer travel times are less important. Therefore night trains should still be shown even though the day trains are significantly faster.

Figure 22: The list of functional requirements

System specification

The (non-)functional requirements of figure 21 and 22 can be categorised into three main layers: the data input layer, the comparison layer and the outcome layer. Figure 23 below shows a visual representation of each layer. This layer structure is a simplified version of the earlier described process of planning a journey from literature (see figure 8). Therefore this structure is in line with requirement NF4 which highlighted the importance of following the platforms convention and general process of planning a journey. This level zero architecture of figure 23a shows the basic level of interaction between the user and the system, including the data input from the user, the system (the travel planner) and the output journey for the user. The system itself is just a black box in this level zero architecture. The users input and output is being shown outside this black box and the data input and journey output.

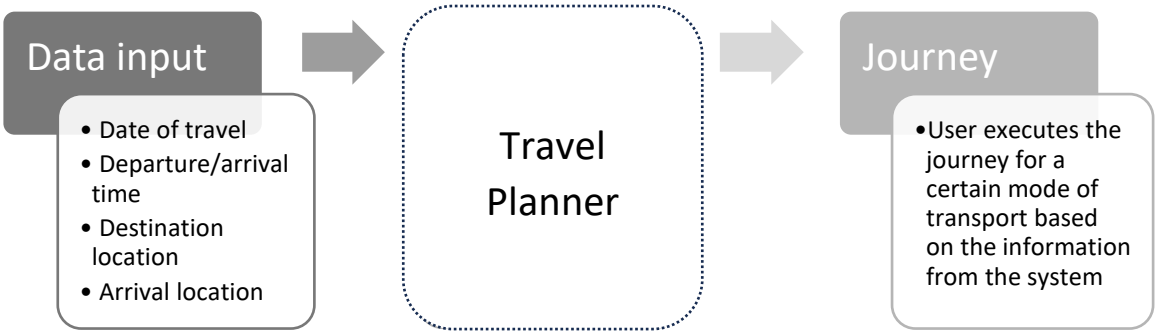


Figure 23a: The system architecture of the travel planner level 0

The level one architecture of figure 23b is more detailed and shows in more detail what happens inside the travel planner. The system is now not just a black box anymore.

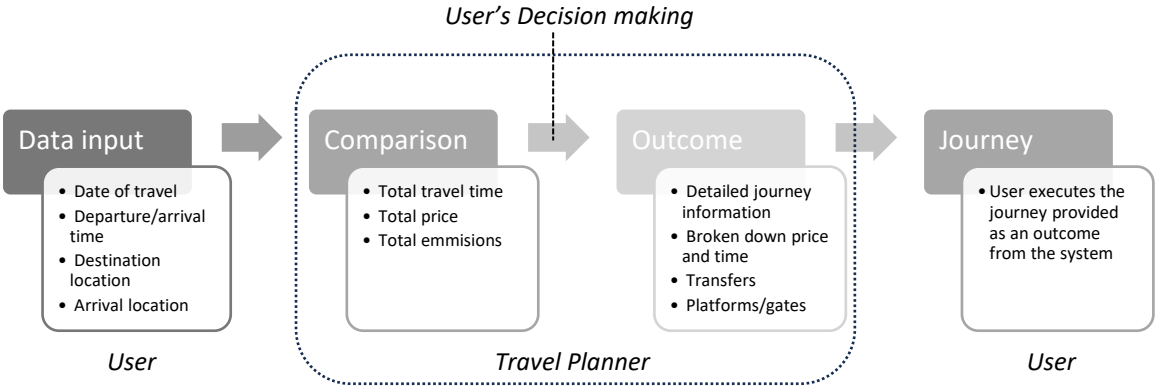


Figure 23b: The system architecture of the travel planner level 1

The first layer in the level 1 architecture is called the data input layer. As was highlighted in the previous section, the travel planner should allow input from the user on the date of travel, preferred departure or arrival time, destination location and arrival location (see requirement F1). This first layer of input data will provide the basis for planning the user's journey and making the travel mode comparison.

The second layer is called the comparison layer. Based on the provided input of the first layer, the second layer should provide a clear overview of total travel time and total price by train and plane, so that a good travel mode comparison can be made (see requirement NF2). Ticket price and travel time were found to be the most important factors in passengers travel mode decision making and therefore the main variables of interest in the air rail travel mode comparison. Additionally, it was highlighted by literature as well as the expert interview that this comparison on price and travel time must be unbiased (see requirement F2). The comparison layer should therefore provide an objective comparison on door to door travel time and ticket price of both the air and rail journey.

The background research also highlighted the importance of communicating a win-win situation in order to persuade passengers to take the train instead of the plane (see requirement NF1). Therefore, it is also important to show the total emissions associated with each mode of transport. When passengers see themselves benefiting from shifting from air to rail, because of the reduction in price and/or travel time, as well as the benefits it has for the climate, they are very likely going to change their travel behaviour. For that reason it is important that the comparison layer makes an unbiased comparison on price and travel time, but also on emissions.

The third layer is called the outcome layer. This layer should provide the user with sufficient information to make the actual journey for the selected mode of transport of the previous layer (see requirement NF3). It is therefore important that the total price and total travel time can be broken down into smaller more detailed blocks of information. In order to achieve that, the outcome layer should inform the user about the following elements:

- Train station names;
- Train platforms;
- Train number and final destination;
- Broken down travel time for each train leg;
- Airport names;
- Flight gates (if available);
- Flight number and final destination;
- Flight duration;
- Number of transfers;
- Transfer time;
- Broken down flight price;
- Broken down train price;
- Where to buy a ticket for each leg;
- Total flight emissions;
- Total rail emissions.

In order to provide the user with accurate and up to date information inside the output layer, it is important to further specify the architecture design of figure 23b. The further specified architecture design should clearly describe where the system will get its information from. An overview of the required information by my system and potential data sources can be found in figure 23c and 27 below.

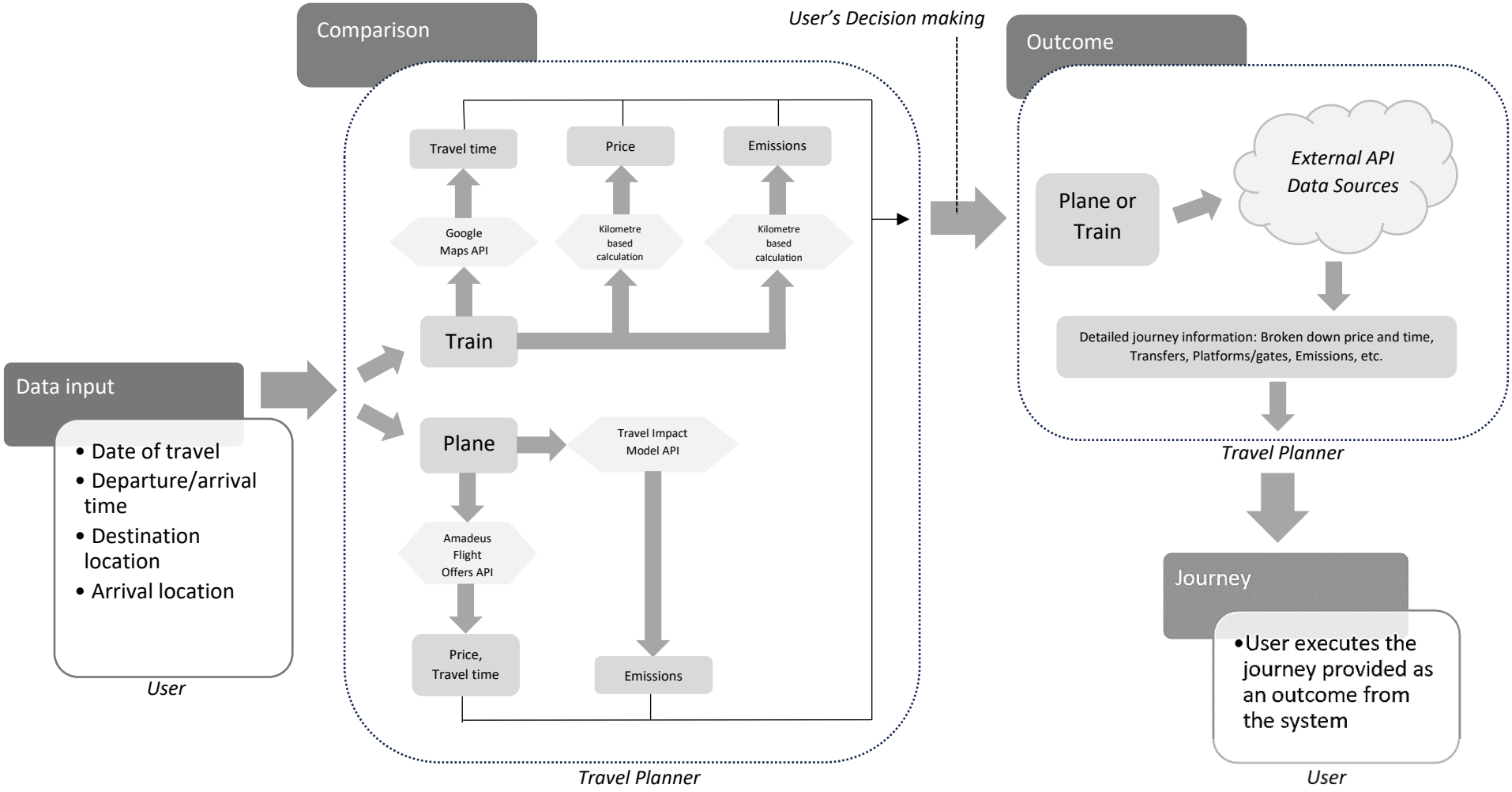


Figure 23c: The system architecture of the travel planner level 2

Type of information	Data source
Train station names	Google Directions API[48]
Train platforms	-
Train number and final destination	Google Directions API[48]
Broken down travel time for each train leg	Google Directions API[48]
Airport names	Amadeus Flight Offers API[49]
Flight gates	Amadeus Flight Offers API[49]
Flight number and final destination	Amadeus Flight Offers API[49]
Flight duration	Amadeus Flight Offers API[49]
Number of transfers	Amadeus Flight Offers API[49]
Transfer time	Google Directions API[48] + Amadeus Flight Offers API[49]
Broken down flight price	Amadeus Flight Offers API[49]
Broken down train price	Kilometre based calculation[55]
Where to buy a ticket for each leg	-
Flight emissions	Google Travel Impact Model API[50]
Rail emissions	Kilometre based calculation[56]

Figure 27: An overview of the required information and its data sources

As can be seen in figure 23c and 27, the main data source for the rail journeys is the Google Directions API [48]. This API provides detailed information for planning train journeys. For the flight routes, the Amadeus Flight Offers API will be used [49]. This API can plan flights between cities and display detailed information on for example ticket prices as well as flight terminals. Besides that, also the Google Travel Impact Model API will be used to calculate accurate flight emissions for each journey. This API is specifically developed for calculating flight emissions per passenger per travel class [50].

Unfortunately no suitable API was found to calculate rail emissions and rail ticket prices for specific journeys. All analysed available booking platforms did not allow for remote/open access and were therefore not usable in my travel planner. Therefore it has been decided that an average emissions and price per passenger per km will be used [55][56]. Multiplying this with the total rail distance coming from the Google Directions API can still provide a rough estimation of the total price and emissions for the rail journeys. Additionally, displaying accurate train platforms seemed to be difficult. This is because the train platform numbers are not accessible via the Google Directions API. Next to that, it seemed to be difficult to implement a ticketing system in my travel planner. This is because a secure and stable payment mechanism needs to be present for this which can purchase tickets from external partners. Because of the limited scope of this project these functionalities were dropped from the travel planner's functionality.

Once the basic functionalities of all three layers have been implemented, it might also be interesting to incorporate some of the factors which are of secondary importance for passenger's travel mode decision making. This includes for example seat availability and punctuality. It is expected that such additional information can provide the user with additional relevant information for their travel mode decision making.

Altogether the aim should be to incorporate as many (non-)functional requirements as possible. The so far described functionalities in this system specification section only highlight the minimum that should be implemented. These are the so called “Must have” requirements from the MoSCoW method. If time allows, all the other “Should have”, “Could have” and “Won’t have” requirements should be fulfilled as well.

Design specification

The previous section described a clear list of basic functionalities of the multimodal travel planner. It is now time to take a closer look at how such a system could be designed and how its layout could look like. The background research highlighted that it is important to make the general layout, structure and interactions of the travel planner similar to the current standards. In that way the new platform is expected to be easy to use for passengers. Besides that, several comparative studies found that the DB travel planner is one of the best travel planners regarding both design and functionalities (see figure 9). Therefore it has been decided that the layout of my travel planner will to a large extent be based on the DB travel planner. The same recognisable DB font [51] and similar white, light grey, red and black DB house colours [45] will be used. This resulted in the layout of figure 24, demonstrating the design of the data input layer of my travel planner.

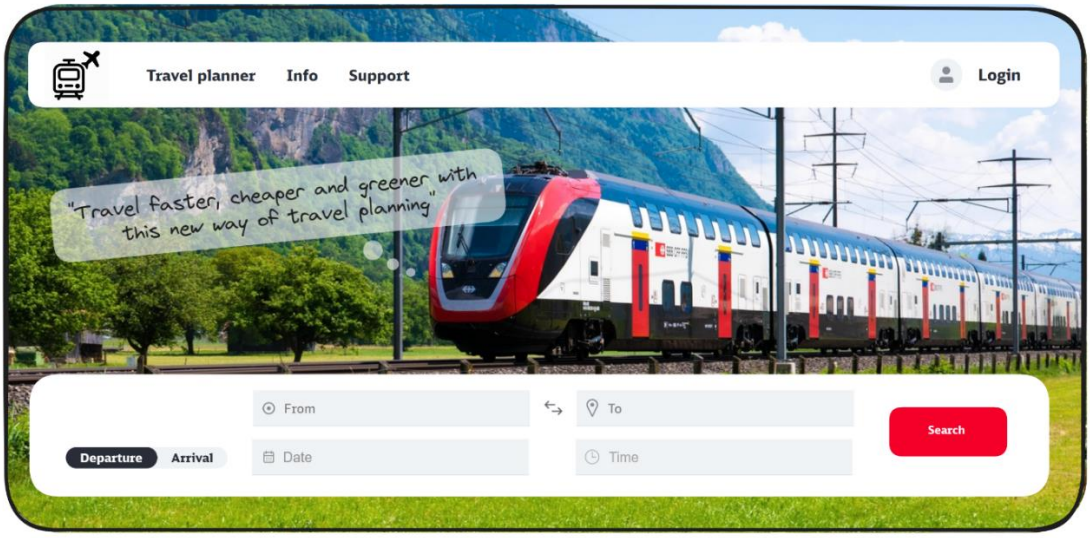


Figure 24: The design of the data input layer

As can be seen in figure 24, the layout of the data input layer follows the convention of current travel planners. The user can provide input on their departure and arrival city as well as the travel date and time. Once the user has provided this input, it is time to continue to the next layer, the comparison layer. In the comparison layer, the travel planner should search for the available air and rail options and show this to the user. Figure 25 below demonstrates the potential outcome of such a comparison and its design layout.

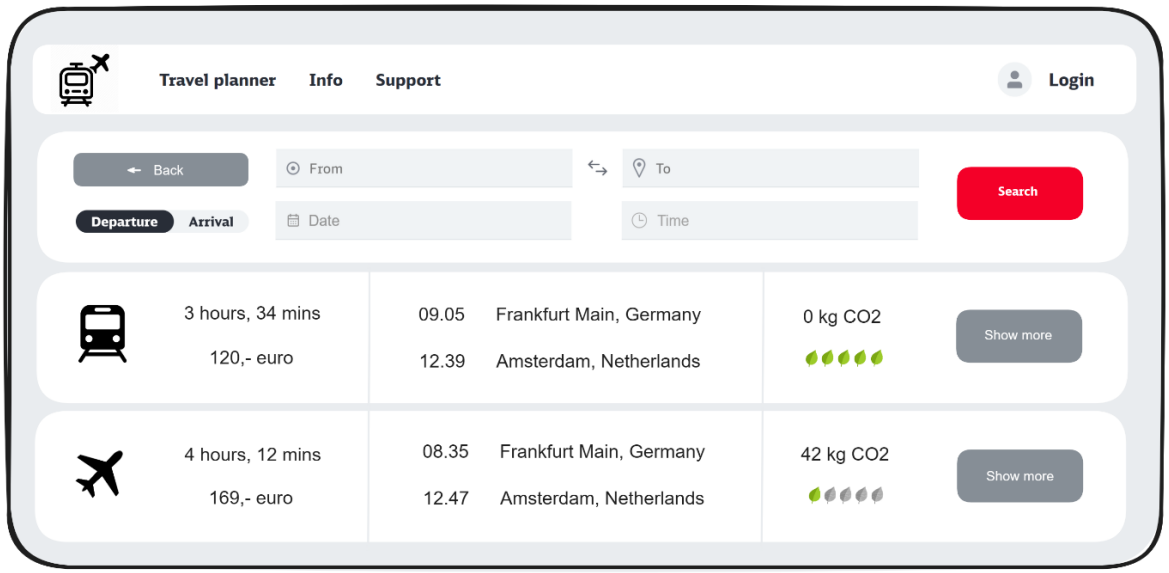


Figure 25: The design of the data comparison layer

As can be seen in figure 25, the design of the travel mode comparison is made very minimalistic providing the user with a clear and unbiased comparison on the primary decision making factors; total price and total travel time. This allows for an easy comparison of each mode of transport. Also additional emissions data is shown to communicate the persuasive win-win situation. Once the user eventually decides to take the train for example, additional information can be shown when the user clicks on the “Show more” button. Clicking on this button means that one shifts from the comparison layer to the outcome layer. The outcome layer demonstrates the outcome of the comparison and provides detailed journey information (see figure 26).

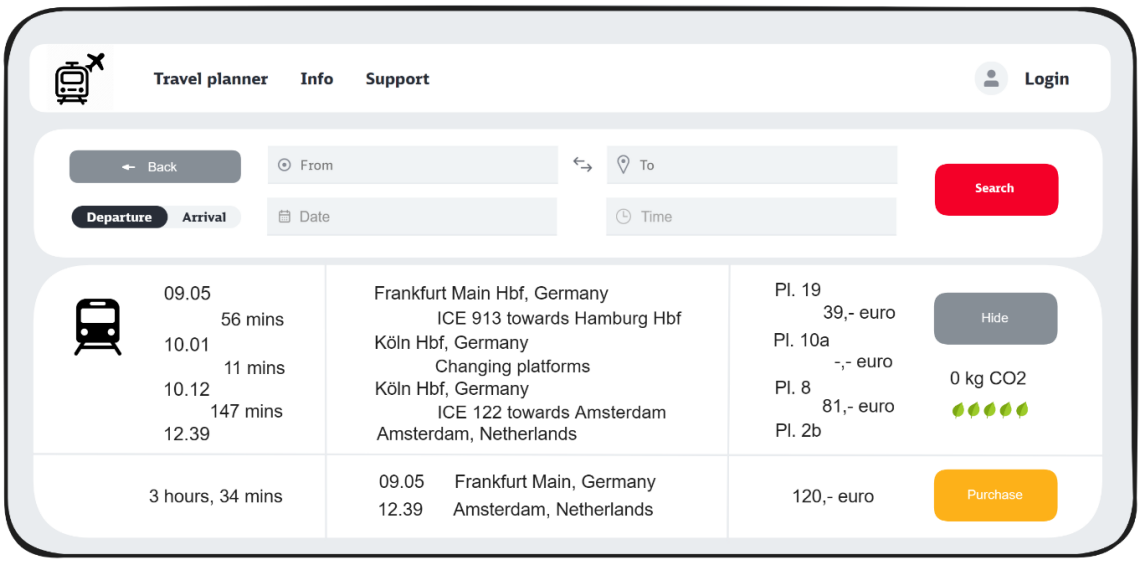


Figure 26: The design of the outcome layer

The information provided by the outcome layer (see figure 26) should give the user enough information to execute the journey and travel from a to b with the selected mode of transport. This includes showing platforms, station names, departure times, transfers etc. Also broken down price and travel time for each leg of the journey is shown. In that way the user can transparently see how the total price and travel time is being determined. Besides that, the outcome layer gives the user the option to purchase a ticket for this journey. This often means purchasing the ticket on the external website of the corresponding airline or railway operator. By pressing the purchase button, the user will automatically get redirected to this website to purchase the ticket there. This functionality was chosen, because it is simply not possible to get access to the ticketing system of the carries as an external party. Therefore, buying the tickets has to be done externally.

Altogether, the functional and design specification provided a clear detailed description of the looks and feel of the persuasive multimodal travel planner. A clear vision has been determined on the information the system should provide at each step in the process of planning a journey. This was achieved by translating the (non-)functional requirements into a final design. However, before such a system can fully be realised it is important to also take a closer look at the systems architecture including a detailed analysis on where which information will come from exactly. This is where the next “Systems architecture” section will dive into.

8. Realisation

With the deeper understanding about the final travel planner design, its functionalities, the system architecture, potential users and the context of use, it is now time to make persuasive multimodal travel planner reality. Therefore this chapter will dive into the realisation of such a platform and how it could be built. After describing the building process of the travel planner its design and functionality will be evaluated.

The building process

To realise the described travel planner design and functionalities of the previous chapter, an online environment had to be set up. The online environment was initially hosted on InfinityFree, a free PHP website hosting service [60]. However, due to the limited amount of PHP requests that could be made with this free plan, the website was later migrated to the paid iFastNed alternative which allowed unlimited PHP resources [61]. Once this online environment was set up, the travel planner could be programmed. The main programming languages used for the travel planner prototype are PHP, HTML, CSS and JSON.

The first step in realising the travel planner was building the data input layer (the homepage). This homepage should follow the design of figure 24 and therefore facilitate user input and process this accordingly. First of all the front-end of this page was built by using both HTML and CSS. This included the navigation bar at the top, the input field at the bottom and the background image. Once this was finished, it was time to work on the back-end of this page by using PHP. The back-end of this page should fetch the user's input data from the form, process it correctly and send it to the comparison layer. Eventually this resulted in the homepage of figure 27 below.

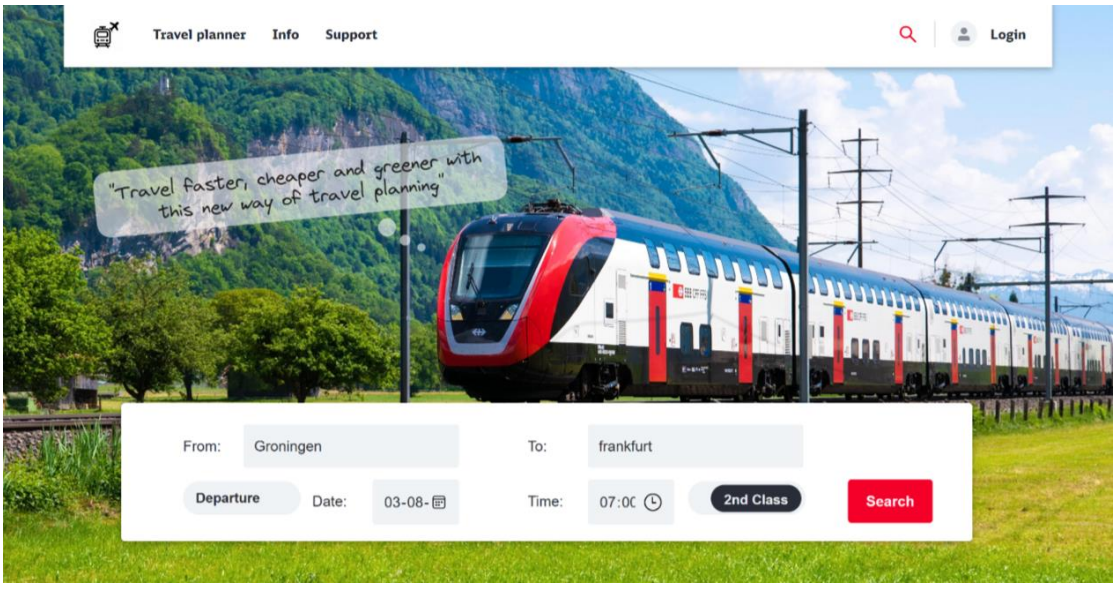


Figure 27: The realisation of the data input layer [63]

The second step in realising the travel planner was building the comparison layer (the travel mode comparison page). This homepage should follow the design of figure 25 and display the right data based on the user's input from the previous layer. This was realised by reusing the navigation bar from the previous layer and moving the same input field upwards. By doing this, extra space was created to display the travel mode comparison. The train and flight journey were placed below this navigation bar.

One of the most time consuming elements to realise, was displaying the total price, travel time and emissions for the journeys inputted by the user. PHP code was used to request data from the external API servers (see figure 23c) which returned JSON code. This JSON code then had to be decoded in order to fetch the journey details for each mode of transport. Besides that, quite some calculations were necessary to get to an accurate total price, travel time and emissions. Especially for flights this was a challenge since the public transport journey of getting from and to the airport had to be combined with the flight itself. Therefore data had to be merged to come to a total journey. Eventually, this resulted in the comparison page of figure 28 below.

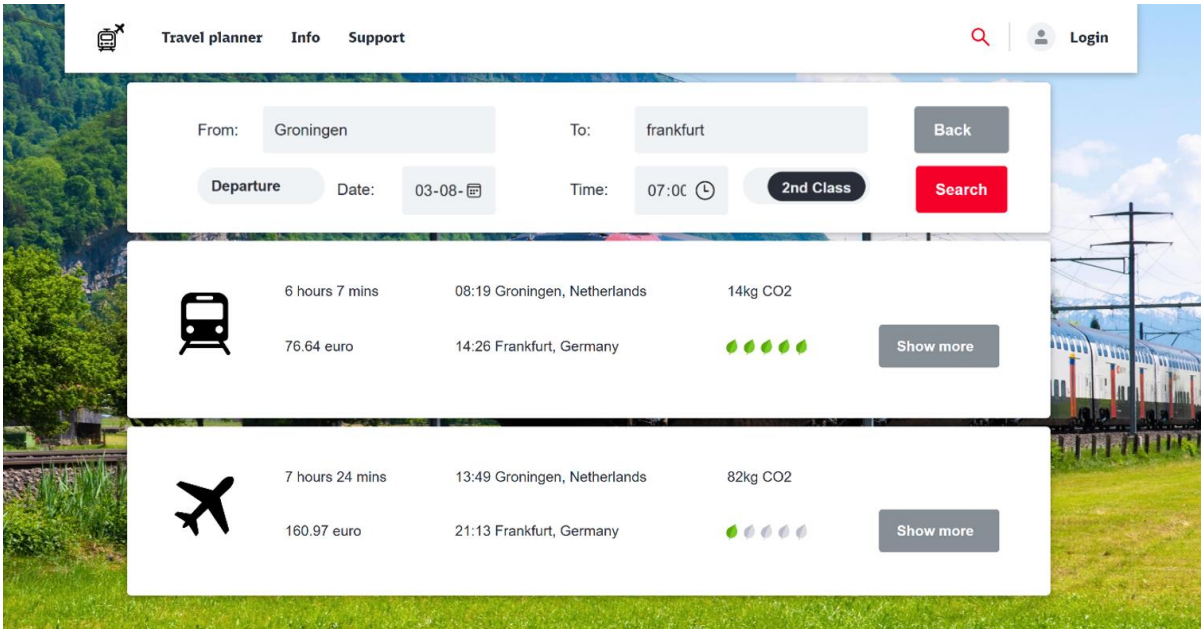


Figure 28: The realisation of the comparison layer [63]

The third and last step in realising the travel planner was building the outcome layer. This homepage should follow the design of figure 26 and therefore display detailed information on the selected mode of transport from the previous layer. The same navigation bar and input field from the input layer was used in the comparison layer. One of the train/flight boxes from the comparison layer also remained present. This box was expanded to display the detailed journey data fetched in the previous layer. Getting this data in a clear layout was the most challenging to achieve. Especially since this layout had to be dynamic dependent on the number of transfers of a journey and the user screen size. Altogether this resulted in the two outcome pages of figure 29a and 29b below. The website URL and code for each layer can be found in Appendix 4.

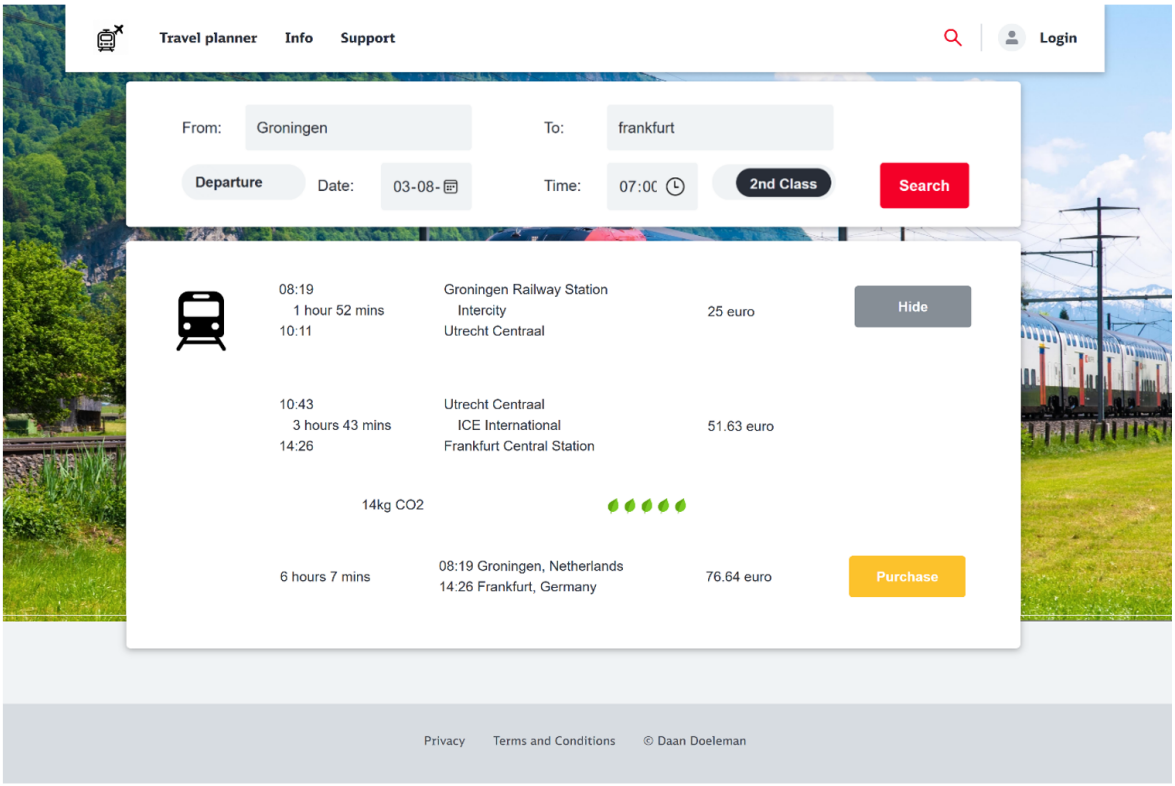


Figure 29a: The realisation of the outcome layer (train decision) [63]

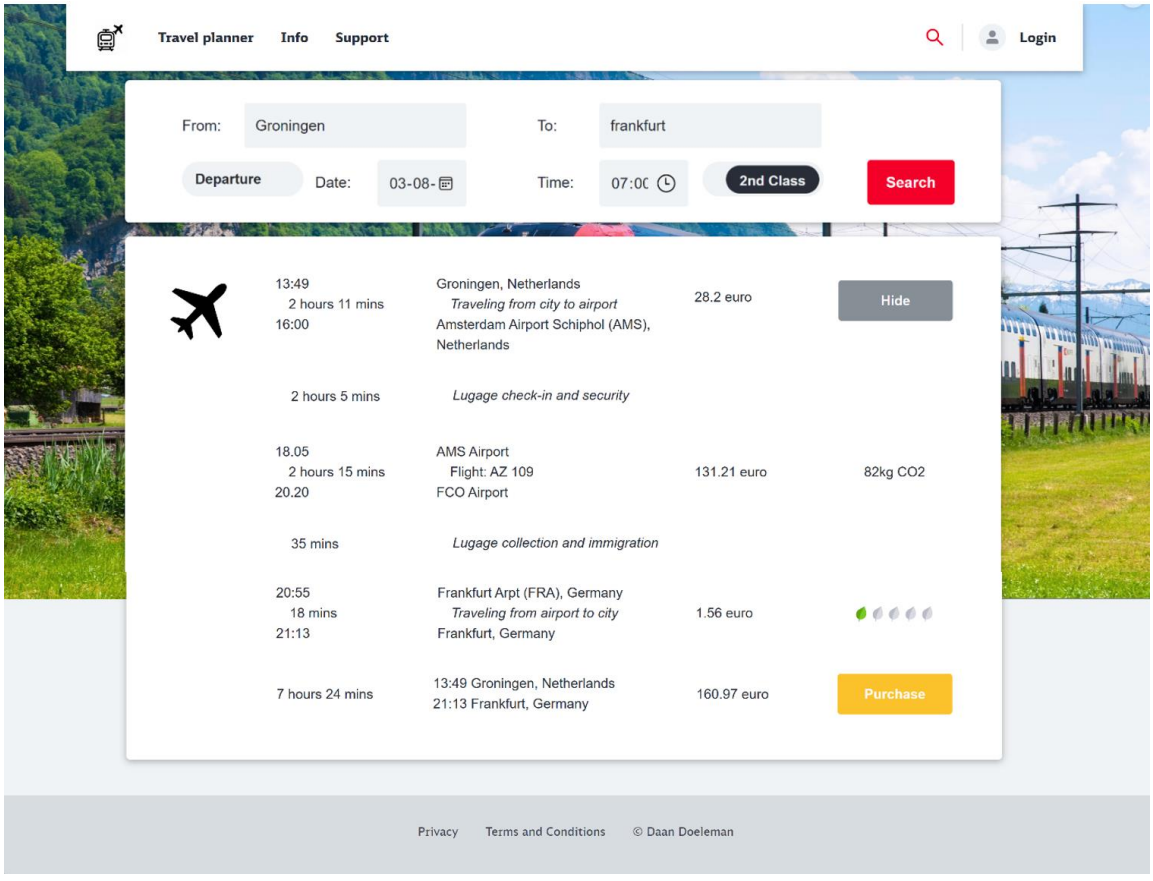


Figure 29b: The realisation of the outcome layer (flight decision) [63]

Functional evaluation

Since the first prototype of the travel planner has now been realised, it is time to evaluate whether the functional and non-functional requirements of the previous chapter have been met. To analyse that, the full list of requirements in combination with to what extend they have been implemented has been put in figure 30 and 31 below.

Category	Requirement	Implemented?
Must have	NF1: Passengers must be informed about the win-win situation associated with taking the train instead of the plane.	Yes*
	NF2: The design should facilitate a clear overview of both travel time as well as ticket price.	Yes*
	NF3: The platform's design must visualise additional information such as total and broken down price, total and broken down travel time, total emissions.	Yes
Should have	NF4: The information shown should appear in a natural and logical order, similar to the currently existing travel planners. All in all, the platform's UI elements should follow the platform convention and general process of journey planning.	Yes*
	NF5: The travel platform should provide sufficient information to make a good comparison, but on the other hand the user must also not be overloaded with too much information.	Yes*
Could have	NF6: The platform's design could incorporate train capacity/availability and show if tickets are available or not.	No
	NF7: The platform's design could visualise long distance coaches and the total travel time, emissions and price for it.	No
Won't have	NF8: The platform will not show any car only journeys.	Yes

Figure 30: The evaluation of non-functional requirements

** = To draw a final conclusion on whether the highlighted requirements have successfully been implemented, they will be evaluated in more detail during next chapter's evaluation phase.*

When looking at the non-functional evaluation of figure 30 it can be seen that all must have, should have and won't have requirements have at first glance successfully been implemented in the travel planner design. Unfortunately the could have requirements were not realised within the given time. This is mainly because of the complexity of these requirements in combination with their lower priority as compared to the other requirements.

Category	Requirement	Implemented?
Must have	F1: The user must be able to provide the following input: departure city, destination city, departure or arrival time, date of travel.	Yes
	F2: The platform must make an objective price and travel time comparison between air and rail which is unbiased towards any mode of transport.	Yes
Should have	F3: The platform should provide clear user feedback to validate the provided input. This includes for example correcting for misspelled city names or wrong date and time input.	Partly
	F4: The travel platform should make use of real time data if possible. For example live information should be shown on train delays, travel platforms etc.	No
	F5: It should be possible to incorporate multimodal car + train/plane combinations for some legs of the journey if they are very fast.	No
Could have	F6: The platform could incorporate data crowdsourcing to provide even more accurate and up to date data.	No
	F7: The platform could provide a personalised experience by taking individual travel behaviour into account and store things such as frequently visited locations and other travel patterns.	No
Won't have	F8: The user will not select a mode of transport beforehand. The platform should output any mode of transport (in this case both air and rail options).	Yes
	F9: The platform will not make people change trains for only +/- 5 minutes of time gain. Fewer transfers should be preferred over insignificant time gain.	Yes
	F10: The platform will not exclude night trains even though they might be significantly slower.	Yes

Figure 31: The evaluation of functional requirements

The evaluation of the functional requirements of figure 31 shows that all must have and won't have requirements have successfully been realised in the travel planner. It can also be seen that the should have and could have requirements haven't all been implemented. Requirement F3 was partly implemented, because all input except the location input was validated through the travel planner design. The other should and could have requirements were not implemented within the given time, because of the lower priority of these requirements in combination with the limited scope of the travel planner prototype.

However the realisation of the travel planner can still be considered as a success. This is because the main idea of the prototype was to implement the basic most important (must have and won't have) requirements and that goal has successfully been fulfilled.

Suggested future improvements

Still, the travel planner's design and functionality is not perfect, so several future points of improvements can be described to further improve the travel planner. It would for example be interesting to take a look at how to incorporate train capacity/availability and show if tickets are available or not. Next to that, future designs could add long distance coaches and cars as transport options. If the total travel time, emissions and price are also shown for these modes of transport, a comparison on all available modes can be made. This would make the travel planner attractive for an even broader audience. Also combining different transport modes might be a very relevant addition to my travel planner. By also showing multimodal journey options, even more useful travel options might be displayed.

Additionally, the use of real time data, including live information on train delays and travel platforms, would make the travel planner more accurate with the real life journeys. This would be a very important future functionality to implement as well. Crowdsourcing could also play a role in this. This means that users can input relevant data to the travel planner on for example crowdedness of a train. It is expected that this will better inform passengers because of the more accurate and up to date data.

On of the most important functionalities which should be implemented in the future is the option to purchase tickets within my platform. This is a last crucial step in the process of planning a journey. Future versions of my travel planner can work on the realisation of ticketing mechanisms for each transport mode. Also the realisation of a more personalised experience is interesting to look into in the future. This can be achieved by for example taking individual travel behaviour into account and store things such as frequently visited locations and other travel patterns.

Altogether, the realisation of these suggestions for future improvements will ensure that all Should have and Could have requirements are achieved as well. This would be a very nice addition to the currently realised Must have and Won't have requirements.

9. Evaluation

The final phase of the CreaTe design process the evaluation phase. During this phase the platform made during the realization will be evaluated with users. This evaluation is done to assess whether the non-functional requirements specified during the specification phase have been fulfilled. The evaluation was executed with both physical as well as online participating users.

In total 12 individual users and one focus group consisting of 4 people participated in the user testing. The 12 individual users were mainly students from the University of Twente as well as friends and family members. The focus group consisted of 4 experts from the client, the European Union Agency for Railways. Both the focus group and individual participants followed the evaluation procedure described in Chapter 5. The raw data from both the surveys, observations as well as the interviews can be found in Appendix 5. This appendix namely contains all three types of overviews as they have been described in Chapter 5. The summarised results following from these three overviews will be described below.

Demographics

Each participant was requested to fill in a short survey with some demographic questions. The results from this survey are described below:

- The age of the participants ranged from 18 till 56 with an average age of 30 years;
- 12 out of the 16 participants were male and 4 were female;
- 11 out of the 16 participants were student, 1 was entrepreneur and 4 were employers;
- A vast majority of the participants travelled with their family, in total 9 out of 16 did this. 5 out of 16 participants travelled mainly with friends. The remaining 2 out of 16 participants travelled most of the times on their own.
- 10 out of 16 participants categorised themselves in the low income category. 1 out of 16 did not have any income and the remaining 5 participants categorised themselves in the high income category.
- 11 out of 16 participants travelled mainly for leisure while the remaining 5 participants travelled for business the most frequently.

Since we now got a bit of an understanding about the demographic characteristics of the participants, it is time to take a closer look at whether there is a correlation between their travel mode decision making and factors such as gender, income and type of travel. The background research of Chapter 4 namely indicated the following:

- Males usually prefer to travel by train, while women usually prefer to fly [14][17].
- When people travel in groups, they are more likely to take the train [14];
- People with a higher income usually have a stronger preference for flying [14];
- People with a lower income usually prefer travelling by train [14][17];
- Business travellers are less driven by price as compared to leisure travellers [14];
- Business travellers usually travel alone while leisure travellers travel more in groups [14];

The survey conducted with the 12 individual participants indicated that a correlation exists between gender and whether people prefer to fly or take the train. 3 out of 4 female participants namely preferred taking the train over flying while for males this was 7 out of 8. Even though the difference is small it seems to be in line with the suggestion by literature that males usually prefer to travel by train, while women usually prefer to fly.

It was also seen that all participants who preferred flying did travel in groups while the 2 out of 10 participants who preferred taking the train did usually travel alone. In this case the survey findings seem to be in contradiction with the statement made by literature. Literature namely states that people are more likely to take the train, when they travel in groups.

When looking at leisure travellers it was seen that 9 out of 11 leisure travellers usually travel in groups. This is in line with the statement made by literature that leisure travellers travel more in groups. Secondly, 7 out of 11 leisure travellers mentioned travel time as one of the most important decision making factors, followed by ticket price, which was indicated by 6 out of 11 leisure travellers as an important factor in their transport mode decision making. This is in line with the earlier made statement by literature that price and travel time are one of the most important decision making factors for (leisure) passengers.

Besides that, it was also seen that people with a lower income tend to travel by train most of the times. 9 out of 11 participants with a lower income preferred taking the train over flying. This is in line with the statement made by literature that people with a lower income usually prefer travelling by train.

Regarding high income it is difficult to draw a well-supported conclusion. This is because only one participant categorised themselves in the high income category. Therefore the sample can be considered too small to draw a conclusion on the correlation between a higher income and a preference for flying. The same counts for the number of business travellers. Since there was only one business traveller present in the sample, no conclusion can be drawn on whether business travellers are less driven by price and whether they travel alone more often.

System Usability Scale

The survey also included questions about the System Usability Scale (SUS). This is a list of 10 questions assessing the usability of your system. The outcome of this survey is a score on a scale from 0 to 100. In my case the average SUS of all 12 participants was 86.25. This means that my system scored well above the average SUS of 68 [62]. Indicating that my system has a good overall usability.

To further asses the usability in more detail figure 32 of chapter 5 will be used. Since my system's SUS of 86 falls within the 80.3-100 range, it can be concluded that my system has an excellent usability and is well above average in terms of usability (see figure 32). This indicates that the system is highly usable and users generally have a positive experience. According to SUS benchmarking studies, a score of 86 would likely place the system in the top 10-15% in terms of usability compared to other systems in the same domain [62]. It is therefore likely that users consider the system to be intuitive and efficient, with minimal issues. Even though a score of 86 is excellent it does not mean that my system is perfect. Ongoing user feedback and usability testing can still help identify areas for further refinement to achieve even higher usability score. These future points of improvement will be further looked into in the next section.

Suggested improvements in design and functionality

As was also indicated by the System Usability Score, my system has a good usability but is not fully perfect. This was also seen during both the 12 individual interviews as well as the focus group with 4 participants. The results of each distinct interview group will be elaborated below.

Individual interviews

The first round of interviews highlighted that most of the participants were positive about the travel planner. 5 out of 6 participants mentioned that the travel planner was intuitive to use and had a recognisable design which was familiar to them. It can therefore be concluded that the fourth non-functional requirement (NF4) was successfully implemented in the travel planner design. This requirement namely states that the information shown should appear in a natural and logical order, similar to the currently existing travel planners. And that the platform's UI elements should follow the platform convention and general process of journey planning. Only one user mentioned that the design was new: "This travel planner is unique, something I haven't seen before." But this person can be considered as an outlier in the sample.

Additionally, 5 out of the 6 users made positive remarks about the travel planner's design and layout. 3 out of 6 users also said that the travel planner was very easy to use for them, especially because everything was in one central space. One user also mentioned that the travel platform has the right balance between simplicity and detailed journey information. Since none of the users felt overloaded by the information of the system it can be concluded that also the fifth non-functional requirement (NF5) was successfully implemented. This requirement namely stated that the travel platform should provide sufficient information to make a good comparison, but on the other hand also not overload the user with too much information.

However, besides many positive remarks, there were also plenty of points of improvements mentioned during the interview. One user for example suggested to rather put the flight and train outcome pages next to each other so that a good comparison can be made on the detailed journeys. "The journey details are now only accessible via two separate pages.", the user mentioned. One user was also confused about the scope of the travel planner, especially for which country it was. This user was namely used to using different national travel planners, but according to him it was not clear that this travel planner is for European wide journeys and not for one specific country only.

Besides that, that it became clear that there was a vast majority of participants mentioning the same two points of improvements. Firstly, the better separation between the journey details and summed up travel time, price and emissions of the outcome layer was mentioned as a point of improvement. Many users thought that the trip summary was part of the journey and did not really saw a clear distinction. Secondly, several users mentioned that the date and time box should be enlarged so that the date and time is more clearly readable. With the current version of the system the year and last number of the time are not very clearly visible (see figure 27).

Since these two points of improvements were mentioned by so many users, it has been decided to make some improvements on the travel planner halfway through the sample. This is a so called iteration on the initial design of figure 27, 28 and 29. This means that the participants of the second round of interviews were presented with a slightly different travel planner design which incorporated an improved input field as well as a more clear separation of the journey details and its summary. The slightly adjusted travel planner design can be seen in figure 32 and 33 below.

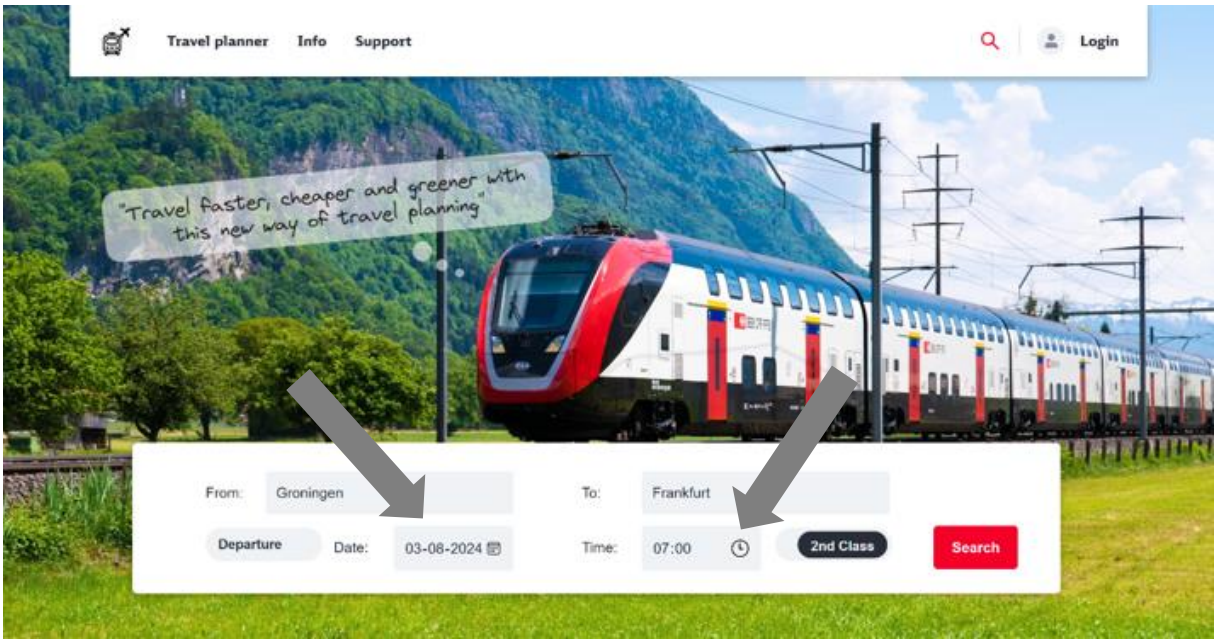
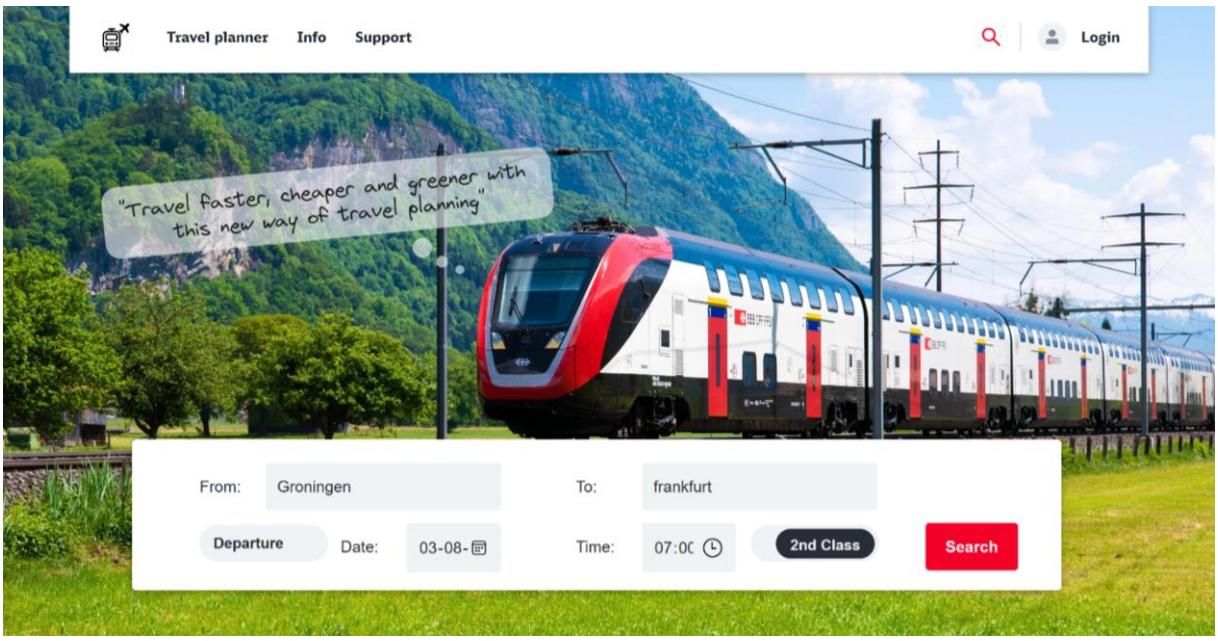


Figure 32: The improved input layer design (grey arrows highlight the changes made to the system) [63]



Copy of figure 27: The old input layer design

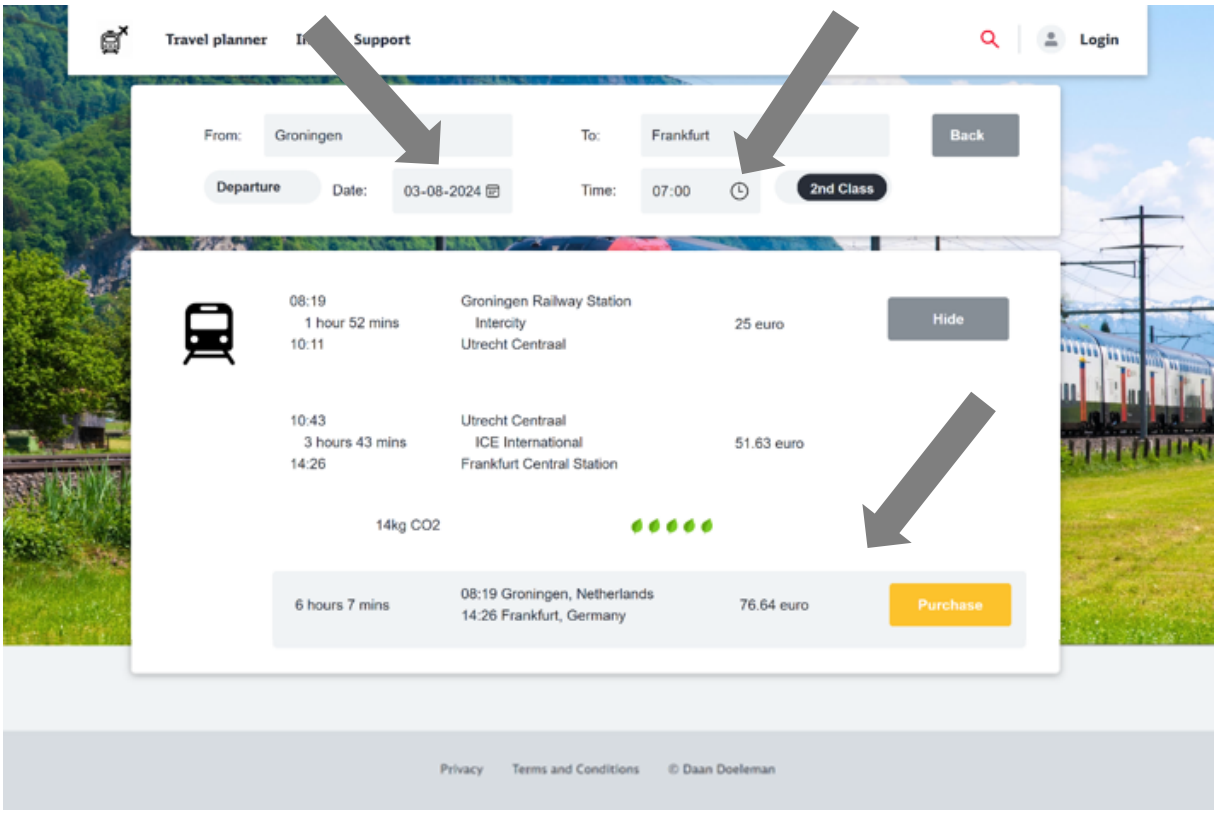
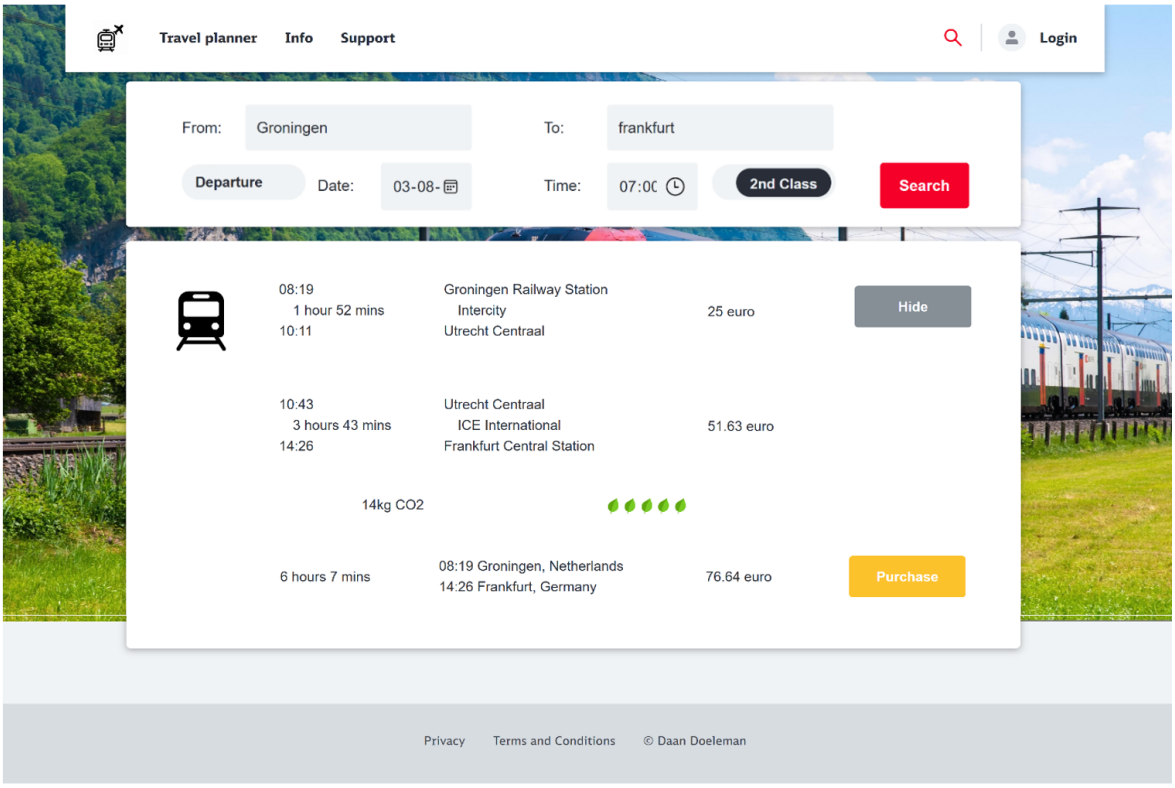


Figure 33: The improved outcome layer design (grey arrows highlight the changes made to the system) [63]



Copy of figure 29a: The old outcome layer design (train decision)

Even though the second half of the users faced the improved travel planner design, they still mentioned several additional points of improvements. By far the most mentioned feedback point was the design of the 1st/2nd Class and Departure/Arrival switch. It was mentioned by 9 out of 12 participants that this switching functionality could be made more clear. Many users did not find it very clear that these two elements could be switched. Therefore it was suggested by several users that both of the options of the switch should be displayed instead of just displaying one. For example displaying both departure and arrival next to each other with one of the two being highlighted might make this functionality more clear.

Besides that, 5 out of 6 users in the second group suggested to validate the location input the user provides. They mentioned that it would be useful for them to get suggestions when inputting the locations, so that they can pick out one of the suggested train station for example. “In that way we know for sure that what we input is correct, right now we don’t know that.”, a user mentioned. One user also said that this would help him/her with typing the input, because she usually makes a lot of spelling mistakes.

Another frequently mentioned point of improvement is related to train transfers. 4 out of 6 participants mentioned that they would like to see the number of transfers and their duration displayed in the overview. Quite some users namely found the number of transfers quite relevant for they transport mode decision making. It would therefore be interesting to incorporate this as well. Additionally, 4 out of 6 users wanted to see more details on the exact meaning of one leaf. They were wondering how the emissions were converted into the amount of leaves. The following solution was suggested by one of the users: “It would be interesting to create a tooltip which displays the emissions per leaf when the user hovers over the leaves.” This could be an interesting additional functionality which makes the travel planner even more transparent about the data it shows and how it is being visualised.

Next to that, 4 out of 6 users made the suggestion to play around with different fonts, colours or blocks to organise the journey details of the outcome layer even better. The user did not say that it was confusing for them now, but they said that it could be done more clear and better organised. With the current version of the prototype they had to look at it for a few seconds to understand the full journey. Another point mentioned by 3 out of 6 users was to make clear that the journeys from and to the airport are now scheduled by public transport. For these journeys it was not mentioned which specific mode of transport was used. That is a good suggestion to improve in the next version.

Also, two users made the suggestion to incorporate bus and car journeys in the travel planner. “It would be interesting to see how all these modes of transport compare to each other and what the overall best mode of transport is to take.”, a user mentioned. On top of that, two users suggested to use visualisations of the journey on maps, to make the progress of the journey more clear. This might make more clear to users where the transfers will take place and how the journeys are different for each mode of transport. Next to that, the suggestion was made by two users to implement a loading icon when the system is searching for routes. Some users were namely confused if the system was still working or if it broke down since nothing happened.

One last interesting comment made by one of the users is to highlight the better option more clearly for each individual comparison variable. This user suggested to change the colour of the text of the three variables (travel time, price and emissions) to either green or red dependent on whether this variable is higher or lower as compared to the other mode of transport. In that way the faster, cheaper and more sustainable transport mode are clearly highlighted by the green coloured text. This could make the travel mode comparison even more clear and potentially the time needed for the user's travel mode decision making.

Next to these more frequently occurring points of feedback, there were also several suggestions made by users which were only mentioned by one user. A brief summary of these suggested points of improvements according to individual users can be seen below:

- Display platform numbers as well;
- Add a search functionality on the outcome layer;
- Expand the show more page on the same page instead of going to separate page;
- Make clear that both trains and flights are compared. I only expected trains in the travel planner;
- Display more than one train/flight offer;
- Set the default date and time to the current date and time;
- Put emissions and leaves closer to each other so that it is clear that they relate to each other;
- Group the input form better, make space between from and to smaller and larger between from and date;
- Create a time window for departure/arrival instead of one single moment;
- Translate the travel planner into different languages;
- Set the input form standard to second class instead of first class;
- User euro signs instead of just the text "euro'.

However, it is important to notice that many users also came up with many positive remarks about the travel planner prototype. A majority of the users namely mentioned that the leaves visualisation and with that the sustainability aspect clearly caught their eye when first seeing the travel planner. The said that this makes them extra aware of the climate impact related to each mode of transport. Secondly, 7 out of 12 users mentioned during the interview that this travel planner facilitates a very clear and fast comparison between travel modes. On often hear quote by many user was: "I can see in one glance what the best mode of transport is to take." It can therefore be concluded that the second non-functional requirement (NF2) was successfully implemented. This requirement namely stated that the design should facilitate a clear overview of both travel time as well as ticket price.

Focus group

Next to that, the focus group user test with the client identified several additional points of improvements regarding design and functionality. The multimodal travel planner has received generally positive feedback during the focus group for among others its ability to provide an unbiased comparison on price, travel time, and emissions for different modes of transport.

One of the key areas for improvement mentioned during the focus group is the need to expand the number of travel options compared. Currently, the planner primarily focuses on a single offer per mode of transport, which may not provide a comprehensive view of all available options. The participants of the focus group suggested to include multiple offers to ensure a more robust comparison. It is expected that this will help users make better-informed decisions by allowing them to see a broader range of options. A user can then select the most suitable combination of prices, travel times, and emission fitting with their personal preferences.

Additionally, the option of incorporating long distance coaches and car journeys, including necessary breaks for longer car trips, can offer users a more extensive range of travel modes to consider. Moreover, the integration of the last mile of the journey, including options to take a car, bicycle, or taxi to and from airports or train stations, was mentioned as a potential point of improvement. Incorporating these additional modes of transport could potentially enlarge the overall target group and climate impact of the travel planner.

The participants also emphasized the importance of providing detailed information for switching between modes of transport. For instance, showing a map that helps users navigate from a train platform to the airport gate or vice versa can significantly enhance the usability of the travel planner. Additionally, providing real-time train platform information could contribute to this goal.

Another noteworthy suggestion was the incorporation of journey visualization on a map. Visual representations of travel routes by air and rail can greatly aid users in understanding their journey, making it easier to visualize the travel time and changes involved. Additionally, breaking down the total travel time into segments, such as time spent on the train versus waiting time, can give users a clearer understanding of the journey dynamics and help them understand their travel time better.

Lastly, an important suggestion on the environmental impact visualisations was made. The participants recommended to normalize the values used to compare rail and flight emissions. The current model, which uses fixed steps of 20kg to display more grey or green leaves, might not be suitable for longer distances. Long distance train journeys might namely have high absolute emissions and therefore only get a limited amount of green leaves. While the relative train emissions of trains (compared to flights) might still be significantly lower. Therefore it is suggested to take a more dynamic approach in in which the number of grey and green leaves are displayed dependent on the relative emissions of the train and flight journeys.

Platform's influence on passenger's decision making

Since we now analysed the results of both the individual interviews as well as the focus group interview, it is time to start analysing the influence of my travel planner on the decision making process of passengers. Will more passengers take the train because of my travel planner? That is the question this section will try to answer. The decision making process of passengers was investigated by using a thinking aloud procedure in combination with a user test in which users had to execute three different tasks. Each task involved a different journey to plan in me travel planner (see Chapter 5). By using a thinking aloud procedure it was possible to get an understanding of the decision making process of each user after they executed the tasks and analysed the different travel options.

Overall it was seen through all tasks that users were very surprised about the total duration of the flight journeys. This was much longer than people would initially expect, making the flights journeys less attractive for many users. Also the visualisation of the amount of emissions directly caught many user's eyes. In total 4 out of 12 participants mentioned that this was the first thing they looked at when seeing the comparison between transport modes.

For the first task it was seen that all users decided to take the train instead of flying for this journey. This was mainly because the train offer was both faster, cheaper and more sustainably. For the second tasks (similar price and travel time) there were two users who still preferred to fly. This was because of the number of transfers they had to take for the train journey. They were afraid of missing a connection and then travelling much longer than initially anticipated. However still a fast majority of the participants (10 out of 12) still decided to take the train instead of flying and did not bother about the amount of transport associated with the rail journey. It is also important to notice that an often heard quote during the first two tasks was "Why should I even consider flying?". Highlighting that users were strongly encouraged to take the train because of my travel planner.

During the third tasks (train a bit cheaper but much longer travel time) most of the users (9 out of 12) did prefer flying over the train. Three users were willing to take the train instead of flying. This was mainly because of sustainability reasons as well as comfort. The other users all preferred flying because of the significantly lower travel time and similar price. On top of that, the large number of transfers associated with taking the train scared of many users.

All in all, it can be concluded that my travel planner successfully persuaded passengers to take the train instead of flying. This is because for 2 out of 3 tasks people preferred taking the train over flying. In general it was seen that if taking the train is faster, cheaper and more sustainable, it is a no brainer for almost all participants to just take the train. If all factors similar, then the number of transfers started to play a role for some users, but overall taking the train was considered to be more attractive. And if taking the train is similar in price, but significantly slower (and usually also more transfers), then most people tend to fly. Since for most of the journeys planned in my travel planner passengers were convinced that taking the train was the best option, it can be concluded that the last non-functional requirement (NF1) was successfully

implemented as well. This requirement namely states that passengers must be informed about the win-win situation associated with taking the train instead of the plane.

However a side note has to be made on the analysed decision making process of the participants. This is because several users mentioned that their preference for the mode of transport was also dependent on additional factors such as the purpose of journey (is it a shorter or longer visit) and the people accompanying them. Therefore the outcome of their preferred mode of transport might change dependent on the context of their journey. In order to get more accurate results, it is suggested that future research takes this into account as well.

Since we now walked through all four phases of the CreaTe design process, it is time to formulate the final conclusion based on the results of each distinct phase. The next and also second to last chapter of this report will describe the detailed the conclusion we can draw based on this. The conclusion chapter will try to describe the final answer to our main research question.

10. Conclusion

First of all, it can be concluded that price and travel time are for passengers the most important factors in deciding which mode of transport to travel with. Even though, many other factors have their influence as well, price and travel time were found to be the most reoccurring in both literature as well as the small user study conducted as a part of this research project. Next to that, it was found that the reciprocity and unity principle are one of the most important principles which can contribute to a change in travel behaviour of passengers. Unity in this case relates to the pressure from a specific group or society, while the reciprocity principle relates to the realisation of a persuasive win-win situation. Especially the reciprocity principle was found to be relevant for this research project. All in all, the combination of the important decision making factors (price and time) with the key principle which can contribute to a change in travel behaviour (creating a win-win situation), has successfully been applied throughout the entire development process of this Graduation Project's travel planner.

After having gone through the entire Creative Technology design process, a clear answer has been found to the main research question of this Graduation Project:

How to develop an online platform that persuades passengers to take the train instead of short haul flights by informing them about the different modes of transport (including price, climate impact and travel time)?

The conducted user test indicated the possibility of developing a behaviour changing win-win situation. It was namely seen that a majority of the participants preferred to take the train when this was shown as a faster, cheaper and more sustainable option. Additionally, a majority of the participants said to be more likely to take the train instead of the plane when using my travel platform. Overall it can be concluded that by providing an accurate comparison on total city to city travel time, price and emissions the suggested platform design was able to successfully persuade passengers to take the train instead of flying. Especially the incorporation of the total time needed for check-in, immigration, security and getting from/to the right gate, made the train offers in my travel planner much more attractive as compared to the offers shown in other travel planners.

After finalizing the development of the suggested travel platform prototype, this platform is very likely going to fill up the currently existing gab in the travel planner market. This is mainly because no unbiased multimodal air-rail platform currently exists, even though the importance of such a platform was clearly indicated. Train travel should namely be encouraged, since it was found to be more sustainable, more comfortable and profitable than short haul flights, and therefore beneficial for both the climate, passengers and the economy.

11. Discussion and Future Work

Even though a clear conclusion could be drawn from this GP and most evaluation findings were in line with literature, not all research findings were aligning with the statements made by literature. It was for example seen that most of the participants who preferred flying did travel in groups while literature suggests the opposite. Literature namely states that people are more likely to take the train, when they travel in groups. This difference in outcome could be explained by the relatively small sample of two participants who preferred flying.

Next to that, it was found during the user testing that a majority of the participants did state that they were more likely to take the train instead of plane because of this new way of travel planning. However, this user test did not include a comparative study which compares current travel planners with the suggested travel planner design of this GP. In order to draw a stronger conclusion on the successfulness of my travel planner, it is suggested that a group of users will plan certain journeys in for example Google Maps and another group of users plan the same journeys in my travel planner. The results of both travel planners can then be compared, which could lead to a better supported conclusion on whether my travel planner successfully persuades short haul flights passengers to take the train.

In general, the limited sample of 12 users who participated in the user test was found to be a limiting factor in this research project. In order to draw better supported conclusions from the user test, it is important that the sample size is increased. Another issue was the limited amount of high income business travellers participating in the user test. Since only one high income business traveller participated, it was difficult to draw a well-supported conclusion on the correlation between a high income and a preference for flying. The same counts for the number of business travellers. Since there was only one business traveller present in the sample, no conclusion can be drawn on whether business travellers are less driven by price and whether they travel alone more often.

A similar issue arises when looking at the participants age, occupation, nationality and gender. There were only 4 females compared to 8 males present in the sample. Also only one participant had an age above 23 years and a different occupation then student. On top of that, only a limited number of nationalities were present in the sample, causing a potential cultural bias in the data. It is therefore suggested that future research tries to increase the sample size and tries to get a more equal distribution between males/females, low/high income, youth/adults and occupation. This is very likely going to give more accurate and better supported findings.

Secondly, time was also found to be a limitation in this GP, especially during the realisation phase. As a result, not all functional and non-functional requirements could be implemented within the given theme. Therefore it was decided to make a selection and only implement the most important Must have and Won’t have requirements. In order to make the functionalities of the travel planner even better, it is suggested that

the Could have and Should have requirements will be implemented as well. This could give the users an even better impression of the overall functionalities of the proposed multimodal travel planner design. One of the most important functionalities which were not implemented is the combination of long distance trains with long haul flights. Most of the short haul flights are namely used by transferring passengers. Therefore it is important that my travel planner clearly displays these multimodal combinations.

Thirdly, another limitation of this GP might be that there is a small bias present in the research. Even though during the entire process of this GP all efforts have been made to be as unbiased as possible, without preferring any mode of transport, it is not inconceivable that the research outcome might differ slightly if executed by another researcher. Especially during the interpretation of the interview results and while doing observations it is possible that a small bias was introduced to the data. But also within the sample itself a bias might be introduced. This is mainly because there were relatives of the researcher present in the sample. Even though participants were asked to be honest and objective, their opinion might still be slightly biased. For future research it is therefore suggested that the same research procedure will be repeated several times by other researchers so that objectivity can be ensured.

Fourthly, there might also be a small human error present, especially in the evaluation phase of this GP. Since all observations and interviews were executed and processed by humans it is expected that small mistakes might be made. This could for example include missing some important observations while taking notes during the user testing. For future research it is suggested that either the user testing is recorded or that more than one researcher is present during the observations.

Fifthly, the usage of external API servers was considered as a limitation during the realisation phase of this GP. This issue relates to the fact that my travel planner relies on the external data provided by these servers. These external servers might not always provide accurate responses which could lead to inaccurate journey data in my travel planner. Besides that, there were only a limited number of APIs available which made it difficult to display all the desired variables in my travel planner. This was mainly because for some of the variables such as train prices, no external API was available which provides European wide train offers. Highlighting another limitation of this GP.

Lastly, a potential limitation of this research project is the use of the System Usability Score. It can be argued weather this score is the most accurate in this specific context. Especially, since the researcher was present while this survey was filled in. This could therefore result in a potential bias in the data. It is therefore suggested that this survey will be filled in without the presence of the researcher in the future. Besides that, the exact interpretation of the System Usability Score in this specific context might be tricky. The interpretation of the System Usability Score is namely to a large extend based on the hard categorisation of figure 32. A score of 80.4 is for example considered excellent while a score of 80.3 is considered good. It can be argued whether such an interpretation is very accurate and reliable.

Although the effect of the mentioned limitations is expected to be very limited and probably even insignificant for the overall research outcome, it is important to take them in consideration and potentially tackle them during future research.

12. References

1. *H. B. Review, N. Morgan, R. B. Cialdini, L. A. Hill, and N. Duarte, Influence and Persuasion (HBR Emotional Intelligence Series). Harvard Business Press, 2017.*

2. *T. M. Nikolić, S. P. Pantić, I. Paunović, and S. Filipović, "Sustainable Travel Decision-Making of Europeans: Insights from a Household Survey," Sustainability, vol. 13, no. 4, p. 1960, Feb. 2021, doi: https://doi.org/10.3390/su13041960.*

3. *F. Dobruszkes, C. Dehon, and M. Givoni, "Does European high-speed rail affect the current level of air services? An EU-wide analysis," Transportation Research Part A: Policy and Practice, vol. 69, pp. 461–475, Nov. 2014, doi: https://doi.org/10.1016/j.tra.2014.09.004.*

4. *D. Albalate, G. Bel, and X. Fageda, "Competition and cooperation between high-speed rail and air transportation services in Europe," Journal of Transport Geography, vol. 42, pp. 166–174, Jan. 2015, doi: https://doi.org/10.1016/j.jtrangeo.2014.07.003.*

5. *N. Adler, C. Nash, and E. Pels, "High-speed rail and air transport competition: Game engineering as tool for cost-benefit analysis," Transportation Research Part B: Methodological, vol. 44, no. 7, pp. 812–833, Aug. 2010, doi: https://doi.org/10.1016/j.trb.2010.01.001.*

6. *R. Clewlow, J. M. Sussman, and H. Balakrishnan, "The impact of high-speed rail and low-cost carriers on European air passenger traffic," Transport Policy, vol. 33, pp. 136–143, May 2014, doi: https://doi.org/10.1016/j.tranpol.2014.01.015.*

7. *Doeleman, D. (2024). Field study report: European train travel. University of Twente & European Union Agency for Railways. https://1drv.ms/w/s!Am7TXlkeBU34jtobOGPT3QLMOygfOg?e=s4oXjS.*

8. *X. Sun, Y. Zhang, and S. Wandelt, "Air Transport versus High-Speed Rail: An Overview and Research Agenda," Journal of Advanced Transportation, vol. 2017, pp. 1–18, Jan. 2017, doi: https://doi.org/10.1155/2017/8426926.*

9. *F. Pagliara, J. M. Vassallo, and C. Román, "High-Speed Rail versus Air Transportation," Transportation Research Record, vol. 2289, no. 1, pp. 10–17, Jan. 2012, doi: https://doi.org/10.3141/2289-02.*

10. K. Gkiotsalitis and A. Stathopoulos, “A mobile application for Real-Time multimodal routing under a set of users’ preferences,” Journal of Intelligent Transportation Systems, vol. 19, no. 2, pp. 149–166, Sep. 2014, doi: https://doi.org/10.1080/15472450.2013.856712.

11. M. Prussi and L. Laura, “Passenger Aviation and High speed Rail: A comparison of emissions profiles on selected European routes,” Journal of Advanced Transportation, vol. 2018, pp. 1–10, Jun. 2018, doi: https://doi.org/10.1155/2018/6205714.

12. D. Graf, “Die Theorie des geplanten Verhaltens,” in Springer eBooks, 2007, pp. 33–43. doi: https://doi.org/10.1007/978-3-540-68166-3_4.

13. A. Y. Nurhidayat, H. Widyastuti, S. Sutikno, and D. P. Upahita, “Research on passengers’ preferences and Impact of High-Speed Rail on air transport demand,” Sustainability, vol. 15, no. 4, p. 3060, Feb. 2023, doi: https://doi.org/10.3390/su15043060.

14. S. Min, W. Luan, L. Yuan, R. Zhang, and Z. Zhang, “Sustainability Development of High-Speed Rail and Airline—Understanding Passengers’ Preferences:A Case Study of the Beijing–Shanghai Corridor,” Sustainability, vol. 11, no. 5, p. 1352, Mar. 2019, doi: https://doi.org/10.3390/su11051352.

15. C. Chan and J.-T. Yuan, “Changing travel behaviour of high-speed rail passengers in China,” Asia Pacific Journal of Tourism Research, vol. 22, no. 12, pp. 1221–1237, Oct. 2017, doi: https://doi.org/10.1080/10941665.2017.1391303.

16. B. S. Di Teulada and I. Meloni, “Individual Persuasive Eco-travel Technology, a mobile persuasive application for implementing voluntary travel behaviour change programmes,” Iet Intelligent Transport Systems, vol. 10, no. 4, pp. 237–243, May 2016, doi: https://doi.org/10.1049/iet-its.2015.0198.

17. J. Shi, M. Hussain, and X. P. Kong, “Factors Affecting Travel Mode Choice between High-speed Railway and Air Transportation among University Students for Tourism - Evidence from China,” Journal of China Tourism Research, vol. 18, no. 1, pp. 106–120, Aug. 2020, doi: https://doi.org/10.1080/19388160.2020.1802802.

18. K. Hogan, The Psychology of persuasion, 8th ed. Pelican Publishing Company, 1996. [Online]. Available: https://books.google.nl/books?hl=nl&lr=&id=FAHzLM-pY7cC&oi=fnd&pg=PA9&dq=psychology+persuasion&ots=j3m5Qa5Lc2&sig=JwdBe-zcrEu3yWFjq2xUWp4qOUA&redir_esc=y#v=onepage&q=psychology%20persuasion&f=false/.

19. G. Xu, R. Zhang, S. X. Xu, X. Kou, and X. Qiu, "Personalized Multimodal Travel Service Design for sustainable intercity transport," Journal of Cleaner Production, vol. 308, p. 127367, Jul. 2021, doi: https://doi.org/10.1016/j.jclepro.2021.127367.

20. Agile Business, "Chapter 10: MOSCOW Prioritisation." https://www.agilebusiness.org/dsdm-project-framework/moscow-prioririsation.html.

21. D'Alfonso, T., Jiang, C., & Bracaglia, V. (2016b). Air transport and high-speed rail competition: Environmental implications and mitigation strategies. Transportation Research Part A: Policy and Practice, 92, 261–276. https://doi.org/10.1016/j.tra.2016.06.009.

22. Transit, "Plan a Multimodal Trip with Transit+," Transit Support, Nov. 21, 2023. https://help.transitapp.com/article/105-plan-multimodal-trips-with-transit.

23. De Europese Green Deal. (2021, July 14). Europese Commissie. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_nl.

24. THE 17 GOALS | Sustainable Development. (n.d.-b). https://sdgs.un.org/goals.

25. A. Mader and W. Eggink. (2014). A design process for creative technology. https://www.designsociety.org/downloadpublication/35942/a_design_process_for_creative_technology.

26. N. Bruinsma, "Transferring by plane or train?," Master's thesis, 2022. [Online]. Available: https://frw.studenttheses.ub.rug.nl/3956/1/Master%20thesis%20Nils%20Bruinsma%20final.pdf.

27. Ride2Rail, "Home - Ride2Rail," Ride2Rail, Jan. 06, 2023. https://ride2rail.eu/.

28. "Google Maps," Google. https://www.google.com/maps.

29. "Omio Travel Planner," Omio. https://www.omio.nl/.

30. R. P. Ltd, "Rome2Rio: discover how to get anywhere," Rome2Rio. https://www.rome2rio.com/.

31. J. Worth and MEP Jakop Dalunde, Greens/EFA, "Multimodal digital mobility services," report, 2024. [Online]. Available: https://jakopdalunde.se/wp-content/uploads/2024/03/MDMS-Report-FINAL-WEB-reducedsize.pdf.

32. *"Multimodal travel information," Mobility and Transport. https://transport.ec.europa.eu/transport-themes/intelligent-transport-systems/road/action-plan-and-directive/multimodal-travel-information_en.*

33. *France et al., "Integrated Passenger-Centric planning of multimodal transport networks." [Online]. Available: https://multimodx.eu/wp-content/uploads/2024/01/MultimodX_leaflet.pdf.*

34. *A. Detti et al., "Federation and Orchestration: a scalable solution for EU multimodal travel information services," Sustainability, vol. 11, no. 7, p. 1888, Mar. 2019, doi: https://doi.org/10.3390/su11071888.*

35. *Europe's Rail, "Innovation Programme 4 - Europe's Rail," Europe's Rail, Aug. 28, 2023. https://rail-research.europa.eu/research-development/ip4/.*

36. *M. Brachner, D. Kjenstad, and SINTEF Digital, "A distributed and scalable architecture for enabling greener multimodal door-to-door travel within the EU," Eurocontrol Think Paper, p. 2, Jun. 2021, [Online]. Available: https://www.eurocontrol.int/sites/default/files/2021-07/mobility-ws-day-3-sintef.pdf.*

37. *"Bonvoyage 2020 Project | Bonvoyage 2020 Project." http://bonvoyage2020.eu/.*

38. *"Excalidraw — Collaborative whiteboarding made easy," Excalidraw. https://excalidraw.com/*

39. *"User-centered design basics". Apr. 03, 2017. https://www.usability.gov/what-and-why/user-centered-design.html.*

40. *A. Doyle, "What is a semi-structured interview?" https://www.thebalancecareers.com/what-is-a-semi-structured-interview-2061632.*

41. *Fostering Rail Through Green Deal. (2020, July 10). European Agency for Railways. Retrieved November 13, 2023, from https://www.era.europa.eu/system/files?file=2022-11/fostering_railway_sector_through_european_green_deal_en.pdf.*

42. *"CityMapper - the ultimate transport app," Citymapper. https://citymapper.com/.*

43. *E. Cheung and U. Sengupta, "Innovative Digital Tools to Enable Greener Travel: Analysis of Journey Planner Apps and Best Practice Features," ResearchGate, doi: http://dx.doi.org/10.13140/RG.2.2.21841.79202.*

44. D. Esztergár-Kiss, “Framework of aspects for the evaluation of multimodal journey planners,” Sustainability, vol. 11, no. 18, p. 4960, Sep. 2019, doi: https://www.mdpi.com/2071-1050/11/18/4960.

45. “Tickets en aanbiedingen.” https://int.bahn.de/nl/aanbod

46. D. Esztergár-Kiss, “Evaluation of journey planners based on survey data,” www.academia.edu, Jan. 2014, [Online]. Available: https://www.academia.edu/66592851/Evaluation_of_journey_planners_based_on_survey_data.

47. R. A. Karim, A. G. Abu, and F. N. M. Khaja, “BRAINSTORMING APPROACH AND MIND MAPPING IN WRITING ACTIVITY,” English Education International Conference, vol. 1, no. 2, pp. 423–429, Nov. 2016, [Online]. Available: http://eeic.unsyiah.ac.id/proceedings/index.php/eeic/article/download/83/82

48. “Directions API overview,” Google for Developers. https://developers.google.com/maps/documentation/directions/overview

49. “Connect to Amadeus travel APIs | Amadeus for Developers,” Amadeus IT Group SA. https://developers.amadeus.com/self-service/category/flights/api-doc/flight-offers-search/api-reference

50. “Travel Impact Model API | Google for Developers,” Google for Developers.

51. “Typografie.” https://marketingportal.extranet.deutschebahn.com/marketingportal/Marke-und-Design/Basiselemente/Typografie

52. R. F. Dam and T. Y. Siang, “Personas – a simple introduction,” The Interaction Design Foundation, May 12, 2024. https://www.interaction-design.org/literature/article/personas-why-and-how-you-should-use-them

53. “Design scenarios - communicating the small steps in the user experience,” The Interaction Design Foundation, May 12, 2024. https://www.interaction-design.org/literature/article/design-scenarios-communicating-the-small-steps-in-the-user-experience

54. “What are Storyboards in UX Design?,” The Interaction Design Foundation, May 02, 2024. https://www.interaction-design.org/literature/topics/storyboards-in-ux-design

55. S. Yanatma, “Rail fares across Europe: The countries with the most expensive train tickets,” Euronews, Jan. 09, 2023. [Online]. Available: https://www.euronews.com/travel/2023/01/09/rail-fares-across-europe-the-countries-with-the-most-expensive-train-tickets/.

56. “Train, car or plane? - Travel & Climate,” Klimatsmart Semester. https://travelandclimate.org/train-car-or-plane.

57. “What are Semi-Structured Interviews?,” The Interaction Design Foundation, Oct. 22, 2023. https://www.interaction-design.org/literature/topics/semi-structured-interviews.

58. C. M. Barnum, “Establishing the essentials,” in Elsevier eBooks, 2021, pp. 9–33. doi: 10.1016/b978-0-12-816942-1.00001-0.

59. J. Brooke, “SUS -- a quick and dirty usability scale,” ResearchGate, Jan. 1996, [Online]. Available: https://www.researchgate.net/publication/319394819_SUS_--_a_quick_and_dirty_usability_scale?enrichId=rgreq-723cfef7f9cad7cbdebee6c1b659217c-XXX&enrichSource=Y292ZXJQYWdlOzMxOTM5NDgxOTtBUzo5MDIyMTY3MjY2Mzg1OTJAMTU5MjExNjYzODEwNA%3D%3D&el=1_x_2&_esc=publicationCoverPdf.

60. “Free Web Hosting with PHP and MySQL,” InfinityFree. https://www.infinityfree.com/

61. “Web hosting, domain registration, dedicated server, VPS server.” https://ifastnet.com/

62. W. T, “Measuring and Interpreting System Usability Scale (SUS),” UIUX Trend, Feb. 09, 2021. https://uiuxtrend.com/measuring-system-usability-scale-sus/.

63. “Multimodal Travel Planner.” http://travelplanner.42web.io/decide_plane.php

Appendix 1: Consent form user test

Consent Form for research about a Multimodal Travel Platform

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [09/07/2024], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	○	○
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	○	○
I understand that taking part in the study involves audio recordings and written notes. The audio recordings will be transcribed as text and destroyed when the project has ended at the 5st of July.	○	○
Use of the information in the study		
I understand that information I provide will be used for a research report and that parts of this research report can be published in the final bachelor thesis report.	○	○
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	○	○
I agree that my information can be quoted in research outputs.	○	○
I agree to be audio recorded and that observational notes may be taken during the research.	○	○

Signatures

_____	_____	_____
Name of participant	Signature	Date

I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

_____	_____	_____
Researcher name	Signature	Date

Study contact details for further information:

Daan Doeleman, daan.doe@hotmail.com, +31 6 14 26 08 55

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee Information & Computer Science: ethicscommittee-CIS@utwente.nl

Appendix 2: Concluding survey

Please fill in these questions as good and honestly as possible. In this case the word system refers to the travel planner platform you have just used. Many thanks!

1. I think that I would like to use this system frequently.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

2. I found the system unnecessarily complex.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

3. I thought the system was easy to use.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

4. I think that I would need the support of a technical person to be able to use this system.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

5. I found the various functions in this system were well integrated.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

6. I thought there was too much inconsistency in this system.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

7. I would imagine that most people would learn to use this system very quickly.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

8. I found the system very cumbersome (inconvenient) to use.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

9. I felt very confident using the system.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

10. I needed to learn a lot of things before I could get going with this system.

Markeer slechts één ovaal.

	1	2	3	4	5	
Stro	◯	◯	◯	◯	◯	Strongly agree

Demographic questions

11. What is your age?

12. What is your gender?

Markeer slechts één ovaal.

- ◯ Male
- ◯ Female
- ◯ Prefer not to say
- ◯ Anders: _____

13. Which of the following words describes you the best?

Markeer slechts één ovaal.

- ◯ Student
- ◯ Entrepreneur
- ◯ Employee
- ◯ Homemaker
- ◯ Unemployed

14. When I am travelling I usually travel:

Markeer slechts één ovaal.

- ◯ On my own
- ◯ With several friends
- ◯ With my family
- ◯ In a large group
- ◯ Anders: _____

15. Which of the following statements describes the height of your income the best?

Markeer slechts één ovaal.

- None
- Low
- Average
- High

16. I mainly travel for:

Markeer slechts één ovaal.

- Business
- Leisure

Appendix 3: User test plan

Introduction

First of all, many thanks for having this meeting with me today. My name is Daan Doeleman and I am a Creative Technology student at the University of Twente. In case you have any questions for me during this meeting please feel free to interrupt me. Otherwise, I will continue with the content for today. As part of my bachelor thesis, I am developing a new sort of travel planner, which you are going to test today. The idea is that this new travel planner is unbiased and let you make a fair decision on with which mode of transport you are going to travel. Today's user test will take approximately 20-30 minutes and will be structured as follows:

- Introductory semi-structured interview
- User test
- Semi-structured interview
- Concluding survey

I would like to let you know that the interviews will be audio recorded in order to make it easy to analyse the results afterwards. This audio recording will be anonymous and deleted directly after the end of this study. During the user test no recordings will be made. Only your behaviour will be observed and notes might be taken from this. Is that okay for you? If that's okay for you, I would like to ask you to read through and sign this consent form for me. *sign the form* Before starting with the first interview I would like to ask you if there are any remaining questions you may have for me before we start?

Introductory interview

I would like to start with the following set of questions:

- How often do you travel internationally per year?
- How many of these journeys are longer than 500km? How many are shorter?
- For the international journeys shorter than 500km, which mode of transport do you use? Train, plane, car?
- Why do you prefer this mode of transport?
- Is there any particular reason why you try to avoid specific modes of transport?
- How do you decide on which mode of transport to travel with for such international journeys shorter than 500km?
    - Is price, sustainability or travel time the most important for you?

Thank you for answering these interview questions.

User test

We will now continue with the user test. During this user test you will be asked to execute three tasks inside the travel platform. Please try to execute these tasks as good as possible. I would also like to ask you to say directly what you think, a so called "think aloud" procedure.

Task 1

Plan a journey from Groningen to Frankfurt on the third of August 2024, leaving at 7.00 in the morning. You will travel with second class. Compare the different options and make a decision on which mode of transport you want to travel with. You can say your reasoning aloud.

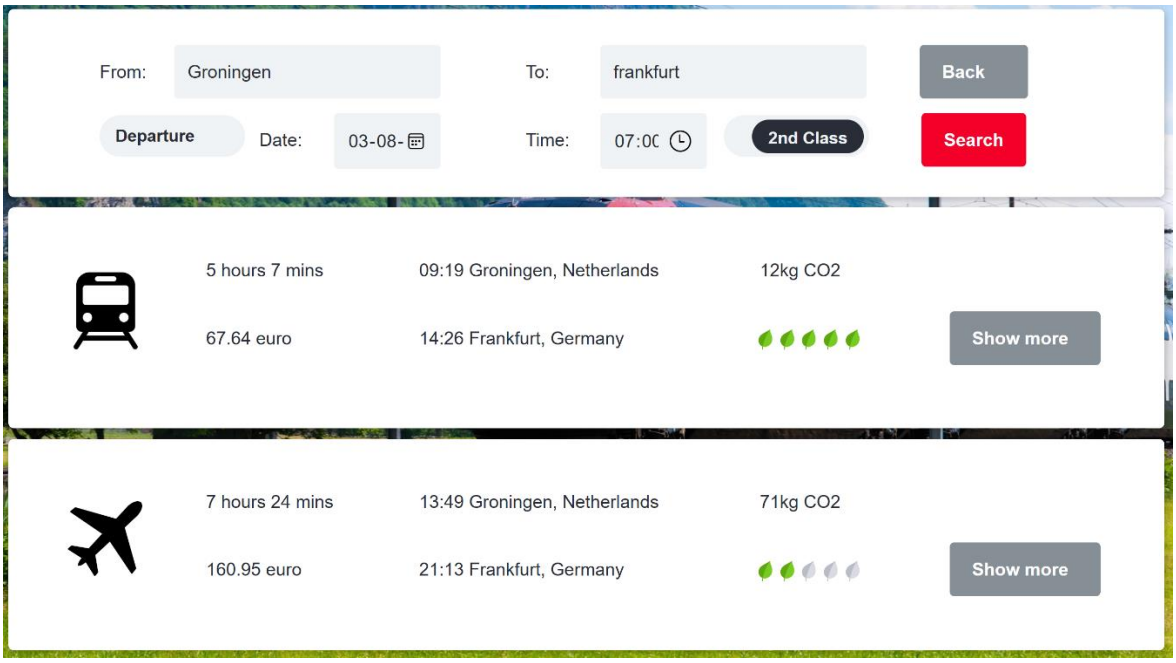
Task 2

Plan a journey from Duesseldorf to Paris on the second of August 2024, arriving at 16.40 in the afternoon. You will travel with second class. Compare the different options and make a decision on which mode of transport you want to travel with. You can say your reasoning aloud.

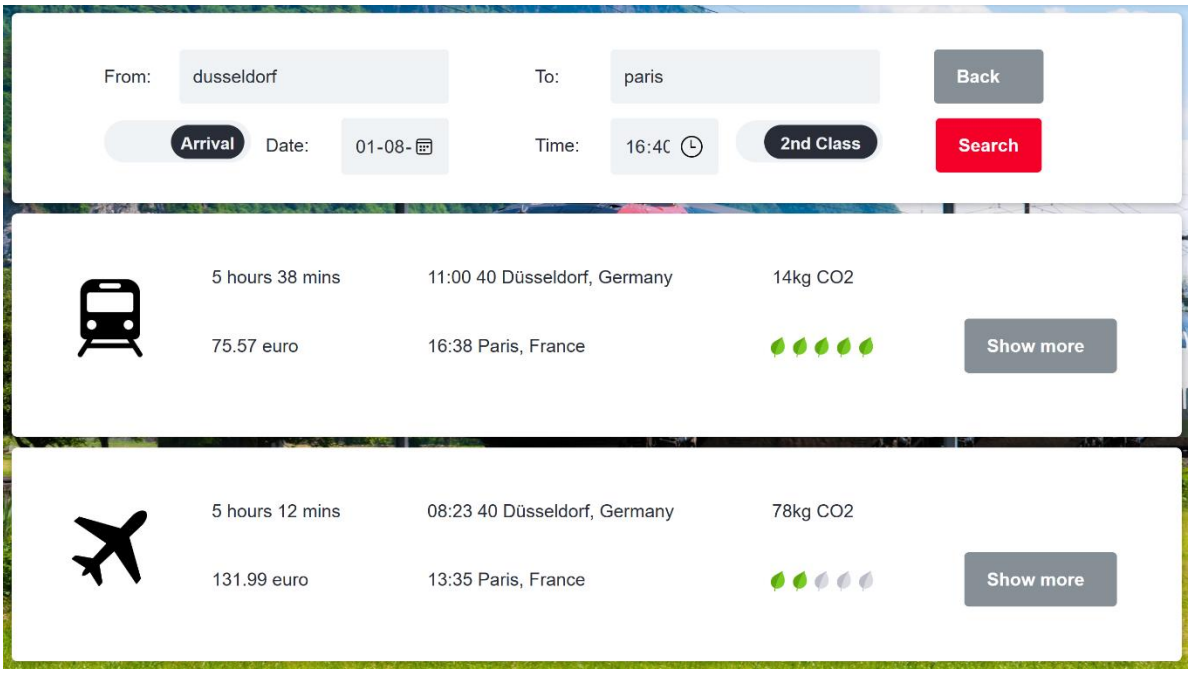
Task 3

Plan a journey from Arnhem to Milan on the fifth of August 2024, leaving at 7.00 in the morning. You will travel with second class. Compare the different options and make a decision on which mode of transport you want to travel with. You can say your reasoning aloud.

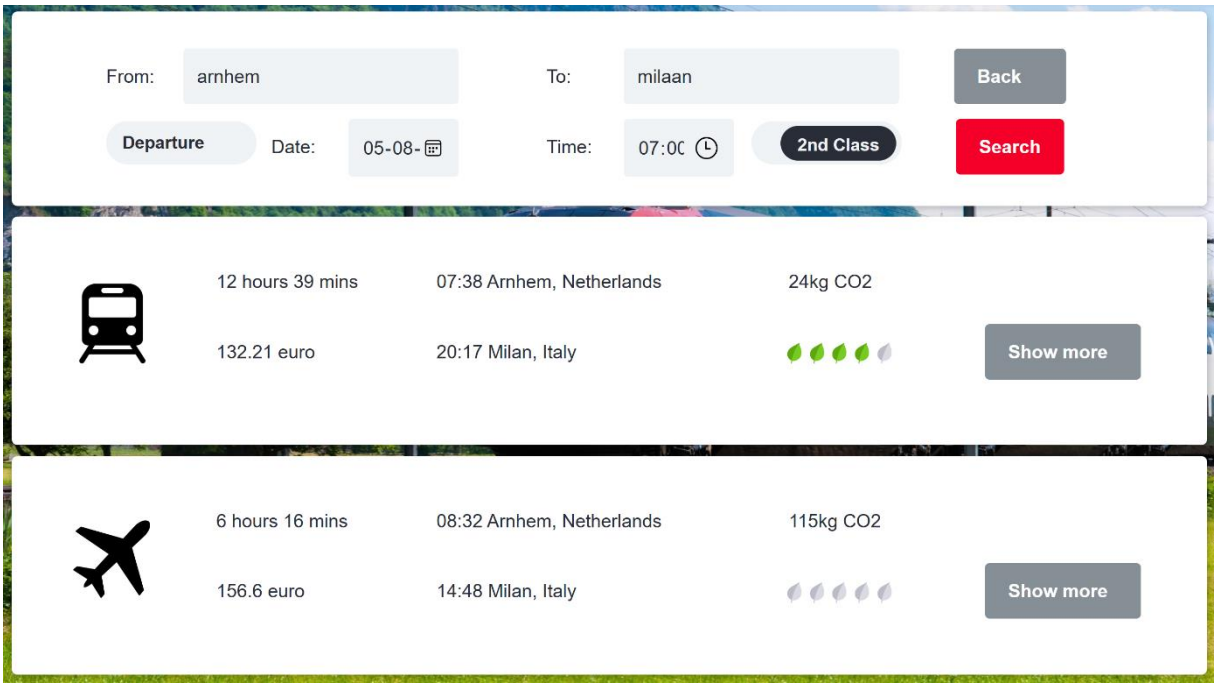
Outcome task 1



Outcome task 2



Outcome task 3



Interview

Thanks for having executed these tasks and for sharing your thoughts. To conclude this user test, I would like to ask some last questions about the travel planner:

- How was it for you plan a journey on this platform?
- What do you think about the design?
- Was it intuitive to use the platform?
- Was the travel mode comparison clear for you?
    - Do you have any suggestions for improvements?
- Were the rest of the functionalities and layout clear for you?
- Would you say you are more likely to take the train with this travel planner as compared to currently existing alternatives?
- When looking at all three tasks and their corresponding journeys, what was in general the most important factor which made you choose for a certain mode of transport?

Concluding survey

The last thing I would like to ask you is to fill in a concluding survey for me. This survey consists of several demographic questions as well as questions related to usability. The survey can be accessed here: https://forms.gle/PhxGdc1Lh2Ei87rE7.

Appendix 4: The travel planner

URL to travel planner: http://travelplanner.42web.io/index.php.

Link to the code used to build the travel planner: https://1drv.ms/.

Appendix 5: The user test results

This appendix contains the results of the user testing procedure described in Chapter 5. The outcomes of the interviews, observations and surveys are described in three separate overviews below:

- The table which combines the demographic questions of the survey with the travel behaviour questions of the first interview: Overview 1.
- The table which calculates the System Usability Score for each user dependent on their answers from the survey: System Usability Score.
- The A4 sheets with written notes for each individual user describing the decision making process of each passengers as well as feedback points they mentioned during the user test and second interview: Written Notes.