Inter modal routing Parameters

What information is needed in the context of an inter modal trip advice and how can information be used?

MASTER THESIS

J. Bronsveld

Study	Civil Engineering & Management
Specialisation	Centre for Transport Studies

Student: Bronsveld

0087491

Supervisors:

Prof. Dr. Ir. E. Van Berkum	*Professor*	University of Twente
Dr. J. Bie	*Daily supervisor*	University of Twente
Ir. A. Van Sorgen	*Daily supervisor*	MRK GmbH

University of Twente

Drienerlolaan 5
7500AE Enschede
The Netherlands

MRK Management Consultants

Herzog-Rudolf-Straße 1
80539 München
Germany

Date: 7 August 2012

Status: Second Final

Version: 1.25

Obey the teaching
of your parents—
always keep it in mind
and never forget it.
Their teaching will guide you
when you walk,
protect you when you sleep,
and talk to you
when you are awake.

Proverbs 6: 20-22

Sometimes what seems right
is really a road to death.

Proverbs 16: 25

Abstract

Route advices are given many times every day. Sometimes by people along the streets, sometimes by navigation programs on smartphones or navigation devices or on the internet where an itinerary is given for a trip. Most of these advices a strictly for one type of mode only, the personal mode or the shared modes. In this paper the development of a route advice system that is capable of mixing both personal and shared modes is researched; an inter modal routing advice system. In this paper the parameters on which a route advice system is based are discussed. What parameters are needed for such a system and can they be differentiated on different levels of importance?

The meta-analysis is performed on the parameters that are found in a research and practice study. The current status is based on a literature research and a review of the different advice systems available at the internet.
The literature research is to find the latest developments and reviews on route advice systems, both on personal modes as on shared modes and the inter modal advice systems that are already discussed in the literature. The practice study is to find the best practices and latest developments from the side of the producers and developers. Together the results of these reviews are assessed in a meta-analysis to see what parameters are most commonly used. The outcome is that time, cost and location related aspects are the most common aspects in the different systems.

The activity theory is performed on different scenarios to break apart the process that travellers undertake when they make an inter modal trip. By examining the different steps and extract what type of information is used or given during the different steps of the trip, it is made sure that all the aspects that are needed during a trip are taken into account. Hereby checking if all aspects that are used in practice are accounted for in the meta-analysis; the same aspects are found as in the meta-analysis.

The last part of the research is an expert interview with consultants and a route advice system producer. Not only is the current status discussed, but also future developments. These interviews reveal several aspects that are not mentioned before or are not revealed in the meta-analysis. Weather, convenience and interchange related aspects are revealed, as well as reasons why several aspects are not incorporated in current route advice systems.

The aspects found in this research are aggregated and prioritized in a matrix which has two scales. One scale based on the different timeframes and one scale based on how much the aspects are needed. Is the aspect critical to provide a route advice, or does it improve a route advice. The outcome is in the matrix below.

	Static	Prognosis	Real time
Need	Date / day Timetable Network (personal and shared modes, P&R's) Travel chain - Departure time / Arrival time - Origin - Destination		
Nice	Routing objective: Number of connecting services Distance Personal speed preferences Via routing point POI information	Historical information Prediction on current situation POI availability / occupancy	
Superb	Convenience level of modes Convenience level through weather	Expected delay through weather	Delay due to weather, accidents, (current status of the network) Rerouting Stress Personal preferences settings

Table 1: input aspects for inter modal routing systems

	Static	Prognosis	Real time
Need	Number of transfers Cost (fare, petrol) Route Travel time		
Nice	Distance Number of connecting services Route on a map Time of departure / arrival	Expected delay Occupancy	
Superb	Convenience level of modes Convenience level through weather	Delay through weather, accidents	Delay Rerouting

Table 2: Output aspects for intermodal routing systems

Preface

The master thesis that lies in front of you is the result of a research at MRK Management Consultants in Munich, Germany for a master's degree in Civil Technology & Management at the University of Twente, the Netherlands.

The research has had its ups and downs, which is reflected in the time period spent on it. First the definition of the research question has been difficult because existing models did not work on the situation and the models that have been tried did not perform as was expected beforehand.

First I would like to thank Jing Bie for the support and positive words during the period that I was back in the Netherlands, still working on my master thesis, especially in the period that I did not know how to proceed.
Also I would like to thank Atze van Sorgen who has been mine supervisor while I was at MRK. Thanks for the support, discussion and the introduction in how to behave in Germany.

My parents and further family for giving me motivational support and kept pushing me. Not only during my master thesis but throughout my entire educational period, giving me the opportunity to be where I am now.

Furthermore I would like to thank the colleagues and roommates who were there to give me a good time during the period that I lived in Munich. Thanks for giving me the opportunity to feel home, far away from home.

Table of Contents

Abstract ..... D

Preface ..... F

Table of Contents ..... G

Glossary ..... J

List of figures and tables ..... M

Chapter 1 Introduction 1

a. Background 1

b. Scope 3

c. Research Question 4

d. Methodology 4

i. The choices available 4

ii. Used methods 5

Chapter 2 Known and used aspects for intermodal trips 7

a. Aspects available according to literature 7

i. Personal modes 7

- Congestion 7
- Stress 8
- Control 8

ii. Shared modes 8

- Cost 9
- Travel time 9

Access / Egress time and walking leg 10

In-vehicle time 10

Transfer time 10

- Most mentioned 11
- (Un)Reliability 11
- Origin and Destination 12

iii. Park & Ride 13
iv. Overview 13
b. Aspects available according to practice 15
i. Personal modes....15
ii. Shared modes....18
iii. Park&Ride 22
c. Differences between literature and practice 25
i. Personal mode 25
ii. Shared modes....25
iii. Park & Ride....25
Chapter 3 Importance of aspects....27
a. Importance of aspects found in the literature....27
b. Importance of aspects based on the number of occurrences in the reviewed systems. 29
i. Requested information....29
ii. Given information 30
c. Cumulating literature and practice 31
d. Information flow 33
Chapter 4 Usage of the identified aspects 38
a. Activity Theory....38
i. History of activity theory 38
ii. An overview of activity theory....38
iii. Appliance of activity theory 39
iv. Why Activity Theory?....40
b. Different motives 40
c. Different time frames....41
d. Example of the application of activity theory....42
- Time....44
- Location 44
- Cost....44

e. The results of the activity theory analysis 44

i. Overall outcomes 44

ii. Outcomes of the process 44

f. Removal of some information 45

i. Cost information 46

ii. Time information 46

iii. Reliability 47

iv. Location 47

v. Implications 47

Chapter 5 Interviews 48

a. Convenience level 48

b. The interchange 48

c. Reliability 49

d. Information 49

Chapter 6 Conclusions 51

a. Overview 51

b. Discussion 53

c. Further research and thoughts 54

Bibliography ....a

Appendices ....d

Appendix A: Overview of found aspects in practice ....e

Appendix B: Overview of aspects found in literature ....j

Appendix C: Overview of comparison found aspects: Literature vs. practice ....u

Appendix D: Different methods available for research v

Appendix E: Overview of motives for travelling ....z

Appendix F: Results of Activity Theory analysis cc

- Abstract of the answers given during the interview with Christoph Mentz (MDV) ....gg

Glossary

Amount of traffic
The volume of traffic on the network or link, including cars, trucks, busses

Aspects
A lot of information is available when it comes to making an intermodal routing advice. All these bits of information can be used in a system. When implemented, it turns into a parameter.

Class
The level of service in public transport, e.g. first and second class or business and economy class

Comfort
The level of physical ease during a trip

Control
The perception of travellers of being in control over the process of undertaking a trip

Cost
All the costs that are involved in travelling: petrol, toll, fare, subscriptions etc.

Distance
The length between two points

Event
A foreseen anomaly on the network situation, such as more traffic during exhibitions or soccer games or road works

Freeway links
The links in the network with the value of freeway/highway

Incident
An occurrence of a disruption compared with normal conditions. In this research unforeseen states of the network due to accidents, road blocks etcetera

Information
The knowledge that is needed by the aspects and parameters to be able to function. Such as the weather situation or the ability to walk stairs of a traveller. In ITS terms this can refer to both data and information.

Interchange time
The amount of time needed to make a transfer from one service to another or from one mode to another (bike -> bus). This includes the time needed to walk from the endpoint of the first mode to the start point of the connecting mode.

Intermodal trips
Trips which use both shared mode and personal mode types

Mode
Means of transport such as walking, biking, bus, train, plane, car, taxi etcetera

Non-recurrent congestion
A state of the network if the demand for mobility is higher than the supply, resulting in traffic jams. In the case of non-recurrent this is not the result of normal conditions, but caused by anomalies

Non-regular situations
Being in another situation than normally, travellers can get confused. This can be based on unfamiliarity such as driving in busy city streets or in unfamiliar public transport.

Occupancy
The rate of demand vs. supply. Incorporated in number of travellers in a carriage vs. number of seats or number of parking places available in parking lot vs total amount of parking places

Parameters
Parameters are the attributes which are part of a navigational advice. To be able to make an advice a certain amount of information is needed, these are given to the model as parameters. An example is trip travel time. The difference between parameters and aspects is that aspects are possible candidates for parameters and parameters are implemented aspects

Parking time
The time that a vehicle is parked

Personal mode
Modes which are available at the travellers demand including car, bike, and taxi

Recurrent congestion
Regular congestion, such as rush hour during work days

Reliability
The consistency of information, which can be travel time, connections made or the quality of prognosis

Routing objective
The value that is minimized in an algorithm to provide the best alternative. This can be travel time, average speed, distance etcetera

Shared mode
Modes which are shared between several travellers which are not available at the travellers demand but use some kind of timetabled service. Including all public transport (bus, tram, metro, train, ferry, train), carpooling and planes

Stress
The negative impact on a traveller's mental and physical wellbeing

Time
All the time elements that are involved in travelling: access / egress, waiting, in vehicle time etc.

Transfer time
The amount of time given or available to make a transfer, preferably bigger than the transfer time, but not too much since that can lead to waiting time.

Travel time
All the time that is part of the time used during travelling: every single step including: access time, wait time, interchange time, in vehicle time, delay, egress time and walking time. Also Value of Time (VOT) components as found in the research are used as a components related to time, not as costs.

Traveller's knowledge
The knowledge of the traveller, this involves knowledge of information on regular used links, or the lack of it

Trip
The activity undertaken to get from a place to another place

Uncertainty
The psychological version of reliability, but not measurable

Weather
The state of the atmosphere, to the degree that it is hot or cold, wet or dry, calm or stormy, clear or cloudy

List of figures and tables

Figure 1: Overview of a routing system 2
Figure 2: What information is needed before you can go from A to B 3
Figure 3: Overview of different travel time parts in a trip 9
Figure 4: Google Maps routing form 15
Figure 5: Tomtom routing form 15
Figure 6: Real network (around MRK HQ) 16
Figure 7: Network representation 16
Figure 8: Google maps overview 17
Figure 9: Google Maps summary 17
Figure 10: Tomtom summary 17
Figure 11: Geofox fill in form for PT routing 19
Figure 12: EFA's fill in form 19
Figure 13: HAFAS's fill in form 19
Figure 14: transport direct's fill in form 19
Figure 15: 9292ov's fill in form 19
Figure 16: 9292ov trip advice 20
Figure 17: EFA trip advice 20
Figure 18: HAFAS trip advice 20
Figure 19: 9292ov P&R advice (part 1) 22
Figure 20: 9292ov P&R choice (part 2) 22
Figure 21: MVV P&R advice (EFA) 22
Figure 22: NS P&R advice 23
Figure 23: VMZ Berlin P&R Advice 23
Figure 24: Ruhrpilot P&R Advice 23
Figure 25: Rejseplanen P&R Advice 23
Figure 26: P&R Hessen information example 24
Figure 27: Travel time dependencies 33
Figure 28: Recurrent delay dependencies 33
Figure 29: Extended travel time dependencies 34
Figure 30: Relations between the aspects 35
Figure 31: Relations between cost aspects 36
Figure 32: Relations between time aspects 36
Figure 33: Relations between distance aspects 36
Figure 34: Roots of Activity Theory 38
Figure 35: Activity Theory scheme (Engeström, 1999) 39
Figure 36: Motives for travelling 40

Table 1: input aspects for inter modal routing systems .... E
Table 2: Output aspects for intermodal routing systems .... E
Table 3: Overview of shared transport navigation systems 18
Table 4: Used aspects in P&R systems 24
Table 5: Number of references per aspect in literature 28
Table 6: Overview of found aspects in practice 29
Table 7: Aspect analysis 33
Table 8: Different scenarios 41
Table 9: Overview of user characteristics 42
Table 10: Example of the application of Activity Theory 43
Table 11: Aspects per time frame 45
Table 12: what does the system need (input) 53
Table 13: what does the user need (output) 53

Chapter 1 Introduction

a. Background

The main focus of navigational products has been in motorized vehicles such as cars and motorcycles where Personal Navigation Devices (e.g. TomTom and Garmin) trip advisory websites are used. Also in shared transport modes such as train, bus and metro the trip advisory websites are used. PND's are not often used for these modes. One of the new developments in the use of navigation systems is to use it for other modes than mentioned before (such as walking, cycling, boating) and for intermodal trips. Intermodal trips are travel trips that are completed by the use of multiple kinds of transport, including both shared mode types and personal mode types. A glossary for words and their description is available in Glossary

The field of intermodal navigation is relatively young, according to 9292, a travel advisory website in the Netherlands. 9292 has been the first website in the Netherlands that gave intermodal trip advices and the first intermodal product was launched in 2006 (9292 REISinformatiegroep bv).
In the field of public transport authorities there is a special interest in intermodal transport advice solutions, since it gives them the opportunity to give travellers a better insight in the advantages of public transport above personal transport. One of these public transport authorities is TraffiQ, a public transport company in Frankfurt (Germany). The goal of TraffiQ is to make a transport trip advisor product that combines the different modes that are available in Frankfurt. This research is part of the development for such a product in Frankfurt.

Since TraffiQ knows that not every trip can be taken by public transport alone, their goal is to make a product that can provide intermodal transport trip advices, including public transport. By providing such a product TraffiQ wants to show the travellers that public transport can be a good alternative for current car-based trips. Other objectives are to attract more customers for the public transport and increase the market share of public transport in Frankfurt.

The product that can provide an intermodal routing needs access to different information sources and will involve different disciplines. An overview of the different parts of a navigational product is given in Figure 1: Overview of a routing system. In the next section an overview of the product will be given in which the different parts are explained by different (number) symbols.

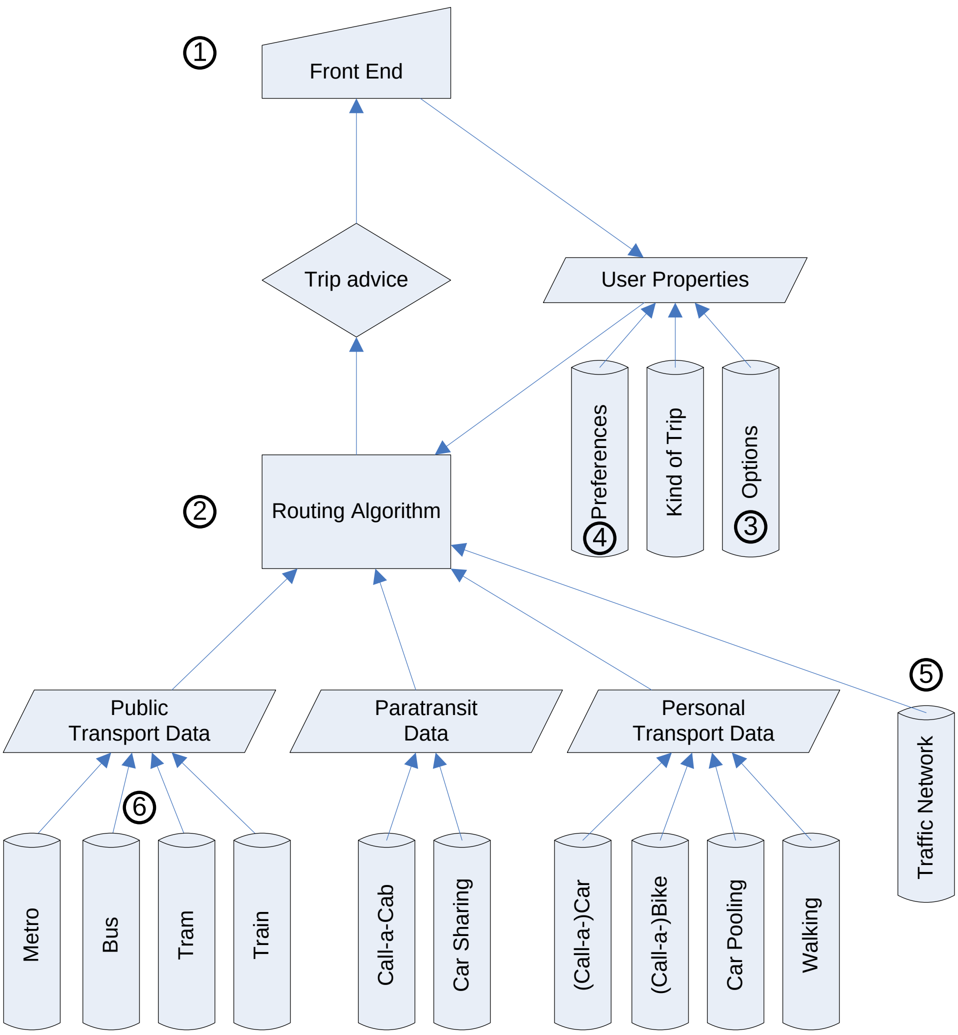


Figure 1: Overview of a routing system

For the front end interface experts are needed to give the user good interaction possibilities and make it a 'natural' experience to interact with the product (1). Furthermore information about the trip is needed. For this part programmers are required to create an algorithm that can provide a good trip advice.

The task of this research is to investigate which parameters are needed for such a product. What information is necessary to make a good trip advice? Especially, what information is needed to make a good product for intermodal trips? An overview of the information within the product is visible in Figure 1: Overview of a routing system. This 'information' includes elements which will be used by both the interface builders and the programmers, such as

- … is the user able to drive a car? (3)
- … is the user in possession of a frequently user pass for the Public Transport? (3)
- … is the user claustrophobic and is he not willing to use the metro? (4)
- … what is the state of the traffic on the network? (5)
- … are there delays in the train or metro which might be part of the trip chain? (6)

Generating trip advice is about knowing what the travellers want and how the travellers can be provided in this need. In the beginning of this chapter it is made clear that there is room to improve the travel advice products available.

b. Scope

When taking a look at the information already available for trip advice, it is clear that information about the origin and destination of the trip is needed. Also, the time of departure or preferred time of arrival can play a big role and the options of how to travel have to be sorted out. Questions that have to be answered include, but are not limited by: Is it possible to go from A to B? What links are available?

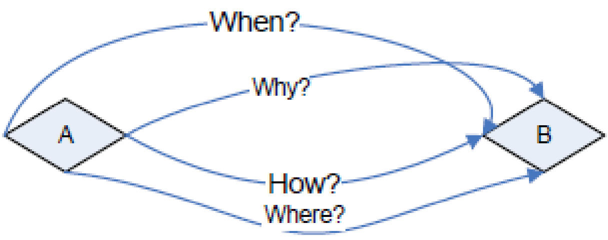


Figure 2: What information is needed before you can go from A to B

So far all of this information is available in the separate fields of shared modes (mostly public transport) and personal modes (mostly by car navigation), but there is not much information about how to link these two kind of modes into one trip chain.

The research in this article is part of the development for an intermodal routing agent. The intermodal routing product under development will be used both in an internet portal for pre-trip and in on-trip consultation, as for an application product for smart-phones which can also provide turn-by-turn information. This means that the information provided by the product can be ‘static’ information such as timetables and travel times but the products will also be about ‘real time’ information that is dynamic, providing information about delays on the highway or disruptions in the public transport system. Information about the weather and its influences, on both the attractiveness of a destination or trip mode (e.g. bike), or the influence on travel times (e.g. snow), could be part of the advice.

Since the advice can include trips by bike or walking, it is a good idea to personalise information about the trip. These two modes of transport are user powered and therefore can have big deviance in the time needed for a trip. People on a bike can have an average speed between 15 km/h and 25 km/h (wikipedia.org, 2010), so personalised information can help to make the outcome more precise according to the user’s abilities.

As stated before, the market for intermodal trip advice is coming up and needs more development to flourish and to be able to make good products. On the internet several programs and websites are available which make it possible to make a trip advice between point A and B. Even the possibility to use a mix of personal modes and shared modes is available. However, all these programs have the disadvantage that their trip advice is not complete, is not optimal or lacks in usability. This makes it clear that there is a need for an intermodal trip advice product, but that the products available are not good enough.

What parameters are needed for an intermodal advice is one of the subjects that still needs more development. Information is available on parameters used in public transport and in personal transport, but these parameters are for separate trips and not the combination of the two. Although

there are some websites available for intermodal trip advice, research on these websites made clear that they are not very useful and can give very odd trip advices. A two-way trip with ruhrpilot.de for example, can give an unreasonable advice if not enough attention is paid.
The website can generate intermodal trip advice in which parking lots adjacent to train stations (a so called Park&Ride (P&R)) are used to change from the car mode to train mode. It is surprising that for a two-way trip the planner chooses a different station on the trip back to change from train to your car, than where you left your car on the first part of the journey.

The scope of the research is to find the important parameters which can be included in the back-end of an intermodal routing product, based on current practices, current research and the latest insights of experts. The product will have several layers of service: static, prognosis and real-time. Also different user levels will have to be implemented, to be able to give the users an environment that complies with their usage.

c. Research Question

In the previous section the problems and possibilities of the current situation in the inter modal routing market are revealed. This research will present the current status of the route advice systems and their (im)possibilities. The goal is to find the building blocks for a new developed inter modal trip advice and present these building blocks in a ranking based on how useful they are.

This leads to the following research question and sub questions:

- What information is needed in the context of an inter modal trip advice and how can information be used?
    - What are the known and/or used parameters for route advice?
    - How important are the single parameters within a routing system?
    - How can the parameters be utilised?

This research question will be answered based on literature research, a review of the current systems and experts interviews. An overview of how the research is carried out is available in the next section Methodology. The research itself is in Chapter 2 and further.

d. Methodology

i. The choices available

Several research methods are available for a research to establish the current status of inter modal routing advice, the possibilities and the near future development.

The research will be focusing on the aspects that are available and tries to rate them in an order of need to have in a new inter modal route advice program. Due to the characteristics of the aspects that are included in inter modal route advice it is not possible to rate them in a monetary way. It is possible to calculate the costs of some aspects (such as the costs involved for information gathering to make historical database to base prognosis information on), but it is not possible to rate the effects in the route advice outcome for every single aspect. This behaviour rules out cost based analysis such as cost benefit analysis and cost effective analysis.

Other rating analyses are neither an option since it is hard to connect a value to the single aspects themselves. Also the probability method, sensitivity analysis and multi criteria analysis are not an option for this research.

Another method is to interview the intended users to assess their expectations and values for different aspects in an inter modal route advice system. This could reveal the need for different aspects, their combinations and the value that is given to the different aspects. One of the problems however is that the research is carried out in Munich (Germany), while the researcher is Dutch and everything should be translated into German to make a survey possible. Furthermore undertaking a survey is very time consuming and the outcomes are not always clear, since there is a difference between stated preferences of the travellers and the revealed preferences. Based on this the choice is made to avoid making a survey and use other methods to get the same kind of information.

The way to get this information is to interview experts in the field of inter modal routing. Due to some restraints (long distances to other experts, low expected response rate on a paper survey and the language barrier) only a few experts are interviewed. These experts have different approaches to inter modal routing, due to their different backgrounds as producer, public transport expert or traffic expert.

An overview of all the different methods and their (dis)advantages is available in Appendix D: Different methods available for research.

ii. Used methods

The analysis is based on three pillars of knowledge:

- Previous research, as found in literature
- Best practice, as found in the practice
- Best knowledge, based on the experts

The pillars of research and practice are used in a meta-analysis to find out the most used aspects. The risk is to miss out on new aspects that can be important for an inter modal route advice. To be able to find these aspects as well in the expert interviews are used. These experts have a good view on the current situation and the developments in the inter modal market or the separate modes themselves, making it possible to reveal the latest possibilities in the inter modal transport market. The data for the best practices is collected by analysing the systems that are in use throughout the world. The focus is on Germany, the Netherlands and the UK, since this is the targeted market for the product that will be based on this research.

The Activity Theory is method to take apart processes to see how and when things happen, avoiding the pricing of the aspects as in other evaluation models such as cost benefit analysis, multi criteria analysis and the probability method. A more detailed explanation of activity theory is given in Chapter 4a. Activity Theory. With the activity theory several scenarios will be analysed to find out what information or aspect is used at what point during the planning and performing of a inter modal trip. The aspects that are found in the meta analysis phase are used here. Also this process is used as a check to see of the previous processes have accounted for all aspects that are used. Also the outcomes are used for the distinction of the aspects in the different time frames (static, prognosis or real-time) of travel advice. Although the analysis focuses on the information that is needed by the traveller (the output of the system in the advice), the analysis can be used to see what output is needed. By reversing the information flow within routing systems, the data needed as input for the routing system is revealed.

This methodology leads to a matrix in which the aspects can be ordered for future product development based on two dimensions: time and service. The matrix is given below.

	Static	Prognosis	Real time
Need			
Nice			
Superb			

The paper is built up in the following way. First an overview will be given of the available aspects in Chapter 2 according to literature in section Chapter 2a. and practice in Chapter 2b. In Chapter 2c. an overview of the differences between the two previous sections will be given.
The importance of the different aspects will be researched in Chapter 3, followed by Chapter 4 where will be discussed how the different aspects are used by using the activity theory. The results of the interviews with the experts are in Chapter 5. Finally in Chapter 6 Conclusions the conclusion and recommendations will be given.

Chapter 2 Known and used aspects for intermodal trips

a. Aspects available according to literature

A separation will be made between the different modes in respect to the relevant aspects. First the aspects which are related to personal modes will be addressed.

i. Personal modes

The basic rule in personal modes is the formula of generalized cost concept (Ortúzar & Willumsen, 2001):

$$C_a = \alpha(travel\ time)_a + \beta(link\ distance)_a$$

However, link cost should be used instead of link distance, since the distance is the main originator of the link costs in the view of Ortúzar & Willumsen. This gives the following formula

$$C_a = \alpha(travel\ time)_a + \gamma(link\ cost)_a$$

$Travel\ time$ is the travel time in minutes

$Link\ distance$ is the distance of the link

$Link\ cost$ is the cost for the link (toll etc.)

α, β and γ are coefficients associated to the elements of cost above

It can be concluded that time and cost are the main aspects in this formula.

However, these are not the only aspects that are mentioned in the literature; also congestion, stress and control are mentioned.

•*Congestion*

Congestion is a disruption in the flow on a network which is so severe that it results in a situation in which the drivers cannot drive the speed that they would like; the free flow situation. Due to lower speeds the travel time increases. This also influences the stress levels of travellers since they have the idea that they are no longer in control of the situation and do not know what is going to happen next.

Two types of traffic jams can occur on a network, daily occurring traffic jams and incidental congestion (Zuidgeest, Maarseveen, & Zuilekom, 2004). The first type is regular and does not have a large impact on regular travellers since they get used to these and gain experience about the occurrences of this type of congestion.
The other type are incidental congestions, these are mostly caused by non-recurring incidents like accidents or bad weather circumstances. Since these are non-regular it is not possible to obtain experience on this type of congestions. For unfamiliar drivers however, both types are regarded as the same, since they do not have built up experience.
For planning purposes there is a big difference between the two kinds of congestion, the first type (recurrent) can be expected and therefore be implemented in a travel advice. In this way recurrent congestion does not lead to issues of unreliability or uncertainty (Rietveld, Bruinsma, & van Vuuren, 2001). Although an indication of a minimum travel time is important, there is the fact that travellers

do not always choose to avoid congestions, a 15 minute delay is found to be the threshold for drivers to choose a known alternative (Hall, 1993). The second type (incidental congestion) however, cannot be predicted, making it nigh impossible to impossible to implement in a future travel advice. According to Curtis & Schreurer (2010) congestion also has an influence on the experienced travel time. Travel time in a congested environment is experienced as stressful and not being in control, increasing the experienced travel time more than the actual travel time. These two aspects will be discussed later.

•*Stress*

As has already been mentioned in the previous section, stress is a component which can be influenced by congestion. This is also found by Galovski & Blanchard who found that driving in a car can be very stressful. Especially in congested environments the stress levels increase compared to other drivers. This is a problem since stress is a factor that influences the cognitive resources of people in a negative way.

A difference in unpredictability level has been found between car drivers and train commuters in the New York area, resulting in a different level of stress between personal mode users and shared mode users (Wener & Evans, 2010).

•*Control*

Being in control is one of the factors in which people choose personal modes over shared modes (Lyons & Harman, 2002). Being in control is about knowing what will happen next and feeling confident that everything will be going as planned. If disruptions such as incidental congestion occur, this influences the level of being in control in a negative way. Recurrent congestions do not have this influence, since experienced commuters had already expected this type of congestion. In a research of Wener & Evans (2010) high levels of control were measured for both personal (in this case: car) and shared (public transit) modes. This research included only commuters on their preferred kind of transport, explaining the difference with the outcomes of the research of Lyons & Harman as mentioned under *stress* where all kind of people were questioned.

ii. Shared modes

For shared modes different aspects are relevant to make the decision on what route to take. Also more circumstances are variable, since different routes can lead to different kinds of transport. In personal modes the kind of transport is less relevant, since only one is available (their own vehicles).

Again a standard formula for generalized costs made by Ortúzar & Willemsen (2001):

$$C_{ij} = a_1 t_{ij}^v + a_2 t_{ij}^w + a_3 t_{ij}^t + a_4 t_{ij}^n + a_1 \delta^n + a_5 F_{ij}$$

Where

C_{ij} is the total cost for the travel between i and j,

t_{ij}^v is the in-vehicle travel time between i and j,

t_{ij}^w is the walking time to and from stops (stations),

t_{ij}^t is the waiting time at stops,

t_{ij}^n is the interchange time,

δ^n is an intrinsic 'penalty' or resistance to interchange, measured in time units (typically 2 to 5 minutes),

F_{ij} is fare charged to travel between i and j

a_1 to a_5 are coefficients associated to the elements of cost above.

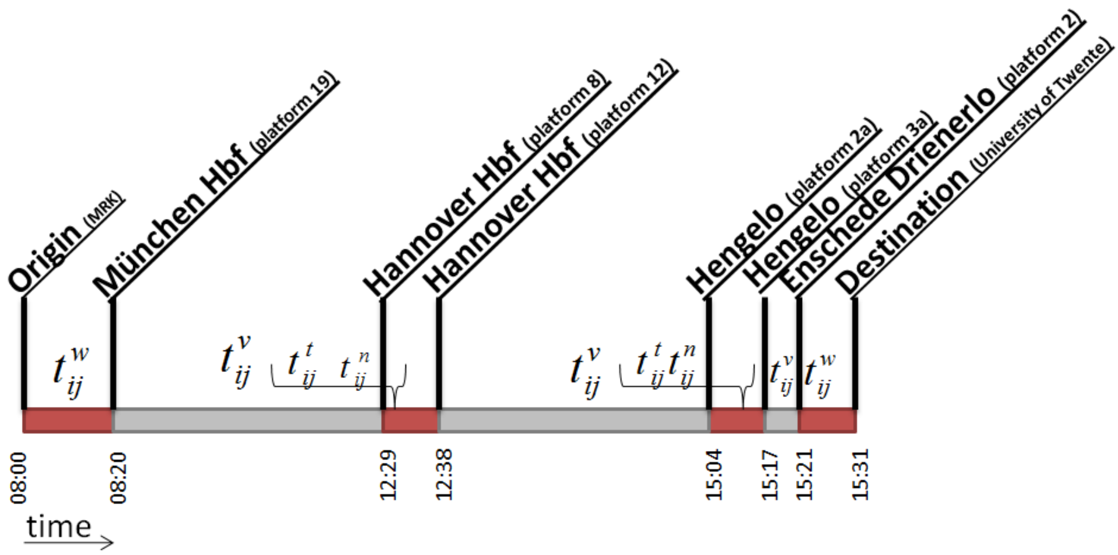


Figure 3: Overview of different travel time parts in a trip

In other research articles the same aspects as given in the formula given above have been found, and more. First the aspects given in the formula will be explained, then the others.

•Cost

One of the most mentioned aspects in the literature is cost. A differentiation is made between two kinds of costs. The real cost such as the fare for the trip is the first kind. The other kind of costs are how several sorts of activities are measured in costs, resulting in Value of Time (VOT) costs (Lo, Yip, & Wan, 2004) (Liu, Huang, Yang, & Zhang, 2009). These are both integrated in the formula given in the section above where the costs are the costs and the VOT is reflected by the different coefficients in combination with the different other aspects.

•Travel time

Travel time can be divided in several different aspects, being:

- The time needed to go to the nearest stop (access time)
- The time in the vehicle (in-vehicle-time)
- The time between two connecting services (transfer time)
- Excess time between two services (waiting time)
- The time to go from the last service to the final destination (egress time)

These will be discussed in this order. Travel time is an important aspect on which people rely to make the decision on what route to take. Also the number of interchanges that a trip contains is regarded as important for the route choice. An overview of the different sections of travel time is available in Figure 3: Overview of different travel time parts in a trip.

Access / Egress time and walking leg

The time spent between the origin of the trip and the first 'service' by the used kind of transport is called access time. Normally this trip is made by foot to the bus station, railway station or with a bicycle or a car (Cervero, 2001). In case of a taxi it is not clear to what time has to be taken. Initially one could say the access time is the time between the phone call for the taxi and the time the taxi arrives. On the other hand, this 'waiting time' could be expected and used for other activities, such as packing the luggage.

Egress time is the time spent between the last service and the final destination of the trip. According to Krygsman et al. (2004) egress and access time are the second important disincentives for public transport after transfer- and waiting time (see further).

Most of the access and egress trips are a walking or cycling activity (Krygsman, Dijst, & Arentze, 2004) making the walking leg an important part of a trip. The walking leg cannot be too large since a distance bigger than 800 m (Kim, Ulfarsson, & Hennessy, 2007) or 10 minutes (Abdel-Aty M. A., 2001) is perceived as very negative, which can result in larger travel times in comparison to other route choice possibilities which are rendered inactive due to the constraints above.

In-vehicle time

Travel time can have both a positive as a negative impact on the travel. Longer rides in a comfortable environment can give the opportunity to work or relax and this will have a positive impact (interviewed person in Redmond & Mocktarian (2001)). However, if the ride is short or less comfortable (e.g. no seat available) the travel time can have a large negative impact. This is also recognised by Lo, Yip & Wan (2004): "Travellers may have non-linear valuation of travel time – small amounts of time have lower value whereas large amounts of time are very valuable."

It can be concluded that travel time perception is experienced in a different way, based on the environment and the amount of time. The environments can be mode based, because different kinds of modes are experienced differently (bumpy bus ride vs. comfortable high speed train). Another kind of circumstances can be congestion based, there is a big difference in the experience between low occupancy and high occupancy (Curtis & Schreurer, 2010). In public transport there is also a difference between being inside a vehicle or not (Rietveld, Bruinsma, & van Vuuren, 2001). In-vehicle time is mostly passive and usable, while out-of-vehicle time is often transfer time (stress) or waiting time (unproductive-time) (Tapiador, Burckhart, & Martí-Henneberg, 2009), leading to different experiences of the same amount of time.

Transfer time

Transfer periods have to be long enough to offer a safe transfer to the connecting service, but cannot be too long, since it then will be regarded as waiting time. Since waiting time is a key element of the passenger's assessment of transit service quality (Wardman, 2001); (Luethi, Weidmann, & Nash, 2007) this could be one of the aspects to optimise to. No optimum time is mentioned in the literature, but this should be linked to the time interval between connecting services. According to Curtis & Schreurer (2010) there is a limit of three transfers per trip within the observed region of

Hamburg. If more transfers are needed, the trip is perceived as not being a viable option. Other studies do not mention a maximum but state that an extra transfer makes the trip less attractive.

In some literature the transfer time is taken together with interchanges. Every intermodal trip has an interchange, since a transfer has to be made from the personal transport to the public transport. Mode transfers can be uncomfortable, time consuming and carry an inherent risk of delay if the connection fails to arrive on time (Transport for London, 2002). According to Abdel-Aty (2001) and Lyons & Harman (2002) the desirability of a trip decreases if in contains more interchanges. Whether this is due to an effect on the in-vehicle time (long / short in-vehicle time with many / few interchanges (Guo & Wildon, 2010)) or based on the number of interchanges is not clear from this literature.

Interchanges inherently lead to extra time to be able to make a reliable transfer, which can result in extra waiting time. The waiting time is regarded as one of the key components of the attractiveness of a trip chain (Wardman, 2001) (Luethi, Weidmann, & Nash, 2007) and therefore has been studied quite a lot. Over the years several estimates have been made of the influence of waiting time ranging from 1.6 times as much as in-vehicle time to over three times the amount of in-vehicle time (Rietveld, Bruinsma, & van Vuuren, 2001)(Tapiador, Burckhart, & Martí-Henneberg, 2009).

A different insight is given by a study by Walter & Norta (2002) that waiting time is not weighed in a linear way, but that the weight of waiting time increases exponentially and thereby influences the attractiveness of public transport greatly.

•*Most mentioned*

In literature more aspects are given than travel time and costs alone. A selection has been made of the 10 most mentioned aspects:

- Cost
- Congestion
- (Un)Reliability
- Travel time
- Interchanges
- Access time
- Origin and destination
- Transfer period and connection interval
- Walking leg

The remainder of the aspects will be explained below.

•*(Un)Reliability*

Many kinds of reliability are given in the literature, relating from travel time reliability to interchange unreliability. The key aspects related to reliability are **travel time** (Lo, Luo, & Siu, 2006) (Abdel-Aty, Kitamura, & Jovanis, 1995) (Vande Walle & Steenberghen, 2006) (Modesti & Sciomachen, 1998) (Rietveld, Bruinsma, & van Vuuren, 2001) (Givoni & Rietveld, 2007) (Kenyon & Lyons, 2003), information (Calvo, de Luigi, Haastrup, & Maniezzo, 2004), **connectivity** (Lo, Luo, & Siu, 2006; Transport for London, 2002) and **service** (Hsu, 2010)

Reliable travel time is important in the traveller's route choice behaviour and is chosen by 54% of the travellers as being the primary or secondary reason for a chosen route (Abdel-Aty, Kitamura, & Jovanis, 1995) (Lo, Luo, & Siu, 2006). A reason for this is that low reliability costs time due to risk avoiding behaviour. If the (perceived) reliability is too low, people will use an earlier connection to make sure that they arrive on time by public transport (Rietveld, Bruinsma, & van Vuuren, 2001).

Connected to this is the reliability of the information about travel times and further actions during a trip chain (Calvo, de Luigi, Haastrup, & Maniezzo, 2004). If the information is incorrect then connections can be missed. Connection reliability is important since connections occur often in trips; missing a connection has a big impact on the travel time and includes waiting time (Transport for London, 2002). It is therefore very relevant in the total picture of reliability of travelling. This also connects to the reliability of the different services, a low reliability of one service in a chain can make the entire chain unreliable (Hsu, 2010).

•*Origin and Destination*

The bases of a trip are the origin (where the trip starts) and the destination (where a trip ends). These were not mentioned very often in the researched articles. Most of the times there is a reference to these aspects with a link to the travel distance. Another way the destination is mentioned is that the disutility of the trip itself is less than the utility of the destination, since travellers are expected to behave rational and will not undertake trips that cost more to perform than the utility at the destination is (Redmond & Mocktarian, 2001).

Other aspects found in literature are:

- Reliability of the information
- Barriers
- Remaining travel time
- Time saving
- Availability of the information
- Unfamiliar travellers
- Availability
- Egress time
- Pre-trip
- Parking availability
- Protection
- Possible connections
- Service reliability
- Time of day
- Distance
- Comfort
- Day of week (difference between days: Monday-Thursday, Friday, Saturday, Sunday according to (MDV, 2007))
- Journey purpose
- Familiar travellers
- Security
- Effort saving

- Area type
- Booking process
- Possible departure time
- Knowledge about stops/station in the neighbourhood
- Weather information
- Waiting time

iii. Park & Ride

The implementation of Park & Ride (P&R) systems in products that give a travel advice is not discussed often in articles. Most P&R related articles are reviews of P&R schemes with a dedicated bus service between the P&R place and the city centre while very little is found about routing travellers via P&R places. Garcia & Marin (2005) found that most P&R users explicitly choose the P&R for the trip. In other words: before finding a route, the P&R was already part of the solution (part of behaviour). One study researches the possibilities to implement P&R systems in a travel advice by adding the following aspects to the mix of used aspects to be able to optimise to the aspects cost and time in the search of a P&R routing: estimated parking place searching time, estimated walking time from parking place to the station, costs for parking and the occupancy rate of the parking lot (MDV, 2007). These can be summarized in travel time and travel cost.

According to Rehrl et al. (2007) the problem for intermodal routing is not only the routing aspects for the long hauls that are needed to guide travellers on their multimodal trip. It is especially the increased complexity of multimodal trips and the several kind of information sources needed. Roads have the similar layout, all over the world. In public transport modes however the stations and vehicles can be very different decreasing the recognisability and increasing the complexity when using them.
The result is that someone has to navigate through an environment in which he is not familiar. Orientation in an unfamiliar station or at a bus stop is difficult and guidance is needed for the traveller. While information about roads for cars is widely spread these days, information about how to get around as a pedestrian is often not available in a good format. The largest problem is that detailed information is not available, although it is needed by pedestrians for guidance in complex and poorly organized situations such as train stations.

iv. Overview

So far we have seen that there are some differences between the emphasis that is given to the aspects in the different sections of the transport. In the personal transport modes the congestion, stress and control are found to be important. Congestion is added time during a trip, while it also is involved in the stress levels and the level of control of the driver. These three aspects relate to how the driver feels during the trip.
In the shared modes the emphasis is on the costs which relate to the trip and to the time it takes to make a journey. Furthermore the reliability of the information about travel time, cost and connections (again measured in travel time) is mentioned. Looking at the P&R, special aspects such as unfamiliar surroundings are mentioned (control) and further some time related aspects that are related to the transfer from the personal mode to the shared mode.

The literature stressed the importance of the control that travellers have over their journey. It is notable that for P&R systems there has not been much research on how to develop such a system other than extending existing systems.

In the following section the existing systems will be discussed and analysed to see what kind of information is used in practice.

b. Aspects available according to practice

For selecting the aspects that are used in practice for routing personal, shared and intermodal routing advices several websites and systems were used that can give navigational advice. The websites have been reviewed through an analysis of the requested and given information for an advice. Not only the primary requested fields have been taken into consideration, also the possibilities that are accessible through the 'more' or 'extended' options buttons.
The next section contains the analysis of the personal mode websites.

i. Personal modes

For the analysis of the personal modes a number of websites have been reviewed that are capable of giving routing advice for car use. All the systems reviewed function quite similar and request the same type of information by forms as visible in Figure 4 and Figure 5.

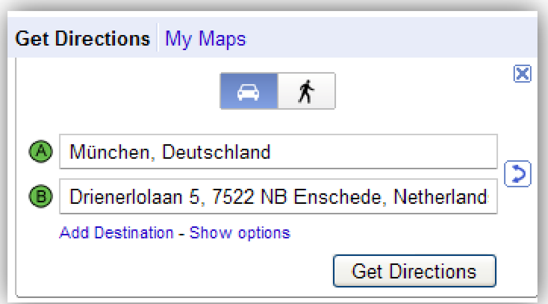


Figure 4: Google Maps routing form

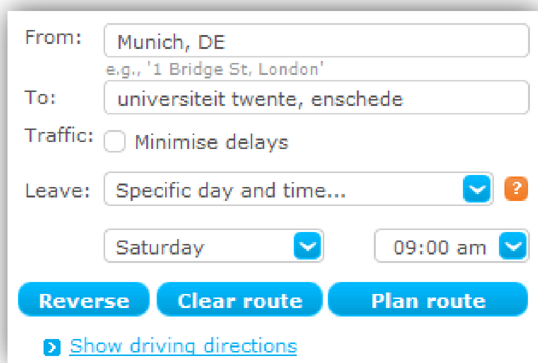


Figure 5: Tomtom routing form

The basic information requested of the users by navigational systems consists of the origin and destination information only. This is however not the only required information to make a navigational advice, in the back-end information is stored about the network. This background information is based on the real network as it is in the world, only simplified and stored with the attributes that correspond with the real features. In the background the network consists of arcs and nodes which represent the roads and the intersections in a network. An example is given in Figure 6 and Figure 7 which both represent the same network section. Most of the time the arcs are referred to as links.

Figure 6: Real network (around MRK HQ)

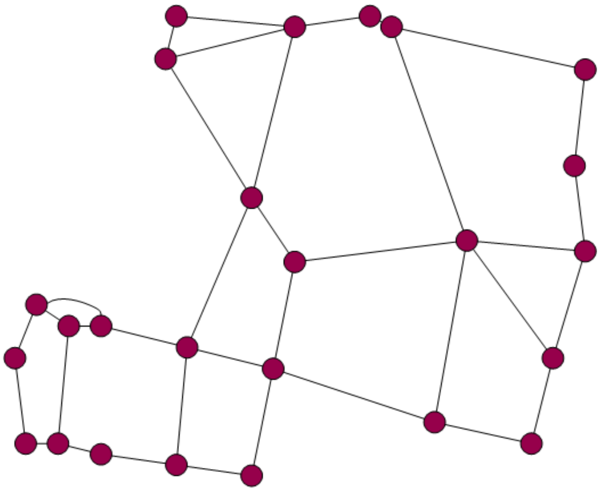


Figure 7: Network representation

Different real roads can have different characteristics, e.g. a road through a residential area is different from countryside roads or highways. The different characteristics are captured in the attributes that are assigned to the different links. Some attributes are:

- Maximum speed on the link
- Travel time (free flow) on the link
- Number of lanes
- Direction of the lanes
- Allowance of traffic kinds (car, bicycle, foot)

All the above attributes are static, but there are also attributes which rely on changing or real time information like the following:

- Historic speed at link per day per hour
- Actual speed at link (real time)
- Travel time delay at a link (real time)

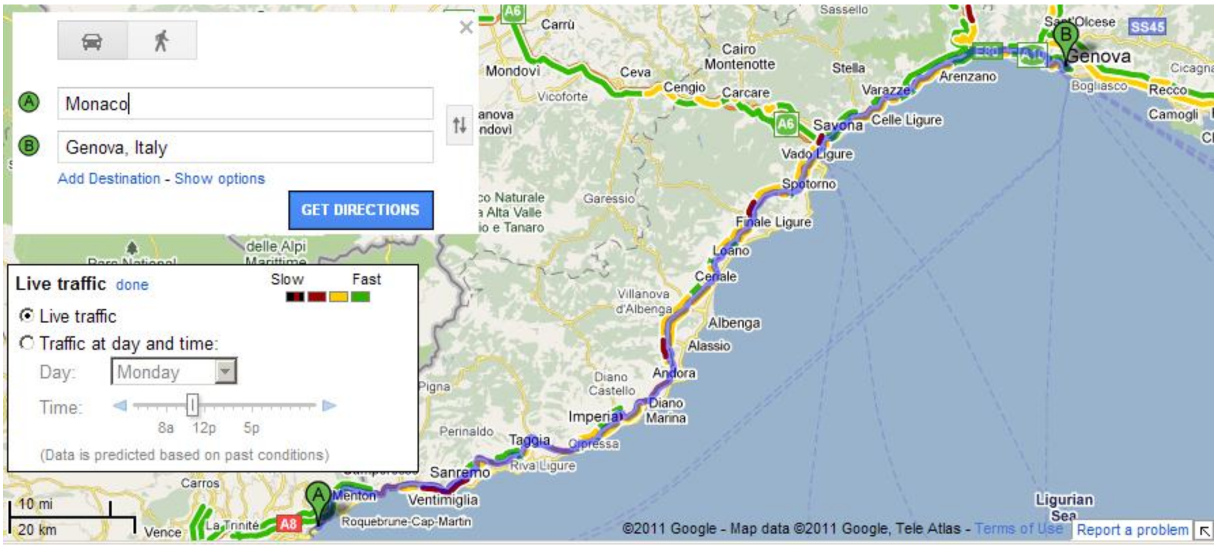


Figure 8: Google maps overview

Based on this information different advices can be made. How exactly the algorithms function is not available, the manufacturers are not willing to release this kind of information.

Looking at the outcome of the advice some more information can be extracted about the functioning of the algorithm and the required information for travellers according to these systems.

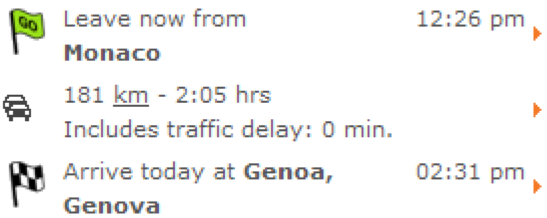


Figure 9: Google Maps summary

Figure 10: Tomtom summary

From these summaries it can be extracted that information about the length of the journey and the travel time are important, since both systems present this information. Further information about the costs is given and the expected delay. Although only the websites of Tomtom and Google Maps are mentioned in this overview, similar functions and outcomes have been found on other websites researched, namely:

- Map24.com
- Locatienet.nl
- Bayerninfo.de
- Routes.tomtom.com
- Maps.google.com

A complete overview is available in the Appendix A: Overview of found aspects in practice.

Other available options are alterations in the free flow speed of different roads, to match the user's characteristics. Most systems give only one final outcome, but what the basis of this outcome is, is not given, it is not clear to what routing objective this outcome has been optimized. Some websites give the following options to direct the outcome to the user's preferences:

- Shortest route
- Quickest route
- Optimal route

The shortest route is optimized to route the route over the minimal travel distance, the same is done with quickest route for the minimal travel time. Optimal route is an option given by locatienet which is 'a combination of the shortest and fastest route, in which speed is more important than the distance'. Google Maps seems to have a kind of algorithm which also looks at the number of instructions needed to give a route advice.

ii. Shared modes

For public transport a lot of systems are available to give a route advice. A quick analysis reveals that there are many systems available over the world. A selection has been made for this research that includes only three countries: Germany, the United Kingdom and the Netherlands. This resulted in two widely used systems manufactured respectively by HaCon (HAFAS) and MDV (EFA). Furthermore the systems of IVV (ASS), HBT (Geofox) 9292 and transportdirect.info have been reviewed. An overview of the analysed systems is given in Table 3.

Product	Manufacturer	User(s)
HAFAS	HaCon	Many worldwide
EFA	Mdv	Many worldwide
Geofox	HBT	HVV (Hamburg)
ASS	IVV	Some (only South West Westfalen)
9292ov	REISinformatiegroep BV	9292ov (NL)
(no product name)	Atis Origin / Department for Transport (UK)	Transportdirect.info (UK)
Google integration	Vmzberlin	Berlin

Table 3: Overview of shared transport navigation systems

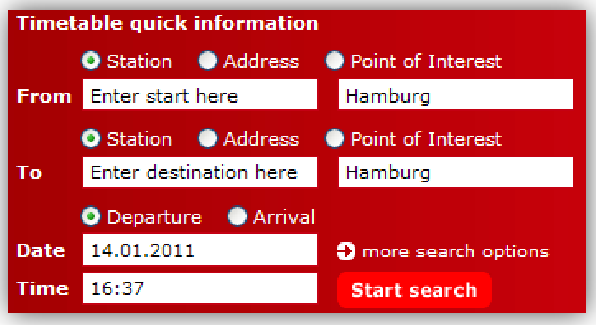


Figure 11: Geofox fill in form for PT routing

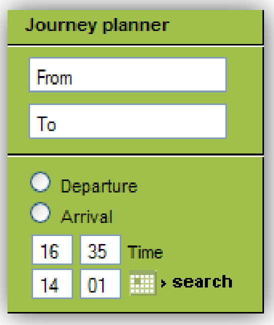


Figure 12: EFA's fill in form

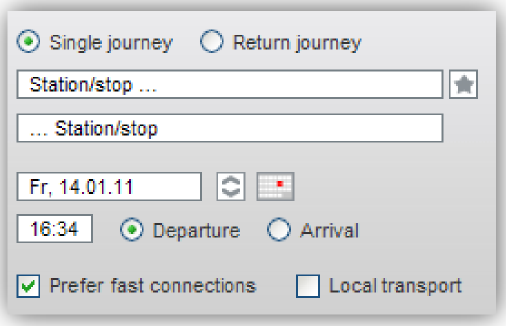


Figure 13: HAFAS's fill in form

Figure 14: transport direct's fill in form

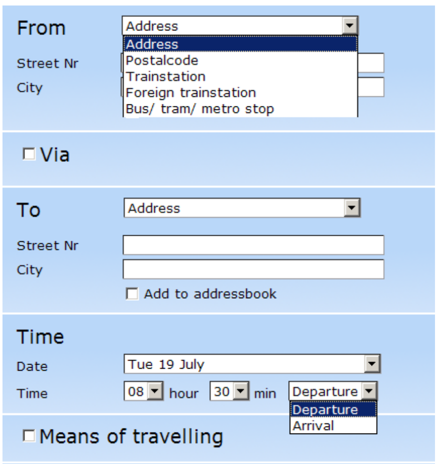


Figure 15: 9292ov's fill in form

The analysis is done in the same way as the personal modes were analysed. First the requested information by the systems of the user is analysed. All the systems make the following requests:

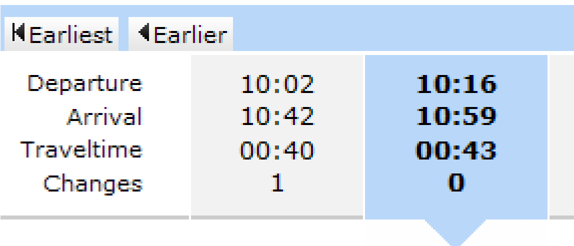
- Origin
- Destination
- Time of departure/arrival
- Date

The reason for requesting the origin and destination are clear, these are the two points between which the trip will take place. It is possible to give needed coordinates based on address, Point of Interest (POI), postal code or map input.

Furthermore the time of departure or time of arrival and the day on which the journey has to take place are requested. These attributes play a significant different role in public transport circumstances in comparison to personal modes. The background-systems rely on train or bus services that drive according to timetables. These timetables are not constant throughout the day or week, but show different headways on different times and days.

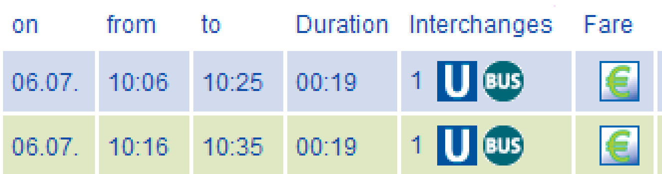
In the next step of acquiring an advice it is possible to change more preferences such as which of the different modes (intercity train, regional train, ferry, bus, metro) are allowed to use for a route advice. Access and egress modes can be adjusted in some systems, making it able to give door-to-door route advice. These access and egress modes include Bike&Ride, Park&Ride and Kiss&Ride options (as found in MDV based systems) as well as walking to the needed train station or bus stop (as found in most systems).

By investigating the advices that are given by the systems more aspects are revealed. The screenshots of the advice pages are in Figure 16, Figure 17 and Figure 18.



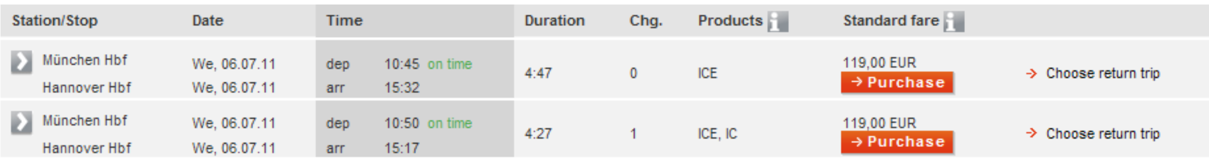
Earliest / Earlier		
Departure	10:02	10:16
Arrival	10:42	10:59
Traveltime	00:40	00:43
Changes	1	0

Figure 16: 9292ov trip advice



on	from	to	Duration	Interchanges	Fare
06.07.	10:06	10:25	00:19	1 U BUS	€
06.07.	10:16	10:35	00:19	1 U BUS	€

Figure 17: EFA trip advice



Station/Stop	Date	Time		Duration	Chg.	Products	Standard fare	
München Hbf Hannover Hbf	We, 06.07.11 We, 06.07.11	dep arr	10:45 on time 15:32	4:47	0	ICE	119,00 EUR → Purchase	→ Choose return trip
München Hbf Hannover Hbf	We, 06.07.11 We, 06.07.11	dep arr	10:50 on time 15:17	4:27	1	ICE, IC	119,00 EUR → Purchase	→ Choose return trip

Figure 18: HAFAS trip advice

The following used information aspects can be extracted from the screenshots:

- Different options of travelling
- Date
- Departure (from)
- Arrival (to)
- Travel time
- (Inter)Changes
- Fare
- Products

The different options for travelling reveal that there is more than one way to get from A to B via different routes or at different times. The second aspect is 'date'. This aspect is used for planning purposes to extract the day of week and day of year. This information is important due to different time tables over the week (during the week vs. weekend) and throughout the year (holiday, work week etcetera). The third and fourth aspect are the departure and arrival time, needed for the traveller to see what connections are possible within the time window that travelling is possible for the traveller. Most travellers want to be somewhere at a certain time (due to an appointment) or cannot leave before a certain threshold time (leaving at 05:13 (AM) for example is not feasible for everyone).

The travel time is given for the different options. We have already seen in the literature that travel time is one of the important aspects on which a trip choice is based. Also the perception of travel time is not equal over the trip, it notably rises when an interchange is encountered. This information is also given in the overview of options to travel. Furthermore the fare and the different products (modes) used during the trip are given, since not everyone is willing to pay full price to get the best comfort, but are willing to use less comfortable modes for a lower price and a longer travel time.

The fare itself is not always given on the analysed websites. Based on the analysis the following is worth to mention: fare systems are very complicated, especially when more than one transport company is involved in the trip chain. Most fare systems are complex because they are based on zone systems (rings or zones), tier systems (e.g. intercity vs. regional train) and/or fixed price systems for certain links (e.g. ICE services in Germany). Also it is possible to use subscriptions and saver fares for (certain parts of) the trip, which can have a big influence on the total trip price.

There are also many aspects used by only some of the systems, an overview of these is given in the following list:

- Maps of the entire trip (EFA, HAFAS, ASS, transportdirect, 9292ov)
- Maps of the interchanges (ASS)
- Maps of the access and egress trip (9292ov, HAFAS)
- Occupancy of the train (reserved seats/capacity) (sbb.ch)
- Travel distance (oebb.at, vmzberlin.de)
- Weather (gvh.de)
- Accessibility information (EFA) about slopes, stairs etc. on stations.

iii. Park&Ride

Some advice systems already have a kind of P&R option within their system, which can be found in the 'more options' section of the system. The following websites that give P&R advice as an option are analysed:

MVV München	www.mvv-muenchen.de
VMZ Berlin	www.vmzberlin.de
Danish Travel Plan (rejseplanen)	www.rejseplanen.dk
Dutch Railways (NS)	www.ns.nl
9292 Journey Planner	www.9292ov.nl
Ruhrpilot	www.ruhrpilot.de

Large differences have been found between the different websites and used systems. MVV, NS and VMZ give a P&R capable advice through limiting the access and egress modes in a P&R fashion, meaning using a car as access mode and walking as egress.

The used aspects are visible in the following Figure 19-Figure 24.

Website/system	Aspects

Datum: 6 juli 2011
Vertrek: w.d. van Dommelenstraat in HEERDE
Aankomst: Treinstation Utrecht Overvecht
Vertrektijd: 14:25

	Vervoersoort	Reistijd	Vertrek	Aankomst	Opmerkingen
route	openbaar vervoer	2:00	14:31	16:31	Buurtbus, Stoptrein
route	auto	0:59	14:25	15:24	reistijd is met mogelijke files en parkeren
route	auto - parkeren - OV	1:14	14:17	15:31	P+R Piet Mondriaanplein in Amersfoort

Figure 19: 9292ov P&R advice (part 1)

Aspects: Travel time, Departure time, Arrival time, Modes, P&R location, Origin, Destination

	Parkeerlocatie	Plaats	tijd	tijd	reisduur	per uur
snelste reis						
route	P+R Piet Mondriaanplein	Amersfoort	14:17	15:31	1:14	5+
andere mogelijkheden:						
route	P+R t Harde	t Harde	14:38	16:01	1:23	2

Figure 20: 9292ov P&R choice (part 2)

Aspects: Number of connections per hour

on	from	to	Duration	Interchanges	Fare
06.07.	11:14	11:52	00:38	2 U BUS	€
06.07.	11:32	11:58	00:26	1 S	€
06.07.	11:34	12:12	00:38	2 U BUS	€
06.07.	11:31	11:52	00:21	0	

Figure 21: MVV P&R advice (EFA)

Aspects: Date, Arrival time, Departure time, Travel time, Interchanges, Modes, Fare

Departure 12:08 → Arrival 13:31 Buy Ticket →

Wednesday July 6, 2011

Time	By car to Wezep (distance 8.0 km , duration ca 10 min.)
12:08	8181MA (W.D. van Dommelenstraat, Heerde)
12:18	Wezep

→ Show directions

Time	Station/Stop	Track	Direction	Journey details
12:26	Wezep	2	Amersfoort	Stoptrein (NS)
13:31	Utrecht Overvecht	3		

→ Show train stops © 2011 NS / ProRail

→ Information about stations
→ Shops, restaurants, etc. in the area
→ Put the travel advice in your calendar
→ Live departure times
→ Terms and conditions per carrier

Fare for travelling with OV -chipkaart	2nd class		1st class	
	Full-fare	Discounted fare	Full-fare	Discounted fare
One-way journey	€ 11.90	€ 7.10	€ 20.20	€ 12.10
Same-day return journey	€ 23.80	€ 14.20	€ 40.40	€ 24.20

Figure 22: NS P&R advice

Departure time
Arrival time
Track
Fare
Modes
Origin
Destination

Driving directions to Berlin-Tegel, Berlijn
24.17 km about 46 mins

Figure 23: VMZ Berlin P&R Advice

Travel time
Distance (entire trip)

Start	46535 Dinslaken
Destination	44787 Bochum

The route start time lies in the past. To consider traffic information for this route, the route start time has been set to the current time.

Start: between 11:26 h and 11:33 h	Journey time: between 0:46 h and 1:06 h	
Departure: 06.07.2011 11:27 h Arrival: 06.07.2011 12:04 h	Journey time: 0:37 h km: 49 km	

Figure 24: Ruhrpilot P&R Advice

Origin
Destination
Departure time
Arrival time
Travel time
Distance (car)

	At:	Duration	Chg.	CO_2	Price	Route
Bike + public transport	dep 12:49 arr 15:31	2:42	1	5.6 kg	From 112.10 kr.	Details
Car	dep 12:20 arr 13:39	1:19 – incl. rush hour	0 – without parking	16.9 kg	191.77 kr	Details

Figure 25: Rejseplanen P&R Advice

Arrival time
Departure time
Travel time
Changes
CO2 emission
Fare

All the used aspects are similar to the ones that are given in the shared transport route advice systems. The reason for this is that all the P&R systems are an extension of the existing shared transport systems. 9292ov gives more information if already is chosen for a P&R advice (visible in Figure 20) and is the only system that gives the number of connections per hour at the P&R.

The last system worth mentioning is pundr.hessen.de (P&R in the State of Hessen, Germany). This website is not based on an existing shared mode module and gives information about the different P&R's that are available in the area, giving information about the number of parking places, disabled parking places, bicycle parking places, accessibility information, parking costs, opening hours, occupancy, reservation of park place possibility, other available modes and other available products. An example is given in Figure 26.

If a P&R location and a destination are selected an advice can be requested directly via rmv.de (HAFAS).

In Table 4 an overview is given of the information that is requested by P&R systems and the information that is given by the P&R systems in an advice.

Parkplatzinformationen

Stellplätze PKW	17
Behindertenstellplätze	2
Fahrradstellplätze	ja
Barrierefreier Zugang	ja
Parkgebühren	keine
Einschränkungen	keine
Öffnungszeit	keine Begrenzungen
Auslastung	keine Angabe
Parkplatzreservierung	nicht möglich
Zusätzliche Verkehrsangebote	Bus Taxi
Sonstige Infrastruktur	täglicher Bedarf Briefkasten
Parkplatznummer	26701

Fotos

Figure 26: P&R Hessen information example

Needed information (input)	Given information (output)
Origin	Number of parking spots
Destination	Price for parking
Time of departure/arrival	Price for public transport (fare)
	Price for car use (petrol), distance
	Travel time
	Number of transfers
	CO2 emission
	Number of connecting services per hour

Table 4: Used aspects in P&R systems

c. Differences between literature and practice

The aspects that have been found in the literature and those that have been found in practice have some overlap, but there is a difference between the aspects found. The differences will be discussed in this section. Some aspects are already in use in practice but not mentioned in the literature while other aspects are recommended in the literature, but not used in practice. In Appendix C: Overview of comparison found aspects: Literature vs. practice an overview is given of the aspects that are found in the separate sections. In the next subsections the differences will be explained by mode.

i. Personal mode

Looking at the differences between the use of aspects in literature and in practice it is stands out that the information that is used in practice is more detailed. Foremost the information about the links is more detailed by knowing the allowance of traffic, maximum speed of the links and the travel time per link. Also it is possible to provide more information about the driver, whether the driver likes to put the pedal to the metal, or is more a 100 km/h on a highway type (driving behaviour). Origin and destination are not mentioned in the literature, but the need for these two is evident.

The most important aspects in literature are stress levels and control over the journey. These can be part of the routing objective; a definition of the 'optimal route' is not available, neither a formula for it nor a rule of thumb.

ii. Shared modes

The aspects for the public modes given by the practice are overview maps, travel distance and the weather. Although overview maps can be part of the guidance, the detail level is too low to guide travellers at the station level. The literature advocates to make use of access time. This access time is not visible within the information given, although these are mostly implemented in the walking leg to the first transport link. Furthermore connection interval is an aspect mentioned in literature, but only one occurrence is seen in practice. This aspect can give insight in the delay if a connection is missed. A way to see the connection interval in practice is to compare the different journey advices. Waiting time is also mentioned in literature, mostly as a 'cost' factor. In practice this waiting time is not given but only the transfer time. This includes the waiting time for a connecting service.
The last factor mentioned in literature is the reliability of several aspects: departure time, service and travel time. This information can be 'learned' by travellers by making a journey on a regular basis, but on the first journeys this information is not available. The basis for the importance of reliability information is the perception of the travellers. Local public transport (bus, tram) seems to have the habit of departing early to be sure to arrive in time (Rietveld, Bruinsma, & van Vuuren, 2001). If such information is available, the travellers do not have to take an extra margin in their access mode to arrive (too) early, and reduce the waiting time. The reliability of the service is not given, so information about any delays and the information about connecting services are unknown. Both these aspects are part of the reliability of travel time. On overview of the possible total travel time and the chance of these travel times can be based on historical data and prognoses based on real time information. This can help travellers who have a certain time window to arrive to choose the best journey available.

iii. Park & Ride

For the Park & Ride comparison the aspects that were already found in personal or public mode are not taken into account, for an overview of these aspects see the previous two sections. Then only the

possibility to include the occupancy rate of parking lots for P&R, the expected searching time for a parking spot, the extra monetary costs due to the parking and the expected walking time to the station are available from literature.
From the practice it is seen that P&R places are chosen by an algorithm, but it is unclear what aspects are involved.

Both literature and practice have their pros and cons in the use of aspects. The practice is more detailed while literature gives other fields of information to gather and use information.

In this chapter the analysis is done on the literature and practice to see what aspects are researched and used in route advising. In the next chapter the importance of the different aspects will be discussed.

Chapter 3 Importance of aspects

In the previous chapter many aspects have been found in literature and in practice. In this chapter their importance will be discussed. First the aspects that have been found in the literature will be discussed, followed by the aspects found in practice. In section c the flow of information between different aspects will be discussed.

a. Importance of aspects found in the literature

Based on the number of references found in the literature the importance of the different aspects is analysed. This resulted in the table which can be found as Table 5: Number of references per aspect in literature.

In the literature there is a group of 11 aspects, responsible for almost half of the total number of reference found in the literature. This group is written in italic in the table. The two most referred aspects and therefore most important aspects are travel time and wait.

Travel time seems to be the most important aspect, especially when it comes to the choice of a route. Within the travel time there is an important aspect: wait. This reveals that the experienced time is important to travellers, in which the time related to waiting is regarded as lost or more costly time than the other time factors during a trip.

The next aspect is transfer, this relates to wait in the sense that if a transfer occurs, waiting time is unavoidable. This is a strong correlation that is found in the analysis. Furthermore the number of transfers during a trip is a good indicator of the quality of the trip, since the likelihood that travellers choose a trip decreases if more transfers are included.

At the fourth place the cost related to the trip are found, another aspect which relates to the way that travellers differentiate between routes.
At the same step stress is found. This shows that stress is important during travelling. Stress influences comfort levels and experienced travel time. A main component of stress is the predictability level of a trip.

The information need is an aspect that is given by literature that relates to the information required by the traveller to make a journey possible. In personal modes only a map with the available links as a network is needed to start with. In shared modes however a network of services and schedules of the available services is needed. Also in case of a disruption the amount of information needed by personal mode travellers is less, they might just go on with the route as planned with an added delay or reroute to via a nearby link. Shared mode users however might get into the trouble that the foreseen route is not available anymore due to missed connections or other causes.

The last two aspects that will be discussed in extend are mode and routing objective. Mode is important due to the different comfort levels and different options that are given by modes. In a car the delay might be not experienced as bad as in a crowded carriage of a train or vice versa for someone who is working during the trip.
The routing objective relates to three previous given aspects, travel time, transfers and travel cost, which gives it such a high importance.

The other aspects in the table are not regarded as being unimportant, they each give their own piece of information to the total field of travel advice. Most of the aspects are incorporated by the aspects given above, e.g. the timetable is incorporated by information need and parking cost by travel cost.

Aspect	Number of references	Aspect	Number of references
travel time	*17*	vehicle operation cost	3
wait	*17*	time of day	3
transfer	*15*	parking cost	3
travel cost	*12*	need for travel	3
stress	*12*	incident	3
information need	*11*	delay	3
mode	*8*	uncertainty	2
routing objective	*8*	petrol cost	2
traveller's knowledge	*7*	in-vehicle time	2
travel distance	*7*	fare (transit cost)	2
non-recurrent	*7*	event	2
recurrent congestion	6	destination	2
frequency of service / headway	6	crowding cost	2
weather	5	time of arrival	1
walking time between	5	punctuality	1
time reliability	5	parking time	1
reliability	5	overcrowding is part of occupancy	1
comfort	5	origin	1
timetable	4	non regular situations	1
time of departure	4	transfer = interchange + wait time	1
predictability	4	freeway links	1
egress	4	detours	1
control	4	class	1
amount of traffic	4		
access	4		

Table 5: Number of references per aspect in literature

b. Importance of aspects based on the number of occurrences in the reviewed systems.

The focus has been on the systems that are available in Germany, the Netherlands and the UK (and implementations of the same systems abroad). The systems have been reviewed for the different kind of services that they produce. By this is meant that if a system can provide a route advice for both personal and shared modes, these both have been reviewed separately.

For the analysis a distinction is made between the input requested by the systems and the output that is given.

Input (requested information)		Output (information given)	
49	Origin	61	Travel time
49	Destination	61	Trip (Chain) [route]
43	Date	52	Departure time
43	Time (departure / arrival)	50	Arrival time
43	Train	35	# of interchanges
38	Bus	27	Distance
35	Tram	24	Cost
34	Metro	15	map(sections)
31	Foot	13	Disadvantage
24	Car	6	Travel time with common congestion
23	Via	4	Station map
20	Ferry	3	# of connecting services / hour
20	Bike	2	Weather
13	Trip chain	1	Occupancy
5	Choose P+R		
3	Avoid Toll		
3	Avoid Highways		
3	Change speed		
1	Cable Car		

Table 6: Overview of found aspects in practice

i. Requested information

First the required information will be examined. The top of the most requested information by the systems are origin and destination, both are in 100% of the analysed cases. This reveals that a routing system cannot function without this information, which is logical since the routing takes place between these two places.

The second in order of most requested information are date and time, only six systems do not require this kind of information to be able to give an advice. It turns out that all of these systems are focussed or only able to provide information for car journeys. This reveals that journeys that use personal modes do not require time and date information, while shared modes do. The reason for this difference in requirements is that shared modes rely on scheduled services that do not run every day and every moment, therefore information about the date/day and time is required to make a shared mode advice.

The different types of modes that can be chosen are also important. In the analysis it is found that systems that focus on car journeys do not provide different mode options to choose from. The systems that provide P&R and shared mode journeys do give the options of selecting the different modes which are accepted to travel with. Bahn.de does even differentiate within the train class by giving the options of ICE, EC/IC, D, NV (translated these are: High speed train, Intercity Train, Regional Trains, Local Trains). This is also found in some other systems.
The differences in frequency that modes occur in systems is based on the local availability of modes; Train, Bus, Metro and Foot are the most common found modes in the systems, while the Cable car is only available in the system of the SBB (Switzerland).

The possibility to influence the routing of the advice is possible by adding a "via" route point. Looking at the number of times this option is given, this is quite an important feature since half of the systems have this option available. The "via" feature is found at equal frequency in the different kinds of systems (personal, shared, combined).

The least found options are P&R, avoid Toll, and avoid Highways and the option to change the preferred speed.
Change speed is found on two car journey based systems and one bike journey based system. This is natural, since shared mode systems are scheduled and therefore have no speed that can be changed to match the user his preferences. The same goes for the usage of toll and highway control in journey routing.

Choosing a P&R requires a trip that uses both shared and personal modes. This option is found in systems that provide route advice that includes both shared and personal modes, since the P&R is the place where the change can be made from one type of mode to another, not many of these systems have been found relative to the analysed systems, which is reflected in the number of appearances.

ii. Given information

At the side of the information output one kind of information is given in all the different systems: travel time. This gives the time it will take if the journey is made according to the advice given by the system. This gives that the information about travel time is very important to the users of the system. Also the trip itself is given each time, listing instructions on how to carry out a trip.

The next two most found pieces of information are departure time and arrival time. Every shared mode and mixed mode system provided this information; some personal mode advice systems however did not give this information. All car journey related did give this information. These findings are similar to the findings of the departure time and the arrival time in the requested information.

The number of interchanges that are needed to make the journey is found in half of all the systems. In personal mode systems the number of interchanges is zero and not important, but in the mixed and shared mode systems it is important, since it is found in almost ¾ of the analysed systems.

In the personal mode systems the information about distance is mentioned in all systems. This is because of the strong relationship between the distance of a trip and the cost and time it takes to make the trip, two other important pieces of information, which have been discussed before (time) and after (cost).

The costs are found in most shared modes systems as an outcome of the trip generation. In mixed systems half of the reviewed systems provide information about the cost of (part of) the trip, but in personal mode systems it is less than a quarter of the reviewed systems that provide information of the costs involved. This is due to the fact that the cost can be very different from user to user, because it is mainly based on the variable costs that occur when using a vehicle. These costs can differ a lot from car to car or from scooter to bike. Since most of the costs are distance related, most systems only provide the distance, require less information from the users to give a feasible advice to the users.

Most personal mode systems provide a map of the route chosen by the system. This is also done for the mixed systems, at least for the personal mode part. Shared mode systems do not always provide a map of the route, for shared modes systems it was found mostly in HAFAS based systems. Sometimes a map is provided that gives information about the actual start of the trip and where the first service starts. The same is done at the final end of a trip. Some systems incorporate gathered data about regular congestions into their systems, all the occurrences of these data are found in the personal mode or in the personal mode part of mixed systems, but not in shared mode systems.

Some pieces of information were only part of shared mode systems such as maps of the stations that are used as transfer point and the occupancy rate of the service chosen based on historical data. The occupancy rate is the shared mode kind of congestion, but not in a time delay like in personal modes, but in a comfort decrease.

The number of connecting services per hour is only found in three systems, once in a mixed mode systems at the level where a preferred P&R is chosen (9292) and twice in a shared mode system (avv.de and rejseplanen.dk). In other systems this information can be derived from the different advices given at different time points(in shared mode systems), but this information is not explicitly given.

The last piece of information that is found in two systems are the weather conditions, one time in a shared mode system (gvh.de) and one time in a mixed mode system (bayerninfo.de), but to what extend is not clear.

c. Cumulating literature and practice

Literature and practice show some difference in aspects but also in importance. In this section the findings of both fields will be discussed and merged into one importance table.

Based on the overviews given above from literature and practice an accumulation of importance can be made. In both the literature and practice analysis travel time has a high score.

The also first rated aspect wait in the literature is not available in practice, due to the fact that it is incorporated in the time between services in practice. This time is not given in overviews but used in the background system to make a travel advice. The same goes for the aspect transfer.
In practice the origin and destination are widely used, but they are almost not available in literature. This can be due to the fact that this information is so standard that it is not specified anymore. The related times with the origin and destination (time of departure and time of arrival) represent the

same importance between the two analyses, highly used in practice but less mentioned in the literature.

Cost and distance are related aspects which are used in about half of the analysed systems, in the literature the cost which are related to travelling are represented quite well. The distance of the journey is less reported, due to the fact that the distance is being represented in the costs in quite a lot of cases.

An aspect like stress is not found in the available systems, since it is difficult to incorporate it at the usage level. In the literature this aspect has a lot of references, mainly related to travel time and especially delays in time.

The mode which is used for the trip has also been found in both the analysis in practice and in the literature. In trips where only personal modes are used this is less relevant, since the mode choice is highly influenced by the personal preferences of comfort. Due to the personal ownership of these modes the level of comfort most of the times represents the need of the user. (high standards, high level, expensive car for example).
In both analysis aspects related to delays are found in the form of 'non-recurrent congestion', 'recurrent congestion', 'common congestion' and 'delay'. Separately these do not have high scores, but taken together they are relevant. In practice this information about delays is most often found in car mode journeys, some public transport sites do offer information about delays as well. But this information is not incorporated into the advices, only a warning is given that a transfer is probably not feasible based on the current information.

Based on the results the aspects are listed below. The categorisation of the aspects is based on the occurrences in the systems. If they are needed in for an advice, they would be recurring in every system and placed in the category 'need'. If the aspect is not needed, but makes a route advice better or more convenient, the aspect is placed in the category 'nice'. At last the aspects that are not common in use yet, or only available from the literature, these are placed in the 'superb' category.

Need	Date / day Timetable Network (personal and shared modes, P&R's) Travel chain - Departure time / Arrival time - Origin - Destination Number of transfers Cost (fare, petrol) Route Travel time
Nice	Routing objective: Number of connecting services Distance Personal speed preferences Via routing point POI information Distance Number of connecting services

Superb	Route on a map
	Time of departure / arrival
	Historical information
	Prediction on current situation
	POI availability / occupancy
	Expected delay
	Occupancy
	Current location
	Convenience level of modes
	Convenience level through weather
	Expected delay through weather
	Delay due to weather, accidents, (current status of the network)
	Rerouting
	Stress
	Personal preferences settings

Table 7: Aspect analysis

d. Information flow

For the traveller a routing advice system gives an output in which a route is given that can be executed by the traveller. The output is based on several processed which have been revealed in the analysis of the systems used in practice and the advised practices from the researchers in Chapter 2. In Chapter 4 Usage of the identified an analysis is done to see what kind of information is used by the traveller. In this chapter the links between the several aspects will be analysed based on the information that has been found before in the literature.

During the literature many descriptions have been found that explain the interaction between different aspects. A list of these descriptions is available in Appendix B: Overview of aspects found in literature, presenting quotes from literature and the translation to the definitions as used in this research within brackets [...].
The interaction of the different aspects reveals a dependency of the aspects and a flow of information. An example is the expected travel time; Hall (1993) states that '*travel time = free flow travel time + recurrent congestion delay + additional non-recurrent congestion delay'*. Translating this information into a diagram leads to Figure 27. It is also known that recurrent congestion occurs during rush hours during working days, making recurrent congestion time of day and date (or day of week) dependable as visualized in Figure 28.

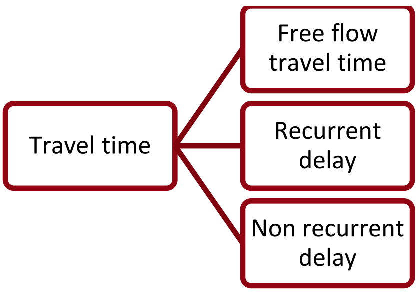


Figure 27: Travel time dependencies

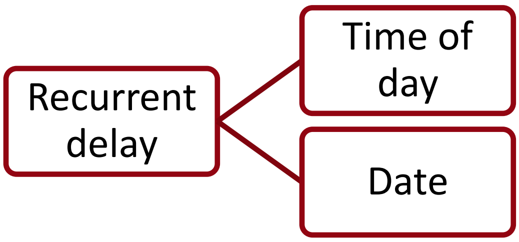


Figure 28: Recurrent delay dependencies

If these figures are combined it becomes visible that the time of day and date have a relation to the travel time, this information has to be known to provide a travel time as visualized in Figure 29. In this figure the information flows from right to left, meaning that the time of day and date have to be available/provided to be able to give travel time.

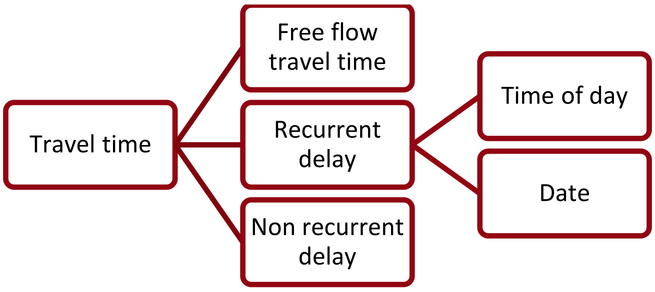


Figure 29: Extended travel time dependencies

This process has been done for all relations that have been found in the literature leading to the relation diagram in Figure 30, Figure 31, Figure 32 and Figure 33. The second, third and fourth figure are the detailed relations within the cost, time and distance boxes, in order to keep the overview clear.

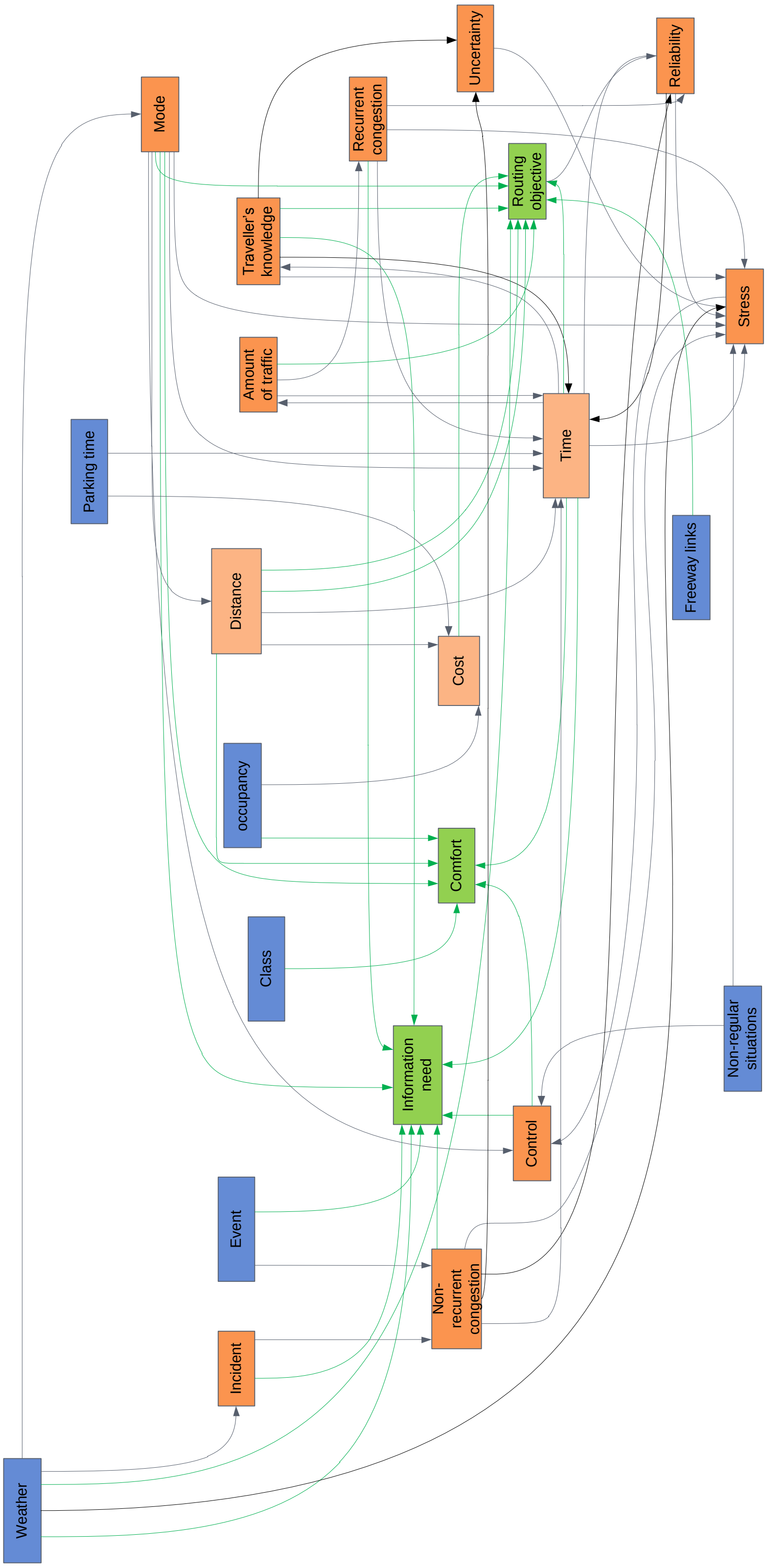


Figure 30: Relations between the aspects

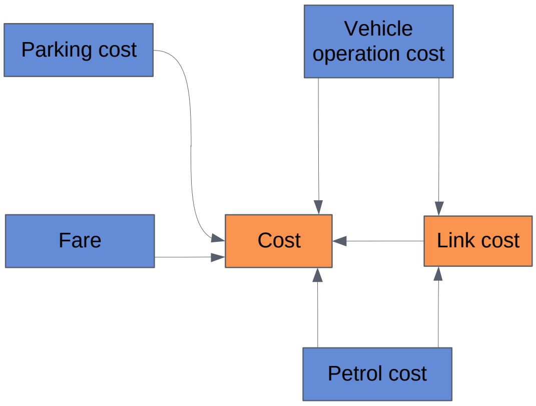


Figure 31: Relations between cost aspects

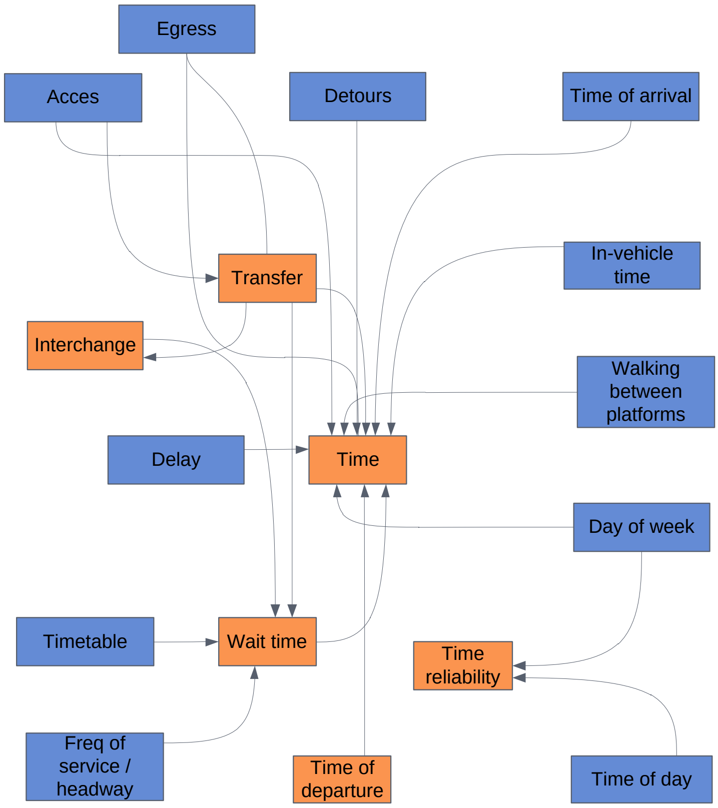


Figure 32: Relations between time aspects

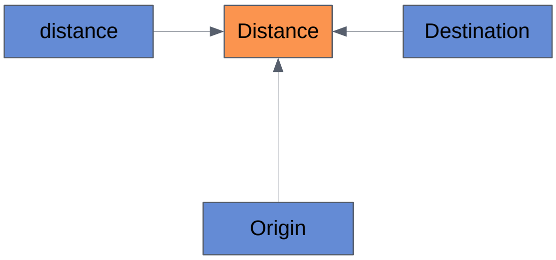


Figure 33: Relations between distance aspects

The different colours of the boxes relate to the dependencies that the aspects have in relation to each other. The blue boxed aspects give information to other aspects, but do not rely on other aspects according to the literature. These are the aspects from which the information can be derived to build a route advice, these also point out what information sources can be used. The arrows represent the way that information flows between the different aspects. An example will be taken to demonstrate the working of the diagram.
Looking at the aspect ‘weather’ three different streams of information flow out, but none flow in, making the weather a bottom aspect. Weather data can be taken and through the aspect weather the information flows to three different other aspects: Incident, information need, and mode. Looking further into the aspect ‘incident’ the one arrow from weather is found, as well as two outgoing connections to ‘non-recurrent congestion’ and ‘information need’. The incoming connection from weather is based on the risk of incidents on the road, which has a strong relation to the weather. But not all incidents are weather related, making that incident also is based on information only found in this aspect. Further the outgoing to ‘information need’ is a final aspect, visualised by the green box. Only incoming connections are found for these aspects. These aspects do cannot exist on their own, their value is based on the information by the other aspects related to them. This does not mean that only the green coloured aspects provide an output which can be used by travellers, that quality is available for every single aspect.

An attempt has been made with the data visualisation tool ‘Tulip’ to categorize the aspects into groups. Tulip is ‘an information visualization framework dedicated to the analysis and visualisation of relational data’ (Auber, 2012). Many algorithms to position the aspects and their relations are available, based on hierarchy, minimal connections length, push-pull relations and minimum of connection crossings.
This did not lead to a clear result, the many relations between the aspects make that the aspects are intertwined and the overview looked like a big tangle of aspects with their connections. There are no groups of aspects that nest together based on their relations. Also the basic functions of Microsoft Visio (2007 and 2010) to organize the aspects did not give a result which gives any insight in the big picture of the relations of the aspects, the algorithms did even perform worse than the Tulip program.
Including the number of times that relations between aspects were found in the research has been the final try to organize the aspects. The goal was to make the connections that are found more often stronger, giving a bigger weight to relations that are more common. In Visio this is not possible and in Tulip the outcome is not repeatable. Based on the (random) beginning situation the algorithm starts to work, finding different local optima solutions.

Chapter 4 Usage of the identified aspects

In Chapter 2 Known and used aspects for intermodal trips an overview is given of the aspects used in practice and the aspects which are used in models (theory). In this chapter the usage of the aspects will be analysed, when is what information needed by the travellers and what is the influence of the information on the journey. This will be done by an analysis based on Activity Theory (AT) to see what information is used when by the traveller.

a. Activity Theory

First the historical background and the basics of activity theory will be explained in section i. History of activity theory and section ii. An overview of activity theory. In section iii. Appliance of activity theory will be explained how activity theory will be applied in this research.

i. History of activity theory

The activity theory is a philosophical framework used to conceptualise the human activities. The theory was developed by Vygotski, Rubinsthein, Leontiev and others in the beginning of the 1920s in Russia (Kaenampornpan, O'Neill; 2004). The theory has its roots in the German philosophy of Kant and Hegel during the Age of Enlightment, the writings of Marx and Engels during the 19th century and started in the cultural-historical psychology of Leontiev, Luria and Vygotski in the beginning of the 19th century (Engeström, 1999)(Kaenampornpan, O'Neill; 2004). In Figure 34: Roots of Activity Theory an overview of the different philosophical movements and the related persons as mentioned is given.

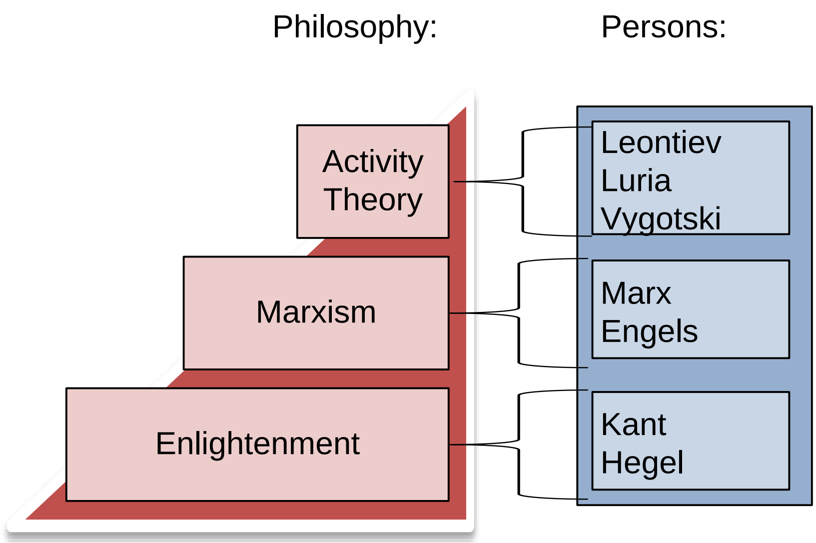


Figure 34: Roots of Activity Theory

ii. An overview of activity theory

The activity theory is a framework which makes is able to give an insight in the interaction between persons, their environments and the tools that the humans use to interact with their environment. In the interaction between the person and his environment the person does actions within the rules set by himself or his environment. In Figure 35: Activity Theory scheme the Activity theory is shown in a graph.

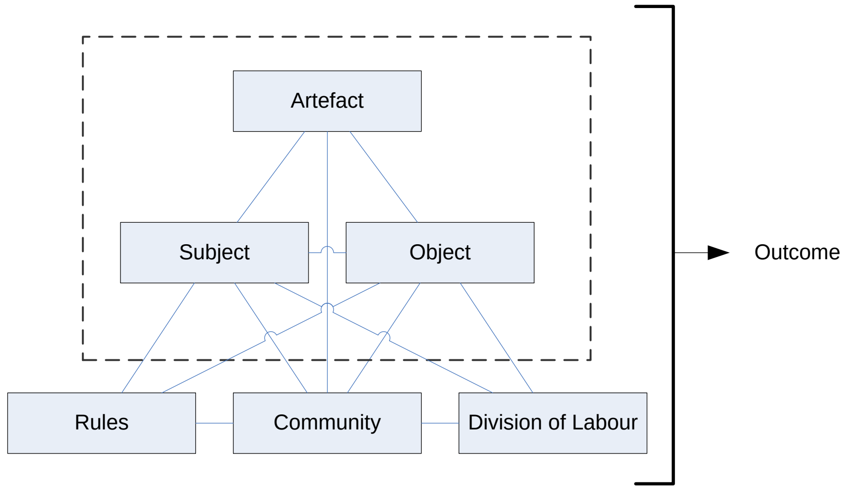


Figure 35: Activity Theory scheme (Engeström, 1999)

The scheme represents the Activity Theory framework. It is visible that different parts of a social network interact with each other to get to the outcome. At the top there is the 'artefact', this is also known as the tool that persons can make or use. Below the artefact are the 'subject' and the 'object'. The subject is the person on which lies the focus in the breakdown; how the interaction between the person and its environment is, in this research this is the traveller who wants to travel. The object is the goal the subject wants to reach, during this research this is to get to the destination where the traveller wants to go. To do this the artefact will be used, in this case the information for travellers by which they can make their decisions and planning how to travel when.

These three parts (artefact, subject and object) are placed within a box, since these will be analysed in this research and can differ from person to person and motive of travel. The other three boxes in the figure are 'rules', 'community' and 'division of labour', these three are the influences from the social environment on the subject, object and artefact. The subject cannot do whatever it wants to do; it will have to obey the rules set by the subject itself. In the scope of this research it can be thought of the preferences the travellers can have. The second box is the community which also forces the subject to behave is some ways because not all the rules set by the subject itself comply with the rules of the community. In the scope of this research can be thought of driving over the roads instead of cross country driving through the fields. The last component is the division of labour; in the framework this is the possibility to work together with other members of the community to share a task. In this research this aspect will not be taken into account.

For a deeper insight of the activity theory 'Modelling context: an activity theory approach´ by Kaenampronpan & O'Neill (2004) is advised.

iii. Appliance of activity theory

The activity theory is used in this research to break down the process of the needed information of travellers. In this way one of the strengths of activity theory will be used, its ability to identify the role of artefacts in a work progress according to Kofod-Petersen & Cassens (2006). The activity theory framework will be used in this research to find out what information is needed from a user perspective when someone wants to travel from A to B. This will be based on several scenarios that will reveal the aspects needed in the several parts of a journey.

iv. Why Activity Theory?

In this research the activity theory model has been chosen to use due to the lack of abilities of other evaluation models such as Cost Benefit analysis, Multi Criteria Analysis and Probability method. By using the Activity Theory it is possible to analyse the process of travelling and the needed bits of information throughout a journey. This makes it possible to find out what information is used when and it is possible to run different scenarios to see what the influence is of using certain information or not. An overview of the assessment of the different choice models is available in Appendix D: Different methods available for research.

Although the activity theory focuses on the information needed by the traveller (output) the analysis is still useful by revealing what information is needed to make a trip possible. By looking into the processes that provide the information not only the output is revealed, but also the needed input to generate the output.

b. Different motives

The reason why a journey is undertaken changes from destination to destination and it can even change from time to time for the same destination. Due to different environments the need for information can also be different. To cover all kind of information needs by travellers a number of scenarios is designed to see what information can be used or requested by the users in the different situations. The user types are based on the most common travel motives in Europe. An overview of the analysis of the motives in Europe (the UK, the Netherlands and Germany) is available in Appendix E: Overview of motives for travelling. An overview of the conclusions can be found in Figure 36: Motives for travelling. Two outcomes are given, a top 5 and a top 7, due to incompatibility of the sources about motives for travelling in different countries. The motives 'Visiting friends' and 'Personal Business' were not defined in the all the sources (respectively not defined in the German and the English reports, as is given in Appendix E: Overview of motives for travelling). But since they both have a significant outcome in the other research they have not been taken out of the research.

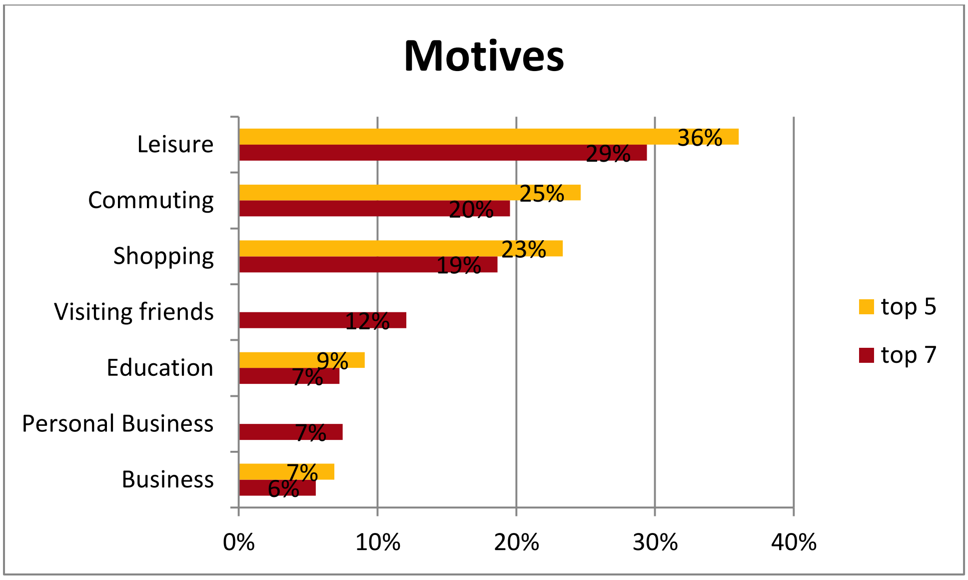


Figure 36: Motives for travelling

c. Different time frames

The different types of time scenarios are based on the different levels of information provisioning of the information keeper. In this case the information keeper could be the local public transport authority providing the information on the public transport. Also it is possible to see a difference between the levels of information being delivered by different devices: static information delivered by time tables at stops / stations or available from leaflets of the public transport company. The second level is information which has been enriched by historical information and statistical data and is able to give some type of prognosis instead of the time tabled times. This level of information is available in newspapers (e.g. the traffic forecast) or via internet. The last level is information based on the current status of the network. This information can be broadcasted to devices in different ways, but RDS-TMC and internet are the most used types.

An overview of all the scenarios is given in Table 8: Different scenarios.

User types:	**Leisure**	**Commuting**	**Shopping**	**Education**	**Business**
Time frames:	static time	prognosis	"real time"		

Table 8: Different scenarios

A quick description of the different user profiles is available in Table 9: Overview of user characteristics.

The users of the system will include every day commuters, who are familiar with the system and want an advice which tells them what their quickest way to work or home is. The user base will also include tourists, who do not have an idea how the local transport system works, the route possibilities and things that can be interesting to do. Also it can be imagined that someone who is a commuter during the week can go shopping with the family during a weekend, this might influence costs and/or preferences due to a subscription for a certain service, which can reduces fares in this case and so on.

Motive	Characteristics of a journey
Commuter	same trip every day
	at the same time
	route is known
	regular delays are known
Leisure	different destinations every trip
	therefore different connections
	route is probably not known
	based on availability
Shopping	short trips
	local destinations
	routine
Education	same destination
	same time / day
	already known information is high
Business	recurrent journeys, therefore ...
	- knowledge of the destination
	- knowledge of traffic situation
	time restraint (fixed appointments)
Visiting friends	can be both local and far away
	different destinations
	information about route may be known
Personal Business	probably local
	route may be known

Table 9: Overview of user characteristics

d. Example of the application of activity theory

To see how the activity theory works one of the scenarios is explained fully in the text below. In this way the needed information and the given information during an intermodal trip are given.

An overview of the entire analysis can be found in Appendix F: Results of Activity Theory analysis.

In Table 10: Example of the application of Activity Theory an overview is given of the information need and the information given during an intermodal trip of a user that makes a certain trip for the first time. The trip goes from a start to a destination using a car as access mode to a P&R and uses both train and bus as public transport modes is used in this example. In this case the artefact is the information needed at different activities during the trip to be able to give a good advice. The object is throughout this example the same (someone going from start to finish), and therefore not described. In the first column the activity is stated, in the other columns the aspects or information needed to do or to improve the activity are stated.

Activity	**Needed artefact**		
Start			
plan your trip	from where (location)	to where (location)	what time to depart/arrive
get your coat	what is the weather	time (of departure)	
get to your car	location	access time	
get in your car		access time	
drive your car to P+R	distance	driving time	route, entrance
park car at P+R	location	reservation	
get ticket for parking the car	costs	walking time	location
go to train station	distance	walking time	location
go to a ticket vendor	location		
buy the needed ticket	costs	information about the network	
walk to correct platform	distance	walking time	location
wait for the train	waiting time		
get on the train	time		
travel by train	travel time	comfort	
arrive at destination by train	time		
walk towards the bus stop	walking time	location	
arrive at the bus stop			
get a ticket for the trip	costs	location	
wait at the bus stop	waiting time	location	
get into the bus			
travel by bus	travel time		
arrive at the bus stop	location		
locate your (call-a-)bike	location		
unlock your bike	code	costs	
cycle to destination	travel time	comfort	weather route
lock the bike	location		
arrive at destination			
Finish			

Table 10: Example of the application of Activity Theory

Based on this example it is possible to extract that information about the (current) location of a target, the current time and the time it takes to do something are the most recurring artefacts in this example. This leads to the conclusion that, if a multi-modal trip is made with the use of real-time information as in this example, the following aspects are important:

- ***Time***

Describing both the time of the different trip parts as the current time related to them

- ***Location***

Both the location of the sub destinations (stops/stations/vending machine etc.) as the current location in relation to the earlier mentioned locations

- ***Cost***

Of the different sub trips per mode and the entire journey in total.

This leaves the aspects comfort, code and weather as less important aspects in the information provision in this example.

e. The results of the activity theory analysis

For the activity theory analysis the information as given in Table 8: Different scenarios and Table 9: Overview of user characteristics have been used.

i. Overall outcomes

An overview of all different scenarios is visible in Appendix F: Results of Activity Theory analysis.

Based at the different outcomes based on the time scenarios (static, prognosis or real-time) it is clear that the difference in the advices between static and prognosis are rather small. The changes are only in the advice given which could be more like the current situation instead of the time tabled situation if there are announced disruptions such as disruptions caused by scheduled maintenance and information about fares which are not included in the static advice. The step to real-time does add a lot of information in the different scenarios. Especially information about non recurrent events such as delays or usage of parking lots is more up to date than in the other scenarios. Further does it give the option to take over some of the decision making and rerouting of the traveller, based on the latest information instead of knowledge of the traveller itself.

Looking into the different user scenarios a couple of conclusions can be drawn. Although made by travellers of different age, the scenarios for commuting, business and education user are quite similar. Both have tight schedules with high punishments if the desired arrival times are not met. Because of the desire to arrive on time they both have a quite high benefit of the real-time information delivery in case of alterations. The difference between the user scenarios is the knowledge of the area. Trips with an educational motive are most of the time to the same location on the same time, business motivated trips however can spread throughout the time and location, resulting in a higher gain of added knowledge from a route advice.

ii. Outcomes of the process

The analysis is done according to the scenarios given in Table 8: Different scenarios. As already shown in Table 10: Example of the application of Activity Theory, the information about the time, costs and location are the most used during a trip. Looking at the static information requests it is visible that for regular travellers (motive: commuter and education) there is only a request whether there are some changes in the normal status or not. The same goes for the prognosis scenario for these two.

Looking at leisure there is a bigger request for information about the costs and travel times already in the planning phase. This corresponds to the fact that the destination itself is not the motive to travel, but it is more a possibility to fulfil the desire for leisure. The differences between static and prognosis is the same as under the earlier mentioned motives: the possibility to use non time tabled information.
The step to real-time information providence gives the possibility to make last minute changes to get the maximum amount of leisure, instead of arriving at a predestined destination, in case of disruptions or overcrowding.

The last motive is shopping, since the destination is chosen for its offers or just based on habitual reasons. Here the planning is not really part of going somewhere, it just needs to be done.

The activity theory process also reveals the use of aspects during the different static, prognosis and real-time time frames. Real time aspects such as current delays during a trip are not applicable in static or prognosis situations, but static information such as the destination is needed at every time frame situation. Based on the analysis it can be concluded that aspects and information that is used in the 'simpler' static time frame, is also used at a 'higher' time frame such as real time. In Table 11: Aspects per time frame the overview is given of the usage of the different aspects per time frame.

Static	Prognosis	Real time
Arrival time	historical information	Current location
Day	Occupancy	Current delay and expectation
Date	Prognosis information	Stress
Departure time		
Destination		
Distance		
Mode preferences		
Network links		
Number of connecting services		
Origin		
POI		
Routing objective		
Speed preferences		
Via		
Weather		

Table 11: Aspects per time frame

f. Removal of some information

Too further investigate what role the information plays in the usage of people a few scenarios were thought of how useful an advice would be without information about some of the aspects used in the normal or full advice.

i. Cost information

Information about the cost occurs in different part of the information stream as has been visualised in Figure 30: Relations between the aspects. The travel cost consists of the following parts:

- Parking cost
- Fare cost
- Link cost
- Link distance (fuel etc.)

For regular travellers the costs can be estimated quite easily, since they have developed knowledge about it and can have a subscription. At least for the trips they make on a regular basis. If a traveller is taken out of its regular travel environment this situation changes, then their knowledge about the costs gets less and are they depended on resources to provide this information. This goes for usual car users about the distance – cost relationship for a trip and for regular public transport users the same applies. Although the relationship for car users is valid for a rather big region (there is only a difference in gas prices in different countries which influences the cost price), the region for public transport travellers can be rather small. This is because of the different fare systems used in different regions and even different cities within a region, which compromises the knowledge of public transport systems they have from their own region.

Parking cost can be a significant factor in the total amount of costs of a journey, depending on the destination this can be for free to 5 euro / hour (highest in Amsterdam (Kodransky & Hermann, 2011)). Since most of the time the parking place (or parking area) is already chosen based on the destination this affects only the information stream while making the decision where to go.
If several car parks are available, the decision can be made on arriving in the area, based on the costs and availability. If parking costs are not available in this stage, it does not really influence the travel advice, since the parking costs are quite similar due to market processes.

ii. Time information

There are some rules of thumb that come into play when information of traffic time is no longer available, especially for personal modes in standard situations. In the case of (public) modes this is more difficult, since there can be a great variety in the services per hour and destinations. Basic information is almost always available at stops/stations in the form of timetables or announcements.

During a trip it is harder to reroute the journey in case of disruptions or delays if information about the arrival / departure /delay of the services is not available. This will increase the stress level of the traveller because the outcome of the trip is not clear, not even whether the trip can be executed or not. In shared modes some information can be extracted out of the bus driver or the attendant at the train, who become the new source of information.
In personal modes the effect of the loss of time information can appear during (heavy) congestion, if the delay is not known. Especially in extreme situations such as the summer holiday congestions on the highway can give delays of unknown length, while travelling to a speed as low as an hourly average of 5 km/h. The advantage of personal modes above shared modes in this case is that the travelling is not bound by services which may not run after a certain time, but is available at the driver's will.
In the case of trips with the characteristic that an arrival at a time has to take place, the trip can

become unachievable. This is only clear at the point that the trip cannot take place anymore based on rules of thumb.

iii. Reliability

Information about reliability is not readily available at the moment. Not for the different services of the public transport, nor for the travel times on the road network. As long as the reliability is higher than a certain threshold that people are willing to plan a journey with a certain services or using a certain link this lack of information is not critical.

Although hard information about reliability is not available for the different links and modes, there is the perception of the travellers, based on their own experience and knowledge.

iv. Location

The last factor that will be discussed about unavailability of information is the unavailability of location information. Locations are very static, they tend not to move over time or occupancy rate, although certain destinations can behave in this way (parking lot *x* is full, please use park lot *y*). And most information is available through information signs that do not disappear under normal conditions.

But especially in a real-time information environment, such as turn-by-turn navigation, the location of the traveller itself is key to provide the travel advice. In newspapers already numerous examples have turned up of people being lost because of giving a wrong input in a navigation device, or if their navigation device stopped working. This applies more to personal modes than public modes, since it is easier to ask for help in a bus or train or service personnel.

v. Implications

Based on the analysis performed in this section it is apparent that the cost of the trip is not really important for a trip. Without the information the trip can still be made, only the cheapest trip and the decision where to change from private to shared modes can be influenced. If time information is no longer available, the rules of thumb and experience of travellers comes into play to give estimates. In shared modes the impact is bigger during the trip, but this lack of available information can be taken care of by the bus driver or the attendant at the train. For the location information it only is important to have the information available in real time situations, but the loss of information is critical in this situation.

This leads to the conclusion that the real time environment is more dependent on available information than static or prognosis situations especially for time and location information. In case of on trip, the costs and reliability are less important, their influence is mainly in the pre-trip planning. Time and location information however are important, especially during disruptions and real time usage of the information.

Chapter 5 Interviews

The interviews have been carried out at both MRK and MDV in Munich. Several discussions and reflections about making an inter modal route advisor system with the consultants of MRK have taken place at different occasions. These meetings were not planned structured interviews but some sparring about ideas, leaving the possibility that not all ideas have been mentioned that are available. The interview at MDV (developer of i.a. EFA, one of the investigated background systems of Chapter 2b.) has been more structured and prepared about their view on inter modal route advice systems and the algorithms that are used. Being a commercial party it is possible that they did not tell everything that they know about.

The following sections will discuss some problems and opportunities in the development of inter model route advice systems.

a. Convenience level

First the convenience level of shared mode systems and personal mode route advice systems is not the same. The amount of information required and given by the different systems differs, making a shared mode system more complicated to use due to limited routing options and differences in the level of comfort of the different modes. Plainly it can be said that shared mode routing is the same as personal mode routing, but with the difference that the links in the network are only available at short times, if a service runs on a link. For the level of comfort it is needed to implement normal occupancy rates at services, since there are travellers who are not willing to use public transport at rush hours due to ‘livestock transport standards’.
The convenience level of an inter modal route advice system will be of the same level as the level of a shared mode system in terms of required information before and advice is given, because this is needed for the (possible) shared mode part of the trip. To increase the comfort level the information about user preferences and personal information such as subscriptions and age (that can give reduced fares at certain times) can be stored (locally), increasing the convenience level when giving the needed information for a route advice. Especially the storing of personal information and preferences has to be locally (at the device itself), due to privacy reasons.

The convenience level while travelling at modes is not always the same. There is a difference between different modes, car a train are mostly higher valued than bike or metro. But that is not all, also the weather can influence the level of convenience of modes. In winter or during heavy rainfall walking and biking become less desirable, this can be implemented in advices. Furthermore the location of waiting during an interchange is important during less comfortable circumstances, such as cold, wind and rain. This also influences the will to use shared modes and should be implemented in an inter modal route advice system. Other aspects related to the interchange are in the next section.

b. The interchange

From the producer’s as the consultants view the interchange is the most important part of an intermodal travel, the advice on this point has to be perfect and convenient for every user without rushing. The producer therefore uses worst case scenarios for the time it takes to park a car, buy a ticket and walking the distance.

The consultants however think further than that the interchange has to be feasible for the traveller. An idea is to use regular street side parking and bus stops as transfer points to the shared mode, however it is hard to get data about the availability of street side parking. The producer prefers P&R sites, since these can be promoted by the owners and an higher level of service can be provided. The producer further wants to eliminate inter changes within the public transport as much as possible. The reason for this elimination is that every interchange brings the risk of a missed connection and costs quite a lot of time due to the worst case scenario time calculation. In de next section the reliability will be discussed further.

Another aspect that is important when several P&R locations are available is, next to the availability of a parking space, the number of connecting services that stop at the designated station. In the case of a missed connection, it is comfortable to minimize the waiting time and the risk of extra travel time. The last aspect to take into account for the interchange between the personal mode and shared modes is the return trip. This requires prior knowledge of the return trip and the time this will take place, since not all stops/stations are serviced at any time of the day.

c. Reliability

Not only the number of transfers influences the reliability of trip, the weather and disruptions are two other aspects that influence the reliability as well. Disruptions due to malfunctions or incidents are hard to predict, but the influence of weather can be taken into account. Also delays that occur on a daily basis can be monitored and taken into account when an advice is made. With the change of a timetable however this information has to be gathered again.

Furthermore there is the reliability of the information that is provided on screens and posts in train stations and bus stops. The static information has to be correct and understandable to reach the travellers, 'real time' information is sometimes also provided at the stations by displaying the current expected time of the next arriving connection. The current status however can be confusing to the travellers, if the information displayed does not match the situation that they see. Busses that already leave the stop with *+1 min* on the screen happen quite often according to the consultants, leading to confusion and mistrust of the travellers. According to them it is better to not give information that is available, but cannot be trusted or delivered in time entirely. The view of the producer on this subject is in the next section.

d. Information

Different users have different needs, there is a large gap between the information need between first time users and seasoned users. The first group needs all information that is available in a logical and organized order, while the latter group only needs to know whether there are disruption on the route they want to take and the situation at other routes to think of an alternative themselves. A novice user would like to get one advice and stick to it, while an advanced user does not care for alternating advices but wants the quickest route.
At the moment it is not possible to distinguish between these two groups, but this could be a step in making the advice more personal.

A problem in giving advanced trip advising can be that the information is not available at the rate that it is needed to make a proper advice. The update mechanisms for the delay for the public transport services rely most of the time at departure and arrival time at stops or stations. During a leg between to stops there is no automatic information available about increasing delays or time savings, causing that information about delays cannot be used in real time advices.

Currently this means that real time information is not available, causing producers not to incorporate it into their advices, since they do not want give an advice which alters all the time. Also the possibility that a traveller goes for a coffee due to a 10 minute delay and misses its train because there was some time saved in the last leg is a reason that producers avoid to use this kind of information. A bad event is better remembered in the mind of the travellers than a good one.

Lastly, the most important pieces of information from the producer's perspective are the time on a trip and costs involved with a trip. These are the basic two information aspects on which route alternatives are selected and presented.

Chapter 6 Conclusions

a. Overview

The central question in this paper has been what the needed aspects are in a multi modal routing system. After an analysis of the literature and the systems that are used in practice many aspects are revealed that can be used in a multi modal advice. Based on the occurrence of the aspects in the systems and the aspects revealed in the literature a categorization is made in three categories: need, nice and superb, referring to whether an aspect is needed to make and advise possible, gives a higher level of advice or is to be used in the future (superb).

Need	Date / day
	Timetable
	Network (personal and shared modes, P&R's)
	Travel chain
	- Departure time / Arrival time
	- Origin
	- Destination
	Number of transfers
	Cost (fare, petrol)
	Route
	Travel time
Nice	Routing objective: Number of connecting services
	Distance
	Personal speed preferences
	Via routing point
	POI information
	Distance
	Number of connecting services
	Route on a map
	Time of departure / arrival
	Historical information
	Prediction on current situation
	POI availability / occupancy
	Expected delay
	Occupancy
	Current location
Superb	Convenience level of modes
	Convenience level through weather
	Expected delay through weather
	Delay due to weather, accidents, (current status of the network)
	Rerouting
	Stress
	Personal preferences settings

Based on the activity theory the differences in the usage of aspects during the trip are analysed. Different scenarios have been used to cover the different situations in time (static, prognosis, real time) as well as the differences in usage by traveller types. This resulted in an overview of the aspects in respect to the different timeframes:

Static	Prognosis	Real time
Arrival time	historical information	Current location
Day	Occupancy	Current delay and expectation
Date	Prognosis information	Stress
Departure time		
Destination		
Distance		
Mode preferences		
Network links		
Number of connecting services		
Origin		
POI		
Routing objective		
Speed preferences		
Via		
Weather		

The matrices can be used for inter modal route advice systems and will rank the aspects on two scales. The first scale is the time frame in which the information can be used, static, prognosis or real time and based on the Table 11: Aspects per time frame. This scale stages the next level on the previous, meaning that the aspects given at a lower level are also useful for the next level.
The other scale is based on the quality of the outcome in the levels: need, nice and superb. The need level contains the information what is needed for a basic advice. In the matrix this is on the different levels of static, prognosis and real time route advice. The categorisation is based on what information is needed for a basic advice (need), what current high level advice systems offer (nice) and what can be implemented in the near future (superb). The differentiation between output and input is based on Table 6: Overview of found aspects in practice as made in Chapter 3. The results of the other chapters are blend into the table.

	Static	Prognosis	Real time
Need	Date / day Timetable Network (personal and shared modes, P&R's) Travel chain - Departure time / Arrival time - Origin - Destination		
Nice	Routing objective: Number of connecting services Distance Personal speed preferences Via routing point POI information	Historical information Prediction on current situation POI availability / occupancy	
Superb	Convenience level of modes Convenience level through weather	Expected delay through weather	Delay due to weather, accidents, (current status of the network) Rerouting Stress Personal preferences settings

Table 12: what does the system need (input)

	Static	Prognosis	Real time
Need	Number of transfers Cost (fare, petrol) Route Travel time		
Nice	Distance Number of connecting services Route on a map Time of departure / arrival	Expected delay Occupancy	
Superb	Convenience level of modes Convenience level through weather	Delay through weather, accidents	Delay Rerouting

Table 13: what does the user need (output)

The tables above reveals the aspects that can be incorporated in an inter modal routing system; for the input in Table 12: what does the system need (input)and for the output in Table 13: what does the user need (output). Based on the different scales, it is visible what parameters can be included to offer a product that provides advices at the level which is intended as for the TraffiQ project.

b. Discussion

The results have been based on an extensive literature and practice research, however it is possible that aspects have been missed. Although over 150 papers have been reviewed, it is possible that a new aspect is found in research and only recently published and has not been taken into account in this research. The expert interviews have been introduced to counteract this gap of knowledge, but during the interviews two things were apparent. Firstly the consultants have ideas what the current systems do en future developments will be and are regular users of the public transport. This makes them experts in how public transport works and the processing of information related to the trip easy. This is not the case for most travellers and they may become overloaded by the amount of information. Secondly the producers are not willing to incorporating many new features at the time. The products available seem to be in the 'cash cow' status of product development and the producer already has a roadmap of future development and implementations, which is aimed at maximizing revenue while keeping the research and developments cost low.

Based on the linear structure of this research (basically: find, test and check aspects) the findings of within this research comply with each other. There is not much conflicting information, even the expert opinions match with the findings of the literature and practice review. There seems to be consensus on what aspects are needed in a route advice system. In a research where the findings are not tested and checked, but are challenged, the outcome could be different.

Finally the categorization of the aspects, this has been based on the three tables (Table 6: Overview of found aspects in practice, Table 7: Aspect analysis and Table 11: Aspects per time frame). The upper two fields are empty, because at a needed level prognosis and real time do not exist. They are not available at the lowest level. On the nice level aspects are found to be used in prognosis systems, but there is no implementation yet of real time navigation. Personal Navigation Devices do come close, but these still rely on updates over RDS-TMC which are not precise enough to be called real time.
One could say that delay and rerouting on the latest row are already in use by current systems, but not as far as is meant in this paper. Delays are presented, but not as real time as real time is due to the updating mechanisms. Rerouting at the moment is rerun of the routing module based on the current values on the network activated by the traveller himself (whether or not promoted by the device), future rerouting will be automatically and not user induced.

c. Further research and thoughts

Based on the research as presented in this paper there is one aspect that was hard to grasp: reliability. It is found in literature as being an aspect which has a significant influence, but it is not defined in a measurable way. To be able to implement reliability in a system research has to be done to make reliability SMART. The part of the journey where public transport is used reliability can have a big impact on the comparativeness of the shared and personal modes in final products.
Another aspect from the literature is stress, a very personal aspect based on traveller's characteristics. Giving this aspect a value and incorporating this into an algorithm is most probably not possible. Also it is only possible to counteract stress in real time situations when stress occurs. Whether or not risk avoidance in routing is smart to lower the stress levels or to provide information about the situation while it is developing to control the feeling of uncertainty (which is a characteristic of stress) is a problem that has to be researched.

As already has been mentioned in the expert interviews the update mechanisms for delay are not usable for real time route advice since their update cycle is too slow. This can be improved by using the same techniques that are currently implemented on busses, their locations are known through GPS and a cellular connection to the systems of the transport provider throughout the trip, not only at the stops.

From the start of the research on there has been the discussion whether this research can provide the right answers, if the travellers themselves are not directly involved in the research. In this research is chosen to approximate the travellers' choices by using the opinions of experts, before implementing the outcomes of this research the opinions of the travellers can be investigated to see what the aspects are that the travellers prefer to be implemented.

In the systems available the difference between the interchange time and waiting time at the platforms during a transfer is not indicated and can only be 'learned'. Adding this information can decrease the stress levels caused by being in stress while the transfer time is sufficient to make the interchange. The implementation is already found in the system of 9292, after the analysis, by providing the interchange time and the time the needed service leaves.

More can be extracted from the expert interviews; one can say that the research is ahead of the current developments in the market. New techniques and algorithms can be made, but the expenses are too costly to incorporate it into current products. An example is the development of the inter modal route advice system of TraffiQ; this research was part of the development of this system, but the project has been cancelled after a few months. This should not stop the development and research though; there will be a day that the cash cow status of the current products is over and the market is ready for the products that now only exist on paper.

Bibliography

9292 REISinformatiegroep bv. (sd). *De geschiedenis van 9292 REISinformatiegroep bv*. Opgeroepen op June 28, 2011, van 9292ov.nl: http://www.9292ov.nl/9292ov107.asp

Abdel-Aty, M. A. (2001). Using ordered probit modeling to study the effect of ATIS on transit ridership. *Transportation Research Part C 9*, pp. 265-277.

Abdel-Aty, M. A., Kitamura, R., & Jovanis, P. P. (1995). Investigating effect of travel time variability on route choice using repeated-measurement stated preference data. *Transportation Research Record 1493*, 39-45.

Auber, D. (2012, April 17). *Data Visualization Software | Tulip*. Opgeroepen op Mai 30, 2012, van Tulip | Better Visualization Through Research: http://tulip.labri.fr/TulipDrupal/

Calvo, R. W., de Luigi, F., Haastrup, P., & Maniezzo, V. (2004). A distributed geographic information system for the daily car pooling problem. *Computers & Operations Research*, 2263-2278.

Cervero, R. (2001). Walk-and-ride: Factors influencing pedestrian access to transit. *Journal of Public Transportation 3 (4)*, 1-23.

Curtis, C., & Schreurer, J. (2010). Planning for sustainable accessibility: Developing tools to aid discussion and decision-making. *Progress in planning*, 53-106.

Engeström, Y. (1999). Activity Theory and individual and social transformation. In Y. Engeström, R. Miettinen, & P. Raija-leena, *Perspectives on Activity Theory* (pp. 19-38). Cambridge: Cambridge University Press.

Galovski, T. E., & Blanchard, E. B. (2004). Road rage: A domain for psychological intervention? *Aggression and Violent Behavior 9*, pp. 105-127.

Garcia, R., & Marín, A. (2005). Network equilibrium with combined modes: models and solution algorithms. *Transportation research part B*, 223-254.

Givoni, M., & Rietveld, P. (2007). The access journey to the railway station and its role in passengers' satisfaction with trail travel. *Transport Policy 14*, 357-365.

Guo, Z., & Wildon, N. H. (2010). Assessing the cost of transfer inconvenience in public transport systems: A case study of the London Underground. *Transportation Research Part A*, p. unavailable.

Hall, R. W. (1993). Non-recurrent congestion: how big is the problem? Are traveller information systems the solution? *Transportation Research*, 89-103.

Hsu, S. C. (2010). Determinants of passenger transfer waiting time at multi-modal connecting stations. *Transportation Research*(Part E), 404-413.

Kaenampronpan, M., & O'Neill, E. (2004). Modeling context: an activity theory approach. *Lecture Notes in Computer Science*, 367-374.

Kenyon, S., & Lyons, G. (2003). The value of integrated multimodal traveller information and its potential contribution to modal change. *Transportation Research*(Part F), 1-21.

Kim, D. (2011, January 20). *Portable Navigation Market to Peak in 2011*. Opgeroepen op June 28, 2011, van IHS iSuppli: http://www.isuppli.com/Automotive-Infotainment-and-Telematics/MarketWatch/Pages/Portable-Navigation-Market-to-Peak-in-2011.aspx

Kim, S., Ulfarsson, G. F., & Hennessy, J. T. (2007). Analysis of light rail rider travel behavior: Impacts of individual, built envirnoment, and crime characteristics on transit access. *Transportation research part A*, 511-522.

Kodransky, M., & Hermann, G. (2011, January 18). European Parking U-Turn. New York, New York, USA. Retrieved April 30, 2011, from ITDP.

Kofod-Petersen, A., & Cassens, J. (2006). Using Activity Theory to Model Context Awareness. *Lecture Notes in Computer Science:*(3946), 1-17.

Krygsman, S., Dijst, M., & Arentze, T. (2004). Multimodal public transport: an analysis of travel time elements and the interconnectivity ratio. *Transport Policy 11*, 265-275.

Liu, T.-L., Huang, H.-J., Yang, H., & Zhang, X. (2009). Continuum modeling of park-and-ride services in a linear monocentric city with deterministic mode choice. *Transportation Research*(Part B), 692-707.

Lo, H. K., Luo, X. W., & Siu, B. W. (2006). Degradable transport network: Travel time budget of travelers with heterogeneous risk aversion. *Transportation research Part B*(40), 792-806.

Lo, H. K., Yip, C.-W., & Wan, Q. K. (2004). Modeling competitive multi-modal transit services: a nested logit approach. *Transportation Research*(Part C), 251-272.

Luethi, M., Weidmann, U., & Nash, A. (2007). Passenger arrival rates at public transport stations. *TRB*, 2006.

Lyons, G., & Harman, R. (2002). The UK public transport industry and provision of multi-modal traveller information. *International Journal of Transport Management*, 1-13.

MDV. (26. january 2007). *Verkehrstelematik in Graz - Werkstattberichte II.* Abgerufen am 11. January 2010 von http://www.fgm.at/transfer/werkstatt/VERKEHRSTELEMATIK_IN_GRAZ_WERKSTATTBERICHTE_II_EFINGER.pdf

Modesti, P., & Sciomachen, A. (1998). A utility measure for finding multiobjective shortest paths in urban multimodal transportation networks. *European journal of operational research*, 495-508.

Ortúzar, J. d., & Willumsen, L. G. (2001). *Modelling Transport.* Chichester, England: John Wiley & Sons, Ltd.

Redmond, L. S., & Mocktarian, P. L. (2001). The positive utility of the commute: modeling ideal commute time and relative desired commute amount. *Transportation* , 179-205.

Rehrl, K., Bruntsch, S., & Mentz, H.-J. (2007, March). Assisting Multimodal Travelers: Design and Prtotypical Implementation of a Personal Travel Companion. *IEEE Transactions on inteligent transportation systems, 8*.

Rietveld, P., Bruinsma, F. R., & van Vuuren, D. J. (2001). Coping with unreliability in public transport chains: A case study for the Netherlands. *Transportation research part A 35*, pp. 539-559.

Sang-Jeong, S. O. (2011, March 10). *Smart Phones to Generate Half of Total Navigation Sales in 2011*. Opgeroepen op June 28, 2011, van IHS iSuppli: http://www.isuppli.com/Automotive-Infotainment-and-Telematics/MarketWatch/Pages/Smart-Phones-to-Generate-Half-of-Total-Navigation-Sales-in-2011.aspx

Tapiador, F. J., Burckhart, K., & Martí-Henneberg, J. (2009). Characterizing European high speed train stations using intermodal time and entropy metrics. *Transportation Research Part A*(43), 197-208.

Transport for London. (2002, August). Interchange plan - Improving interchange in London. London, Great Britain.

Vande Walle, S., & Steenberghen, T. (2006). Space and time related determninatns of public transport use in trip chains. *Transportation Research Part A 40*, pp. 151-162.

Wardman, M. (2001). A review of British evidence on time and serice quality valuations. *Transportation Research Part E 37*, 107-128.

Wener, R. E., & Evans, G. W. (2010). Comparing stress of car and train commuters. *Transportation Research Part F*, pp. xxx-xxx.

wikipedia.org. (2010, November 20). *Wikipedia.org | Bicycle Performance*. Retrieved November 30, 2010, from Wikipedia.org | Bicycle Performance: http://en.wikipedia.org/wiki/Bicycle_performance

Wlater, & Norta. (2002, 07/08). Der Einfluss der Wartezeit auf die OePNV-Qualitaet. *Der Nahverkehr*, pp. 36-38.

Zuidgeest, M. H., Maarseveen, v. M., & Zuilekom, v. K. (2004). Twee vervoerswijzen uitgelicht. In M. F. van Maarseveen, M. H. Zuidgeest, & K. M. van Zuilekom, *Verkeer (Dictaat 2004/2005:874)* (pp. C-1 / C-37). Enschede: Universiteit Twente.

Appendices

Appendix A: Overview of found aspects in practice

Parameters used in front-end of travel advice websites	9292ov.nl			bayerninfo.de				22/ Nov 10	AnachB.at				22/ Nov 10	Ruhrpilot.de	
		OV Planner	Auto & OV		Bike	PT	P+R	Car		PT	Bike	Car	P&R		PT
Origin	V			V	V	V	V	V	V				V	V	
Via / über	V														
Destination	V			V	V	V	V	V	V				V	V	
Date	V			V	V	V	V	V	V				V		
Time (departure / arrival)	V			V	V	V	V	V	V				V		
Means of travelling	V		V	V										V	
Train	V		V	V		V			V				V	V	V
Tram	V		V	V		V			V						V
Ferry	V		V	V											
Bus	V		V	V					V					V	V
Metro	V		V	V					V					V	V
Cable Car															
Foot			V	V											V
Bike				V					V						
Car			V						V				V	V	
Tripchain		V	V			V	V						V		V
Choose P+R			V										V		
# of connecting services / hour			V												
Advice															
Departure time		V	V		V	V	V	V		V	V	V	V		V
Arrival time		V	V		V	V	V	V		V	V	V	V		
Travel time		V	V		V	V	V	V		V	V	V	V		V
Travel time with common congestion			V												
# of interchanges		V				V	V			V			V		
Cost		V	P+R / PT, not for car												V
Distance			V		V			V			V	V			
Teilstreckenplan / map										V			V		
occupancy															
wetter				V											
Umgebungsplan										V			V		
avoid Toll															
avoid Highways															
change speed								V							
Survey date:	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10	22/ Nov 10

	22/ Nov 10	fahrplan.oebb.at	511.org	10/ Jan 11				bahn.de	10/ Jan 11	b-rail.be	efa.de		efa-bw.de			journeyplanner.org	
Car	P+R	Train		Car	PT	Bicycling	P&R selected P&R		PT	NMBS				PT	PR	London	add cycle / B+R
		V	V			V		V		V	V		V			V	
		V	V				V	V			V		V			V	
		V	V			V	V	V		V	V		V			V	
		V	V				V	V		V	V		V			V	
		V	V				V	V		V	V		V			V	
	V	V			V		V		V	V		V		V	V	V	V
	V				V		V		V	V		V		V	V	V	V
					V		V					V		V	V	V	V
	V				V		V		V	V		V		V	V	V	V
	V				V		V		V	V		V		V	V	V	V
	V				V		V		V	V		V		V	V	V	V
						V				V					V		V
V	V			V						V					V		
	V																
V	V	V		V	V		V		V	V		V		V	V	V	V
V	V	V			V		V		V	V		V		V	V	V	V
										V							
V	V	V		V	V		V		V			V		V	V	V	V
				V													
		V			V		V		V	V		V		V	V		
	PT part																
	only	link			V		V					V					
V		V		V			V										
					V	V			V	V				V	V	V	V
22/ Nov 10	22/ Nov 10	10/ Jan 11	10/ Jan 11	10/ Jan 11	10/ Jan 11	10/ Jan 11	10/ Jan 11	10/ Jan 11	10/ Jan 11	10/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11

kvg-lippe.de	kvv.de	metlinkmelbourne.com.au	mvv-muenchen.de	ns.nl		oebb.at	omnipart.de	reiseplanung.de	rejseplanen.dk			rmv.de	pundr.hessen.de	goroo.com	sbb.ch	septa.org	tijdreizen.nl
						Austria	mobilitaetsverbund.de	deutschland	denmark			Rhein-Main		chicago	Switzerland	Pennsylvania	Den Haag
Detmold	Karlsruhe	Melbourne, au	München, de		Car/Bike	PT	Bayern, de	Car	PT	Car	P&R	PT	P&R	Car and PT	PT	PT	
V	V	V	V	V		V	V	V	V	V	V	V	V	V	V	V	offline since 1-1-2011
V	V		V	V		V	V					V			V		
V	V	V	V	V		V	V	V	V	V	V	V	V	V	V	V	
V	V	V	V	V		V	V		V	V	V	V		V	V	V	
V	V	V	V	V		V	V		V	V	V	V		V	V	V	
V	V	V	V	V		V	V		V		V	V			V	V	
V	V	V	V	V		V	V					V			V	V	
V				V		V	V					V			V		
V	V	V	V	V		V	V				V	V			V	V	
V			V	V		V	V				V	V			V	V	
															V		
V	V	V	V	V		V	V				V	V			V		
V		V	V		V				V			V					
V		V	V		V			V		V	V			V			
		V	V		V				V		V						
		no	no		no, possible						V		V				
									V								
V	V	V	V	V	V	V	V		V	V	V	V		V	V	V	
V	V	V	V	V	V	V	V		V	V	V	V		V	V	V	
V	V	V	V	V	V	V	V	V	V	V	V	V	from P&R place	V	V	V	
										V	V						
V	V	V	V	V	V	V	V		V		V	V		V	V	V	
V	V	zone(s) used		V	V				V	V	V			V		V	
					V	V		V		V	V			V			
		V	V														
															V		
		V															
														V			
														V			
11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11

travelineeastmidlands.co.uk	transportdirect.info			Varta-guide.de	verbundlinie.at Verkerhrsverbund Steiermark Online (Austria)		vmzberlin.de							wojhati.rta.ae	routes.tomtom.com	gvh.de	maps.google.com
South East England	UK			Der Varta-Führer			Berlin							Dubai		Hannover	
PT	PT	P&R	Car	11-Jan	PT	Transfer (P&R)		Car	PT	Bike	Walking	Bike & Ride	Car & Ride	PT	Car	PT	Car
V	V		V	V	V	V	V							V	V	V	V
	V		V	V		V	V										V
V	V		V	V	V		V							V	V	V	V
V	V		V		V	V	V							V	V	V	
V	V		V		V	V	V							V	V	V	
V	V				V	V			V			V	V	V		V	
V	V				V	V			V			V	V				
									V			V	V				
V	V				V	V			V			V	V	V		V	
V	V								V			V	V	V		V	
V	V				V	V										V	
V						V			V	V	V	V		V			
			V	V		V		V					V		V		V
V	V		V		V	V			V					V	V	V	
V	V		V		V	V			V					V	V	V	
V	V		V	V	V	V		V	V	V	V	V	V	V	V	V	V
						V									V		
V	V				V	V								V		V	
					# of zones			V	V					V			
			V	V		V		V	V	V	V	V	V		V		V
														V		V	
																V	
																V	
			V	V													
			V	V													
			V														
11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	11/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11

google.com /transit	hvv.de	avv.de	vrminfo.de
	Hamburg	Aachen	Rhein-Mosel
PT	PT	PT	PT
V	V	V	V
	V		
V	V	V	V
V	V	V	V
V	V	V	V
V		V	V
V			V
			V
		V	V
V			V
V		V	V
			V
V			
		V	
V	V	V	V
V	V	V	V
V	V	V	V
		V	V
	V	V	
			V
			V
12/ Jan 11	12/ Jan 11	12/ Jan 11	12/ Jan 11

Appendix B: Overview of aspects found in literature

	access	amount of traffic	class	comfort	control	crowding cost	day of the week	destination	delay	detours	distance	event	egress	fare (transit cost)	freeway links	frequency of service / headway
weather																
walking time between platforms																
waiting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
wait time	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17, 108
vehicle operation cost																
uncertainty																
traveller's knowledge																
travel time	13, 15	14					14		21	14			13,15			
travel distance	9			145				8			10		9			
travel cost						4					2			2, 4		
transfer	89			36					36				89			
timetable																
time reliability		27					27									
time of departure																
time of day		97														
time of arrival																
stress		44			48											45
safety																
reliability																
recurrent congestion		97														
punctuality																
predictability																
petrol cost																
parking time																
parking tariff over time																
parking cost																
overcrowding is part of occupancy																
origin																
non-recurrent congestion												72				
non regular situations					50											
need for travel information	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0
mode				124	51											
link cost																
kind of routing		63									67				67	85
in-vehicle time																
interchange = transfer + wait time																
information need	0	0	0	0	118	0	0	0	0	0	0	77	0	0	0	75
incident																
frequency of service / headway																
freeway links																
fare (transit cost)																
egress																
event																
distance																
detours																
delay																
destination																
day of the week		97														
crowding cost				38												
control																
comfort			40													
class																
amount of traffic																
access																

same colour -> combined into one aspect
need for travel information + information need = information need
waiting + wait time = wait

incident	information need	interchange = transfer + wait time	in-vehicle t	kind of routing	link cost	mode	need for travel information	non regular situations	non-recurrent congestion	origin	overcrowding is part of occupancy	parking cost
62	33, 77			63		114	33					
	122					141	0					
0	0	0	0	0	0	141	0	0	0	0	0	0
0	118	16	0	0	0	141	0	0	0	0	0	0
	0				99		0					
	0						0		32			
	33			101			33, 54					
	0		13, 15	67, 85, 87, 120, 1		141	0		19			
	0			67		141	0			8		
	0			67, 85, 87, 120, 1	2		0				6	2, 3, 6
	0	16		85, 87, 120, 132		141	0					
	75, 128						0					
	0					27	0					
	75			87			0		69			
	128						0					
	0						0					
	0					49	0	50	154			
	0						0					
	0						0		32			
	77						0					
	0						0					
	0					49	0					
	0				99		0					
	0						0					
	0						0					
	0						0					
	0						0					
	0						0					
72	77						0					
	0						0					
0	0	0	0	0	0	0						
	134			132								
	0											
	0											
	0											
	0											
77												

parking tariff over time	parking time	petrol cost	predictability	punctuality	recurrent co	reliability	safety	stress	time of arrival	time of day	time of departure	time reliability	timetable	transfer	travel cost	travel distance	travel time	traveller's knowledge
	116													24, 89				
0	0	0	0	0	0	30, 147	0	143	0	0	0	0	0	24, 89	0	0	13, 15	0
0	0	0	0	0	0	30, 110	0	46	0	0	0	0	17	81	0	0	126	0
															2, 3			
																		53
								52, 53				53, 101		80			53, 101	
					19				18		18			13, 15		145		
															8			
		5																
	116																	
								45										
					32			47		27								
					69													
			47, 49, 152	45	154													
			102		32													

	uncertainty	vehicle operation cost	wait time	waiting	walking time between platforms	weather
			0	0		
			0	0		
	0	0	0			
	0	0				

#	Citations on which the aspects are linked
1	• Travel cost: All costs related to the trip, in the case of an intermodal trip:
2	fare (shared modes, taxi) costs + private vehicle operation cost (non-petrol, other) + parking costs + link (toll, fuel based on distance costs +
3	○ Cost = parking, toll road (Calvo, de Luigi, Haastrup, & Maniezzo, 2004) operating cost of private vehicle, parking cost (Liu, Huang, Yang, & Zhang, 2009)
4	○ Crowding cost (due to privacy loss, body touch, air pollution, venture of pickpocket), transit cost (fare) (Liu, Huang, Yang, & Zhang, 2009)
5	○ [...] petrol and parking cost and possible road tolls for motorists, and fares for public transport users. In such a model, walking and cycling are usually considered free of cost (Curtis & Schreurer, 2010)
6	○ Parking lot link represents the parking cost, parking time and capacity (Florian & Los, 1979)
7	
8	• Travel distance: the distance which has to be travelled to get from the origin to the destination on a suitable network.
9	access trip + trip in personal mode + trip in shared mode(s) + egress trip
10	○ Actual kilometre distance (Calvo, de Luigi, Haastrup, & Maniezzo, 2004)
11	○ Euclidean distance, network distance (Curtis & Schreurer, 2010)
12	○ Origin and destination (Bronsveld, obvious)
13	• Travel time: access time + waiting time + in-vehicle time + transfer time + egress time (Hsu, 2010)
14	○ Time to drive through an arc depends on when the arc is used, include detours (Calvo, de Luigi, Haastrup, & Maniezzo, 2004) [travel time]
15	○ Trip time = Access time, egress time, line-haul time (in-vehicle time or private transport time), wait time, transfer time, service times (timetabled services) (Krygsman, Dijst, & Arentze, 2004) [travel time]
16	○ Interchange time = transfer time + waiting time (Hsu, 2010) [used as transfer time and interchange time respectively in this report, the definition in this report is the other way

around]

○ Waiting time depends on headways (and therefore frequency of services) (Luethi,
17 Weidmann, & Nash, 2007)

18 ○ (expected) Travel time = time of arrival – time of departure (bronsveld)

○ Travel time = free-flow travel time + recurrent congestion delay + additional non-
19 recurrent congestion delay (Hall, 1993)

20 ○ ... rely on free flow values for travel times (from speed limits) (Adler & Blue, 1998)

21 ○ Travel time includes: [...] delay [...] (Bielli, Boulmakoul, & Mouncif, 2006)

22 ○ Delay = congestion? No disruption [e.a. expected delay does not stress people out]

23 ○ Parking time is included in transfer time [if applicable]

▪ Transfer time: waiting for next service, boarding / alighting, walking for transfer (Bielli,
24 Boulmakoul, & Mouncif, 2006)

25 ○ Waiting time:

▪ [...] passenger waiting time is clearly affected by the headways of both feeder and
connecting services. [...] [it also] shows that the service characteristics of the feeder system
have a greater influence on transfer waiting time than the characteristics of the connecting
26 system. (Hsu, 2010) [timetable information influences waiting time]

• Travel time variability is mode depended, amount of traffic depended (*and therefore*
27 *time depended (rush hour)(bronsveld, obvious*)) (Lo, Luo, & Siu, 2006)

○ Travel time consists of the free flow travel time, the recurrent congestion and the non-
recurrent congestion. Hence the travel time is (at least to the traveller) random component
28 following some probability density function [...] (Ettema & Timmermans, 2006)

29 • Reliability:

○ A higher service reliability leads to lower waiting times (Hsu, 2010) (Luethi, Weidmann, &
30 Nash, 2007)

○ Connectivity reliability is concerned with the probability that the network nodes remain
connected , travel time reliability pertains to the probability that a trip between a given OD
31 pair can be completed within a specified time (Asakura and Kashiwadani, 1991)

○ Recurrent congestion basically does not lead to issues of unreliability or uncertainty
32 (Rietveld, Bruinsma, & van Vuuren, 2001)

○ The largest uncertainty regarding the benefits of information concerns the existing
knowledge of travellers about regularities in the travel conditions, related to such factors as
weather conditions and day of the week. The better travellers' insight in these relationships,
the smaller the benefit of travel time information. (Ettema & Timmermans, 2006) [traveller's
33 knowledge]

○ ... information about the frequency of service [...] provides a form of insurance against the
perceived unreliability of public transport (Kenyon & Lyons, 2003)[freq. of services /
34 reliability]

35 • Comfort

○ Mode changes can be uncomfortable, inconvenient, time consuming and carry an
inherent risk of delay if the connection fails to arrive on time. (Transport for London, 2002)
36 [comfort, transfer, delay]

○ [the] travel time which is the least comfortable, as travellers prefer to sit in a vehicle rather than wait on a platform (van der Waard, 1989). (Kenyon & Lyons, 2003) (Wardman,
37 2001) [travel time, in vehicle time, waiting]

○ It is true that mass transit can make people arrive at work on time, but meanwhile it may bring people discomfort generated by the body congestion at railway stations and in carriages if they are crowded. (Huang H.-J. , 2002) (Modesti
38 & Sciomachen, 1998) [comfort, occupancy]

○ Increase comfort by making people feeling more safe (Kim, Ulfarsson, &
39 Hennessy, 2007) [comfort]

○ Tier 1 travelling gives more comfort than a lower class (Lo, Yip, & Wan, 2004)
40 [comfort, class]

○ The cost experienced by a transit commuter should depend on the travel time, the transit fare and the discomfort generated by body congestion at railway stations and in carriages if they are crowded (Huang H.-J. , 2002). [travel time, fare,
41 comfort, occupancy]

42 • Stress:

○ The travel situation is generally qualified as stressful (as a result of waiting, time pressure, uncertainty, etc.). (Commission of the European Community, 2000)
43 [stress, waiting, uncertainty]

○ As the United States continues to become more crowded and highways and urban centres more congested, stress levels on the roads increase (Galovski & Blanchard, 2004) [stress,
44 occupancy]

○ Good timetable planning combined with punctuality, and a dense network of train, bus and coach services make intermodal transport a positive, stress-free experience from the passenger point of view and also saves the country money. (Tapiador, Burckhart, & Martí-
45 Henneberg, 2009) [timetable, reliable, stress]

○ Wait time will have a premium valuation because of the stress and frustration involved
46 (Wardman, 2001) [waiting, stress]

○ ... it has been suggested that stress from crowding on Japanese commuter trains is mitigated by the reliability and predictability of service there (Meyer & Dauby, 2002) [stress,
47 occupancy, reliable, reliable]

○ Williams, Murphy, and Hill (2008) found that drivers in the UK had higher levels of perceived control than those using other transit modes, and consequently lower levels of
48 stress (Wener & Evans, 2010). [reliability, stress]

○ (a) indicating differences in levels of stress between commuting modes and (b) revealing that effort and predictability of the commute largely account for these travel mode effects.
49 (Wener & Evans, 2010) [stress, reliability]

○ Derived from (Galovski & Blanchard, 2004): non regular situations lead to stress and a
50 feeling of less control over the journey. [non-regular-situation, stress]

○ Car travel is seen to give freedom and control over individual mobility. (Kenyon & Lyons,
51 2003) [mode, control]

○ Habitual behaviour prevents people from being stressed and makes people use their time
52 and cognitive capacity effectively (van Wee & Dijst, 2002) [(non)-regular situation, stress]

Therefore, many familiar public transport traveller engage in habitual behaviour in order to save not only cognitive effort and both search and travel time but also stress (van Wee &
53 Dijst, 2002) [traveller's knowledge, stress]'s knowledge, stress]

54 This lead to less need for travel information (Grotenhuis, Wiegmans, & Rietveld, 2007)

○ The approach was designed to allow greater understanding of the lack of knowledge and the stress of the unknown as a barrier to travel, particularly where interchange is involved.
55 (Hine & Scott, 2000) [stress, transfer]

56 • Control:

○ Users need to feel in control and that they will reach their destination on time. (Hine &
57 Scott, 2000) [control, delay]

▪ The feeling of being more in control and keeping to your own timetable were strong elements contained within the attitudes held by the car users (Hine & Scott, 2000) [control,
58 mode]

▪ Car users [...] were not prepared to consider public transport use due to the amount of trip planning that they felt was involved and the lower levels of control. (Hine & Scott, 2000)
59 [travellers knowledge, mode, control]

▪ Many public transport users [...] felt powerless in the face of delays and the lack of
60 information that was available to them. [mode, control]

61 • Weather:

○ Particularly in bad weather conditions this, together with stress situations could end in
62 dangerous situations/accidents. (Giannopoulos, 2004) [weather, stress]

○ ... preferences for routing under variations in traffic flows across the peak period and under varying weather conditions. (Adler & Blue, 1998)[routing objective, reliability,
63 weather]

64 • Occupancy

65 ○ Overcrowding is part of this parameter, since it is a state of occupancy

66 • Routing objective

○ Minimizing travel distance, minimizing travel time and maximizing use of freeway links
67 (Adler & Blue, 1998) [routing objectives]

68 • Congestion:

○ The common response to (information about) congestion is to change departure time, although changing routes also occurs frequently (Ettema & Timmermans, 2006) [delay,
69 departure time, routing objective]

70 ○ Recurrent

71 ○ Non-recurrent

72 ▪ Such as special events or incidents (Adler & Blue, 1998)

▪ Moreover, due to congestion, coordinating transfers in order to reduce waiting time may
73 result in more insecure transfers (Guihaire & Hao, 2008). [reliability, waiting, delay]

74 • Information need for travellers:

○ transit routes network, the frequencies and departure times, (Guihaire & Hao, 2008)
75 [timetable]

○ not having information or knowledge about modes works as a barrier (Kenyon & Lyons,
76 2003) [traveller's knowledge]

• Dynamic information: Congestion, accidents/incidents, road works, weather conditions, events (and related forecasted congestion e.g. football matches) (Giannopoulos, 2004)
77 [delay, incident, weather, events]

• References in the literature referring to Value of Time costs and 'costs' that occur due
78 to waiting and in-vehicle time are taken into account at the side of the time, not as a cost.

79 • Transfer:

80 ○ ... the transfer penalty is affected by a broad range of factors, including safety and security, ease of way-finding during transfers, availability of escalators, weather protection, seating availability, lighting, air conditioning, and concessions on the platforms (Guo & Wilson, 2010) [comfort, weather, occupancy]

81 ○ Transfer experience can be divided into three components: transfer walking, waiting, and the transfer penalty, a purely psychological aspect of transfers that is affected by the transfer environment (Ortúzar & Willumsen, 2001) [interchange, waiting]

82 • Number of transfers:

83 ○ the number of transfers is associated with a decrease in access but an increase in line-haul times (Krygsman, Dijst, & Arentze, 2004)

84 • [frequency, number of transfers, cost, (fare)]:

85 ○ In the real world, transit passengers choose the best path by considering not only the usual link-based shortest criteria but also non-link based factors, which could affect their path choice, such as average headway (frequency) along the path, total number of transfer points along the path, and total path cost (e.g. fare). It is difficult and even impossible to implement the path-based attributes into the link-based cost functions for shortest path calculation in label setting shortest path algorithm. This is why the objective function is presented as three separate optimal criteria: link-based travel time, node-based waiting time associated with the specific entry link, and path-based disutility cost. After the K shortest path model takes care the first two optimal criteria, this evaluation algorithm will select a path with minimized disutility cost. (Li & Kurt, 2000)

86 • [Travel time, number of transfers, modes, cost, time constraint, routing]

87 ○ The objectives of the routing problem may concern minimization of total travel time, number of transfers, number of modal changes, and trip cost. The time constraint considers that a vehicle arrives at a prescheduled transit station—called a time point—with a list of departure times and requires departure from the station at the next departure time. Therefore, the time constraint can be treated as multiple time windows bounded by scheduled departure time lists. (Li & Kurt, 2000)

88 • Transfer, wait

89 ○ [...] represent the following activities: access from origin to transit station, waiting for a bus of train, boarding/alighting bus or train, walking between two transit stations for transfer, etc. (Li & Kurt, 2000)

90 • Comfort, frequency

91 ○ Criteria for using public transport can also include vehicle and transfer terminal comfort, regularity, service coverage and frequency level (Guihaire & Hao, 2008)

92 • Comfort, information, transfer

93 ○ People will use mass transit more easily if they can get clear information and benefit from scheduled transfers between modes. (Guihaire & Hao, 2008)

94 • Comfort, crowding

95 ○ Inconvenience due to overcrowding (Guihaire & Hao, 2008)

96 • Time of day, date, demand for travelling

○ These periods vary according to the following criteria: time of the day (peak / off-peak period), day of the week (Monday-Friday / Saturday-Sunday), time of the year (seasons / vacation periods / others).Since demand is time-dependent.[...] A suitable frequency assignment should provide sufficiently regular service to satisfy the users... (Guihaire & Hao,
97 2008)

98 • Distance, cost

○ Operating cost per unit distance (including fuel, insurance and variable component of
99 highway tolls, etc) (Liu, Huang, Yang, & Zhang, 2009)

100 • Routing, reliability, travel time,

○ In forming their habitual routing plans, travellers select routes to lower their travel time variability, just as they do lower their mean travel time, because travel time variability leads
101 to either early or late arrivals; both are undesirable. (Lo, Luo, & Siu, 2006)

○ In effect, when the network is highly reliable, and hence the travel time highly predictable, travellers need not reserve a large travel time margin to ensure punctual
102 arrivals. (Lo, Luo, & Siu, 2006)

103 • Comfort, occupancy, class

○ For Classes-1 and -2 transport modes, their perceived travel times are modified by
104 discomfort functions to reflect crowding effects (Lo, Yip, & Wan, 2004)

105 • Distance, cost, fare

○ Most transit services or highway tolls are not directly proportional to the travel distance or time. It is common for transit fares to be roughly based on an inter-zonal structure, which
106 cannot be expressed by a simple additive function. (Lo, Yip, & Wan, 2004)

107 • frequency, waiting time, traveller knowledge

○ The results from Zurich illustrate that the half of headway rule is generally accurate until a headway of about 5=minutes; at this point average wait time become essentially smaller than half of headway time for different service frequencies showing that passengers know
108 the schedule. (Luethi, Weidmann, & Nash, 2007)

109 • Waiting time, reliability

110 ○ Higher reliability leads to lower waiting time (Luethi, Weidmann, & Nash, 2007)

111 • Control, mode, information, transfer

○ Travellers need information en route as well as in advance of trips being made. For car trips on the highway this is not generally a major issue, as the driver is or feels in control. For public transport journeys travellers can feel less secure, not in control; especially for those travelling by an unfamiliar route or for regular travellers whose journey is seriously disrupted. Travellers need thorough information en route, and especially at interchanges. In the case of disruptions, this needs to provide thorough, unambiguous guidance on how
112 passengers can continue their journey. (Lyons & Harman, 2002)

113 • Weather, mode

○ A rough estimate for Munich suggest that the share of bike-and-ride could drop from 16% to 6% for train stations, and form 5% to about 2% for metro stations [...] between 'good'
114 days and 'bad' days [from a weather perspective] (Martens, 2004) (Martens, 2004)

115 • cost, time

- We associate with each transition arc a weight expressing the sum of the time required for looking for a car park and the time to go by walking, if necessary, together with a weight representing the parking tariff. (Modesti & Sciomachen, 1998)

- Information, departure arrival, control, waiting
  - Real-time information is probably this important because it gives travellers more control over the departure and arrival times and reduces waiting time (Molin & Timmermans, 2006)
- Routing objective, modes, time, cost
  - Existing PT trip planners usually minimize travel time, but travellers apparently value the possibility to search for routes that are the cheapest or that minimize interchanges or that exclude particular PT modes. (Molin & Timmermans, 2006)
- Information, walking
  - Information on the walking route to the right PT vehicle (Molin & Timmermans, 2006)
- Comfort, in-vehicle time, mode
  - Regarding in-vehicle times, the largest coefficients will typically be on buses and the lowest on trains, as the latter are more comfortable and regular. (Nielsen, 2000)
- Waiting time, arrival
  - Some passengers who arrive too early at the destination may consider this as hidden waiting time (Nielsen, 2000)
- Time of day, frequency, timetable
  - Adding more complexity to the situation is that the turn weight changes over time because the bus headway changes; some buses even stop serving at certain times of the day. (Peng & Huang, 2000)
- Routing objective, time, cost
  - It is universally assumed that travel is a source of disutility, and hence that individuals will seek to minimize their travel time and cost, subject to constraints (Redmond & Mocktarian, 2001)
- Routing objective, modes, transfers, preferred information
  - Parameters for the personalization of the routing process are time, number of transfers, price, and preferred transport means, or Park&Ride (P+R) facilities. (Rehrl, Bruntsch, & Mentz, 2007)
- Information, routing
  - The important difference between road and pedestrian networks is that the routing network and the surrounding environment have to be modelled in a different scale (Rehrl, Bruntsch, & Mentz, 2007)
- Transfer time, delay
  - In the stations that we visited, we based mobility on walking at an average speed of 3,5 km/h with light-weight luggage, If available, escalators, lifts and ramps were used instead of stairs. We considered situations in which the traveller was already familiar with the station in question: we therefore did not take into account the quality of signposting or the possibility of waiting time due to mistakes during the transfer process. We did not take into account any possible slowing of the walking process, due to factors such as mass passenger flows, nor did we consider possible delays due to passengers having to stop to obtain tickets, etc. (Tapiador, Burckhart, & Martí-Henneberg, 2009)
- Reliability, routing objective

○ Also the reliability of travel time is relevant. Many transit users prefer a longer route to an
138 unreliable one.

○ The potential for park and ride is not fully exploited except for some car-train combinations, especially in urban areas. However, high standards in circulation and reliability are required to develop successful intermodality in urban areas. (Vande Walle &
139 Steenberghen, 2006)

140 • Travel times

○ Preparation time, which is the time spent preparing a journey, the walking time, the waiting time, the transfer time and the in-vehicle time, which are each perceived differently by the individual traveller. In mode choice model estimations choice of mode is typically found to be more sensitive to out-of-vehicle times overall than in-vehicle time. (Vande Walle
141 & Steenberghen, 2006)

142 • Wait, stress

○ Wait time will have a premium valuation because of the stress and frustration involved and also to the extent that less productive use can be made of waiting time and it involves
143 more effort and less comfort than seated on a vehicle. (Wardman, 2001)

144 • Travel time, comfort, mode

○ The disutility of a unit of IVT (in vehicle time) may increase with journey duration, as fatigue boredom and discomfort set in. Time savings on longer distance journeys will therefore be more highly valued. [...] Presumably this reflects a fatigue effect and perhaps
145 additional distance related discomfort which is not apparent for rail. (Wardman, 2001)

146 • Reliability, waiting time

○ Unreliability of arrival times and transfer between vehicles or modes also incur waiting
147 time (Wardman, 2001)

148 • Frequency, distance

○ It may also be because longer distance journeys tend to be more planned and hence the
149 convenience of high frequencies is less important.

150 ○ As seems reasonable, headway becomes less important as journey distance increases

151 • Stress, mode, control

○ Our data, and the meditational model, indicate that mass transit is not, in and of itself, less stressful, but, rather, only likely to be so when it offers a greater level of predictability
152 and a trip that involves less physical and/or cognitive effort. (Wener & Evans, 2010)

○ Contrary to expectations, however, both transit and auto modes have similar, relatively
153 high levels of perceived control (Wener & Evans, 2010)

○ Highway congestion increases blood pressure among car or bus drivers (Evans & Carrere, 1991; Novaco, Stokols, & Campbell, 1979; Schaefer, Street, Singer, & Baum, 1988; Stokols,
154 Novaco, Stokols, & Campbell, 978; White & Rotton, 1998)in (Wener & Evans, 2010)

Appendix C: Overview of comparison found aspects: Literature vs. practice

Aspects	Literature	Practice
Personal mode		
allowance of traffic		x
control over the journey	x	
destination		x
driving behaviour		x
incidental congestion	x	*
routing objective (shortest,		x
link costs	x	
link distance	x	x
max speed on link		x
origin		x
recurrent congestion	x	x
stress	x	
time of arrival		x
time of departure		x
travel cost		x
travel time	x	x
Public mode		
# transfers	x	x
access time	x	
available modes		x
connection interval	x	
date		x
destination	x	x
detailed accessibility	x	x
fare costs	x	x
guidance at station level	x	
in-vehicle travel time	x	
origin	x	x
overcrowding / occupancy	x	x
overview maps		x
reliability of departure time	x	
reliability of service	x	
reliability of travel time	x	
time of departure/arrival		x
transfer time	x	x
travel distance		x
travel time	x	x
waiting time	x	
walking time	x	x
weather		x
Park & Ride (added vs. personal/individual advisor)		
# connections / hour	x	x
choose modes		x
occupancy rate parking lot	x	
park place searching time	x	
parking costs	x	
walking time to station	x	

* : real-time implementation is possible
x : available

Appendix D: Different methods available for research

A lot of different research methods are available for research. A list of methods is presented here and in addition an explanation why some methods are not applicable to this study.

a. Cost Benefit Analysis

One of the analysis tools used most widely is the Cost Benefit Analysis (CBA) (Ministerie van Financiën, Afdeling Beleidsevaluatie - en instrumentatie, 2001). This analysis method chooses the best options based on the monetary value of the solutions. The method is based on the monetary value of the things needed to get to the result (the Costs) and the monetary value of the results (the Benefits). If the benefits are more worth than the costs, than it is a good option since the option adds value to the system under analysis and the option should be implemented. On the other hand, if the costs are higher than the benefits, the option should not be implemented since the added value is lower than the costs of the option. In a formula it CBA outcomes look like this:

$$CBA = \text{Benefits} - \text{Costs}$$

b. Cost-effectiveness analysis

If several options are available it may also beneficial to look at what option returns the most value for the least costs. Cost-effectiveness analysis (CEA) does not only look at whether or not an option has a positive outcome, but also how cost effective an option is (Ministerie van Financiën, Afdeling Beleidsevaluatie - en instrumentatie, 2001). In a formula it looks as follows:

$$CEA = \frac{Benefits}{Costs}$$

The bigger the outcome of CEA is, the more cost-effective the option is and therefore should be preferred above options with a lower CEA outcome.

c. Classification methods

Another way to select the parameters needed is to classify them into categories. The downside of this method category is that it is usually used to classify a lot of data into categories using nearest neighbour analysis and similar techniques. Since the amount of parameters at hand in this research is relatively small, the technique cannot be used.

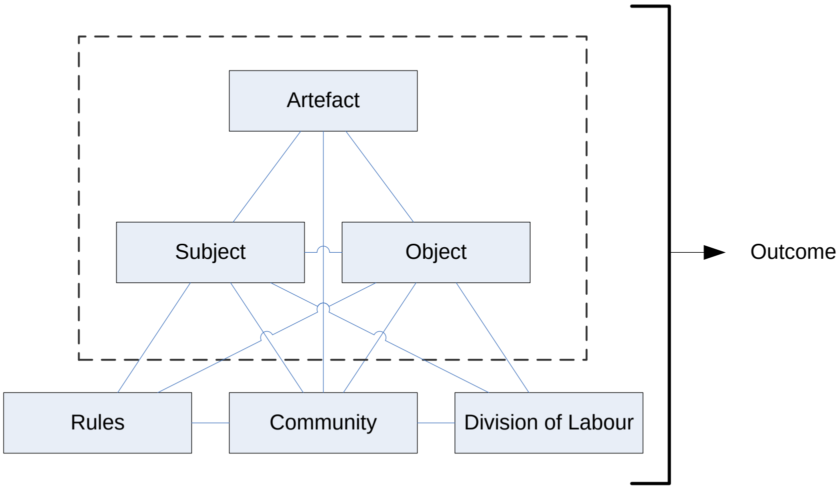
d. Probability methods

Using the possibility that a parameter may be useful in a situation is also a possibility for the sieve. This can be done by giving the parameters probability statistics for several parts out of which scenarios can exist. If the sum of probabilities of a parameter exceed a certain threshold it might be useful in that situation.

e. Activity Theory

This theory has originated in the field of psychology and found its way to the field of Human Computer Interface (HCI). With the help of Activity Theory (AT) it is possible to breakdown actions into activities and operations, which helps the subject to get to the object it wants.

The Activity Theory is based on the following model:



AT uses the Hierarchical Task Analysis (HTA) to breakdown the structure of how to accomplish something. The *Subject* is the person in question who wants to achieve something, here called the *Object*. To be able to achieve this *Object* the *Subject* can use an *Artefact*, a tool or mechanism which provides the possibility to do something.

In the scope of this research this theory can help to identify the parameters (*artefact*) needed for persons (*subject*) to travel (*object*).

f. Multi Criteria Analysis

The use of Multi Criteria Analysis (MCA) is quite similar to the use of Cost Benefit Analysis (CBA). Instead of comparing the monetary (quantitative) impact of the several options available a qualitative impact is used. The options are weighted on different aspects which can be chosen to fit the problem at hand and the options can be scored on these aspects. The option with the best outcome is than the preferred option.

g. Meta-analysis

If there is a lot of literature available on a subject a meta-analysis (MA) can be performed. With MA it is possible to combine the effect sizes of a set of studies, or to compare the variation of the set against the variation of the single research papers. Doing a MA can give a good overview of the literature available and the outcomes of the research. The downside of this method is that it is a purely statistically approach, not a scientific study in itself.

h. Expert interview

When information is not available in literature and can't be done with a survey (see below) an expert interview is a good tool to get the information needed. In this interview an expert on the subject can give his vision and recommendations. This information can be used for the aspects and the weighting of the several options in a MCA. Also the information can directly be used.

i. Sensitivity Analysis

In a travel advice a lot of parameters play a role, but not all the parameters are equally important. In the scope of this research it might be useful to only look for the parameters which have an important role in the outcome of a trip request. With a sensitivity analysis (SA) it is possible to see what influence different parameters have on the trip advice. The starting point and end point of a route will most likely be very important, a trip advice without knowledge of these parameters a trip advice is quite unusable.

j. Survey

With a survey it is possible to find out what people think about a subject or a case. It is possible to question a lot of things and the outcome gives an insight how people think about it. A disadvantage of a survey is that a digital survey might be filled in at random, but a personal approach is very time consuming. Another disadvantage is that not all data will revealed in the survey, since people do not always think about everything they do.

1. Stated Preferences

A disadvantage of surveys is if a survey is done about a product that is not available yet that they answer how they *think* they are going to use it. This is called Stated Preferences (SP). It might even be that they may be an opponent of the product and give strategically answers to influence the outcome of the total survey.

2. Revealed Preferences

Instead of asking what people think about a product in the future it is also possible to ask them what they think about some subjects already available. Such a survey is based on the Revealed Preferences (RP). An advantage is that the data will not be biased by personal opinions, although data might be withheld if the subject thinks that it might influence the outcome.

Another way to get information in a survey like way is to observe people's behaviour and trends and derive information from it.

k. Not usable Methods

1. Monetary values

The downside of the CBA and CEA is that they are based on monetary values. In this research the outcomes of the travel advice is measured in money, but also in time, comfort etc. It is hard to translate these values into monetary values, since both time and comfort are not valued the same by everyone. Also the costs of the parameters are very hard to express in a monetary value. What costs have to be considered? The costs for the research, the costs for the use of the parameter or the costs for the gathering of information which makes it possible to use the parameter in question? This makes it hard to make a consistent monetary value for the costs of a parameter.

Because both the costs and the benefits are hard to express in monetary values in this research all the analysis tools based on monetary values have to be regarded as useless and not usable.

2. Classification, probability and sensitivity

Classification, probability and sensitivity methods are also unavailable in the scope of this research. The classification method is not possible while there are not very many parameters available. The method works by similarity and this is not the case with the parameters in this research. Probability is not available for this research because it is very hard to calculate or guess the change of different parameters being needed. Simulations could solve this and the outcomes could be taken as input, but that is not the scope of this research. This also brings sensitivity analysis in the corner of not usable methods. Although it is possible to run many simulations, it is not the scope of this research to tackle the problem in this way.

Appendix E: Overview of motives for travelling

Commuter
same trip every day
about the same time
route is known
regular delays are known

Leisure
Different destinations every trip (?)
Therefore different connections
route is probably not known
based on availability (?)

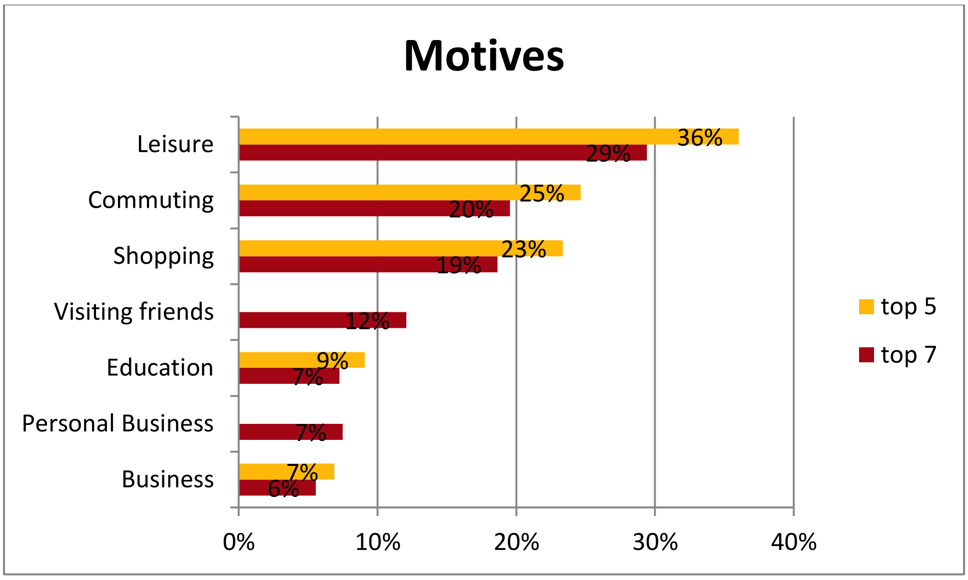
Shopping
Short trips
local destinations
routine (?)

Education
Same destination
Same time / day
Known information is high
Time restraint (fixed appointments)

Business
Recurrent journeys, therefore ...
- knowledge of the destination
- knowledge of traffic situation
Time restraint (fixed appointments)

Year	2008	2007	2009	2009	2009
	MiD (Germany)	**CBS (NL)**	**SWOV (NL)**	**nts0403** (UK)	**nts0401** (UK)
Original data:	Arbeit	van en naar het werk	van en naar het werk	Commuting	commuting
	dienstlich / geschaeftlich	zakelijk bezoek in werksfeer	zakelijk bezoek werksfeer	Business	business
	ausbildung	onderwijs / cursus volgen	onderwijs, cursus volgen	Education Escort education	education (including escort)
	Einkauf	winkelen, boodschappen doen	winkelen, boodschappen doen	Shopping	shopping
				Other escort	Other escort and personal business
	private erledigung	diensten / persoonlijke verzorging		Personal business	
		visite / logeren	visite, logeren, familiebezoek	Visiting friends at private home Visiting friends elsewhere	Visiting friends
	freizeit	sociaal recreatief overig toeren / wandelen recreatief	recreatief (toeren, wandelen, sport, ontspanning)	Entertainment/public activity Sport: participate Holiday: base Day trip Other including just walk	Other leisure
	Begleitung	overig	overig		

Translated:	2008 MiD (Germany)	2007 CBS (NL)	2009 SWOV (NL)	2009 nts0403 (UK)	2009 nts0401 (UK)
Commuting	14%	14%	27%	15%	15%
Business	7%	2%	8%	3%	3%
Education	6%	8%	6%	6%	11%
Escort education				5%	
Shopping	21%	17%	8%	20%	20%
Personal business	12%	3%		11%	20%
visiting friends at private home		12%	20%	11%	16%
visiting friends elsewhere				5%	
Entertainment/public activity	32%	10%		4%	15%
Sport: participate		9%	23%	2%	
Holiday: base		19%		1%	
Day trip				3%	
Other including just walk				4%	
Other	8%	7%	8%		



Appendix F: Results of Activity Theory analysis

Scenario: Commuter, goes from home to work place in the morning. Leaves by car, goes to P&R possibility and takes S-Bahn/U-Bahn into the city.

Static

Activity	Needed artefact
start	
plan trip	find out delays on links which might be used (radio, internet)
	use stored information in the brain about travel circumstances
	what is the weather like, do I have to take in consideration a longer travel time?
	find out delays on services in public transport
	find out what the fares are from different P&R to destination station(s)
	choose leaving time (based on desired arrival time)
make the trip	
Go to the car	
Make the trip as planned	
	if unplanned congestion, listen to radio for information updates
Arrive at P&R	Timing of arrival is uncertain, when does the service arrive?
Buy the needed ticket	or commutation ticket
Wait for service	find out whether the service goes as planned, find extra information if planned service is not available
Take service	
arrive at station	
transfer to other service	
Wait for service	
Take service	
arrive at destination station	
walk to destination	

Prognosis

start planning trip	
	find information about delays on links and their prognosis for when you will get there
	find information about the weather and in influences on the planned trip
	use own information about the other times the trip was made, were the prognoses reliable?
	find out public transport services
	find out delays in public transport and their prognosis
	choose P&R to be used
	choose leaving time (based on desired arrival time)
make the trip	
go to the car	

make the trip as planned	
	if unplanned congestion, listen to radio for information updates
Arrive at P&R	timing is uncertain, when does the service arrive? Easiness to find parking spot
Buy the needed ticket	or commutation ticket
Wait for service	find out whether the service goes as prognosed, find extra information is prognosed service is not available
Take service	
arrive at station	
transfer to other service	
Wait for service	
Take service	
arrive at destination station	
walk to destination	

there is no difference between the 'static' situation, except for the fact that the information should be better (prognosis) and therefore comfort level could be higher, also a higher level of information gathering at the start of the trip

Real time

start planning trip	
	give in destination and desired arrival time
	routing device makes advice
	based on location, delays etc.
make the trip	
go to the car	
make the trip as given by the device	
	reroute if needed through device instructions
arrive at P&R	
buy the needed ticket (or online ticket via device)	
wait for service	device gives advice about what service where to take)

Found aspects:

Start	
Plan your trip	From where (location)
get your coat	what is the weather
go through the front door	access time
get to your car	location
get in your car	
drive your car to P+R	Distance, route
park car at P+R	location
get ticket for parking the car	costs
go to train station	distance
go to a ticket vendor	location
buy the needed ticket	costs

walk to platform where the train will leave	distance, advice
wait for the train	waiting time
get on the train	time
travel by train	travel time
arrive at destination by train	time
walk towards the bus stop	walking time
arrive at the bus stop	
get a ticket for the trip	costs
wait at the bus stop	waiting time
get into the bus	
travel by bus	travel time
arrive at the bus stop	location
locate your (call-a-)bike	location
unlock your bike	code
cycle to destination	travel time, route
lock the bike	
arrive at destination	
Finish	

the difference with the other time states is that the device makes the decisions, not the user

Scenario: Tourist, is nearby or in a city and wants to do some sightseeing.

Static

start	
plan trip	find out what POI are available and interesting
	what is the weather like, is every POI interesting in these conditions?
	find out what the available services are
	find out delays on services in public transport
	choose leaving time (based on desired arrival time)
	find out fares for P&R and services (and POI)
make the trip	
Go to the car	
Make the trip as planned	
if unplanned congestion, listen to radio for information updates (if available)	
Arrive at P&R	timing is uncertain, when does the service arrive?
Buy the needed ticket	or commucation ticket
	find out whether the service goes as planned, find extra information if planned service is not available
Wait for service	find out alternative routes / destinations if service is not available
Take service	
arrive at station	
transfer to other	

service
Wait for service
Take service
arrive at destination station
walk to destination

Commuter within tourist group, this group takes the preferences of the commuter, but change group size for pricing (take into account subscriptions)

Shoppers:
No fixed destination other than mall, street or shopping centre. See commuter, but on different points of time

Business trip:
See commuter, only unknown route/destination, no pre knowledge.

Appendix G: Used experts for references and guidance

MRK Consultants:

Dr. Johannes Reitner

Dipl. Ing. Atze van Sorgen

Dr. Ulli Sprehe

Manufacturers:

Mentz (jr) of Mentz Daten Verarbeitung (MDV)

Users (less influence):

Students
Colleagues at MRK
Friends

- ***Abstract of the answers given during the interview with Christoph Mentz (MDV)***

Date: April 1st, 2011
Time: 14.00-15.30
Place: MDV München

Different datasets are used for different times, these times are Monday-Friday / Saturday / Sunday / Holidays, no school

At the moment only P&R places in the system are available if they have been marked this way. This is to generate more publicity for the P&R owners, also the information about the park places is more reliable than normal park places along the road.
Not only real P&R are used for this information, also information from car parks in the area can be used (as is done in anachb.at).

The reliability of the routing process is optimised in a couple of ways. Usual average speeds are used, not free flow speeds to have some spare time. Also for the entire process of finding a parking place, parking the car, buying a ticket, waiting for the elevator and walk to the station the worst case scenarios are used. Most of the time a time of 12-15 minutes is reserved for this process.
At mdv the reliability of connections is based on the means of transportation, not on the number of connecting services.

Recurrent congestion should be based on the data of the link. Only these data are not always available

Top aspects by mdv for intermodalrouting:
Ganglinie / belegung
gebuhren
zeit : umsteigen / zuverlessig

Other aspects mentioned during the interview:
Computer performance is so good nowadays that more parameters for routing are not a problem. It is the availability of the data which can be a problem. Or the costs to obtain the data (buy)
When the data are available everything can be put into action
And, when the data is not too expensive, e.g. weather data in Austria is not available anymore.

Prognosed data in case of delays is not used often, since the update mechanisms are quite slow. Most of the time the update is derived from a train leaving the previous station.
Thereby, travellers who trust the prognoses and go get a coffee or something while the train does arrive in time will be really angry when they miss their connection.

MDV says that they can build any parameter into their products.
Why don't they?
* They have got more work than they can handle at the moment and are not willing to grow fast (no need to be inventing new products, since the costumers are standing in line for the current offer)
* Which brings it two the second point, if no one pays for an invention, why bother making it. Everything is possible if there is someone who wants it and is willing to pay for it.