D2.2 – Mobility and Travel Time Report

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Public report describing MoTiV conceptual framework based on insight from forecast analysis, expert workshop, routeRANK dataset analysis and overall refinement of concepts described in the MoTiV Grant Agreement.

D.2.2 is associated to the MoTiV Task 2.3, described below.

Description of Task 2.3 "Refinement of Conceptual Framework"
Identified megatrends, outputs of expert workshop and knowledge extracted from routeRANK Dataset analysis will be used to derive the initial proposal of the conceptual framework. This will involve definition of the set of aspects/factors that should be considered as relevant dimensions in the framework to explain the value of travel time. Moreover, important task is to define formalisms how to describe situational context of travellers to be able to associate it with VTT.

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2.0	04/5/2018	Quality check and final version	Giuseppe Lugano (UNIZA)

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About MoTiV

The Horizon 2020 project MoTiV (Mobility and Time Value) addresses the emerging perspectives on changing Value of Travel Time (VTT). Accordingly, it explores the dynamics of individual preferences, behaviours and lifestyles that influence travel and mobility choices. In other words, what does value of travel time mean for the end users, in relation to their travel experience?

The MoTiV project addresses VTT from the perspective of a single individual with a unique combination of personality, preferences, needs and expectations, in contrast with the traditional viewpoint of the economic dimension (time and cost savings). Its approach aims at achieving a broader and more interdisciplinary conceptualisation and understanding of VTT emphasising its “behavioural” component.

The main goal of the MoTiV project is to contribute to advance research on VTT by introducing a conceptual framework for the estimation of VTT at an individual level based on the value proposition of mobility. The conceptual framework will be validated through data collection and evaluation in at least 10 EU countries. The mobility and behavioural dataset will be collected using a mobile application developed by the project consortium, which will combine and integrate in an innovative way features from a multi-modal “journey planner” and an “activity/mobility diary”. With this mobile app, end-users will be able to more easily track, understand, and re-evaluate travel decisions to make the most of their free time in accordance with personal preferences, lifestyle, interests, and budget. The target is to engage in the data collection process a minimum of 5.000 participants actively using the MoTiV app for at least two weeks. Besides validating the conceptual framework, the dataset will be made available to the scientific community as an Open Dataset to stimulate further research in this area.

The MoTiV project findings will produce scientific and policy outcomes, as well as potential business developments, including the development of new mobility services and the extension of existing applications, such as the ones offered by the business partners of the Consortium (i.e. *routeRANK journey planner*[1] and the *PiggyBaggy*[2] app for crowdsourced deliveries).

Partners

[1] https://www.routerank.com
[2] http://piggybaggy.com

List of Abbreviations and Acronyms

ATT	Acceptable Travel Time
CBA	Cost-Benefit Analysis
ECDF	Empirical Cumulative Distribution Function
EDA	Exploratory Data Analysis
ICT	Information and Communication Technologies
PI	Personal Informatics
QS	Quantified Self
RTT	Reasonable Travel Time
STS	Satisfaction with Travel Scale
SWB	Subjective Well-Beings
TTB	Travel Time Budget
VOT	Value of Time
VBTT	Value of Business Travel Time
VPM	Value Proposition of Mobility
VTT	Value of Travel Time
VTTS	Value of Travel Time Savings

MoTiV Consortium Partners and Acronyms

Acronym	**Full name**
UNIZA	Žilinská univerzita v Žiline
CoRe	CoReorient Oy
ECF	European Cyclists' Federation ASBL
EUT	Fundació Eurecat
INESC ID	Instituto de Engenharia de Sistemas e Computadores, Investigação e Desenvolvimento em Lisboa
rRANK	routeRANK Ltd
TIS.pt	Consultores em Transportes Inovação e Sistemas S.A.

Executive summary

Since the Sixties, the Value of Travel Time (VTT), defined as the cost of time spent on transport, has been regarded as particularly valuable by decision-makers, transport planners, engineers, and economists in the context of projects aiming at enhancing transport infrastructure. According to this view, travel time is non-productive (i.e. it has no utility) in the sense that it cannot be allocated to economically productive uses. As everyone spends much time on the move, engaged in leisure or work activities, travel time has significant economic implications. As such, VTT is regarded as the most important concept in the domain of transport economics and cost-benefit analysis of transport implementations.

In the last decade or so, alternative and more holistic VTT conceptualisations emerged. Among others, the idea that travel time is "wasted time" without any intrinsic utility is increasingly questioned, especially when the traveller's perspective is considered. For instance, people can increasingly carry out a variety of productive tasks while on the move, particularly thanks to the increasing use of mobile devices connected to the Internet (Jain & Lyons, 2008). Furthermore, emerging conceptualisations of VTT stress the importance of acknowledging that travel time value should not necessarily be associated only to the "economic" dimensions of utility and productivity. In this respect, value may be rather referred to the ideas of pleasant, meaningful or worthwhile travel time (Wardman & Lyons, 2016). It is worth noting that worthwhile travel time does not exclude the idea that this may be productive, and multiple types of "value" may be associated to each specific journey. For instance, the time devoted to bike to work can be regarded as productive time producing benefits both to personal health and to the environment. Due to these benefits, which can be also described in economic terms, a person may consider it more valuable to spend 10 or 15 minutes more to go to work by bike rather than going by car or by public transport. **Emerging approaches to VTT support the idea that investments and policies in transport infrastructure and services should support various types of requirements and objectives, not only of an economic nature.** These requirements include, among others, accessibility, equity, empowerment, participation, environmental friendliness, individual health and well-being. With one word, these requirements may be summarised with the aim of supporting high-standards of quality of life, in which citizens and communities can increasingly take responsibility and influence the course of their lives.

Although the role and importance of motivational and behavioural factors in VTT research is well recognised, these factors do not usually represent the cornerstone of VTT projects. **The MoTiV project focuses on what value of travel time means for travellers, in relation to their needs, expectations, and lifestyles.** This report introduces the conceptual framework adopted by the MoTiV project to explore the changing value of travel time, and the underlying factors shaping such value across transport modes, gender, generations and socio-cultural contexts. **The MoTiV conceptual framework is grounded on the notion of Value Proposition of Mobility (VPM), a perspective on value of travel time that focuses on the "*promise of value to be delivered, communicated, and acknowledged to the individual traveller*" by a mobility system** meant as a complex socio-technical environment. The value proposition of mobility is the subjective, dynamic and contextual valuation of available (or preferred) mobility options. This can be regarded as the value embedded in individual mobility choices. As such, the value proposition of mobility is focused on the individual traveller and his/her perceived travel experience. **The VPM perspective is based on the idea that each transport mode, or combination of transport modes, provides a different value proposition to the traveller in a specific mobility situation. Time and cost savings represent only two of these factors, not necessarily the one contributing the most to VTT.** Depending on the situation, other factors such as increased comfort or well-being may influence traveller's choice as much as or more than time and cost, therefore considered more valuable.

The report illustrates how the notion of VPM in MoTiV is explored by combining several existing concepts and models on VTT: among them, **the concept of Reasonable Travel Time (RTT) is adopted to develop a holistic approach to decompose the multiple dimensions of the VPM into a set of hypotheses to be verified through the MoTiV data collection.** The main hypothesis states that VTT depends on the elements of Reasonable Travel Time (RTT), namely i) door-to-door travel time; ii) activities at destination, and iii) full experience while travelling, including activities while travelling and addressing travellers' needs related to the dimensions of VPM. In particular, the satisfaction of travellers' needs and expectations during the journey will be quantified by the amount of "worthwhile time" spent while on the move. Worthwhile time embeds the idea of "utility", although due to its economic connotation this term is not widely used in MoTiV. Accordingly, the VTT estimation in MoTiV is expected to include the ratio between the share of worthwhile time vs. the share of "wasted time" revealed by the collected data. In total, the report describes twenty research hypotheses relevant to the estimation of VTT. Although not all of them may in the end be verified in the MoTiV project, due to technical implementation requirements and user experience aspects and risks, the whole list of hypotheses is presented here to stimulate discussion concerning the approach adopted by MoTiV for VTT estimation.

At a methodological level, the analysis will rely on mobility and behavioural data to be collected throughout Europe via a smartphone app (the MoTiV app) developed within the project. The MoTiV app is tailored to the specific project needs and aims at gaining an understanding of traveller's reasons for his/her travel choices in line with the perceived value proposition of mobility. In addition to automatically collecting mobility-related variables, the MoTiV app will also allow users to enter qualitative input both to further edit automatically collected data and to provide additional relevant details on the user (e.g. demographic and socio-economic information), time use and travel experience.

Some elements of the MoTiV conceptual framework (i.e. door-to-door travel planning behaviour) were pre-tested against a dataset on multi-modal journey planning provided by routeRANK, one of the partners of the project. The analysis could not be performed across all dimensions of the MoTiV conceptual framework, since no data about all such dimensions was available. With this in mind, it was found that the main factors affecting travellers' decisions are (in order of importance) travel distance, travel cost, and general time consideration factors (Travel duration, Arrival Time). Travel duration seems to be a key factor for travel choice, in particular for long distance journeys. As far as short-trips are concerned, arrival and departure time seem more critical that the actual travel duration. The analysis also hints that travel plans typically concern long-distance travelling. Therefore, within urban/sub-urban contexts, the journey planner may not be systematically used due to people's familiarity with the area and locations in which they spend most of their time.

1. Introduction

1.1 Traditional view on value of travel time

Time is an intangible and limited resource that everyone possesses. Although one can plan when to use it, time cannot be stopped or stored, and nobody can increase or decrease his/her total stock of time by selling or buying it. As such, it is often felt as a scarce and therefore precious resource. Time can be used more efficiently, or just experienced differently. It is not straightforward to tackle the issue of value of time (VOT), since there is no general definition of this concept, and multiple definitions of time exist[3]. A classic study by Becker (1965) regards the study of the allocation of time as an area of consumer economics in which time value is assessed in relation to working and non-working hours, related respectively to people's role as "producers" and "consumers" of commodities. Becker further argues that "*the allocation and efficiency of non-working time may now be more important to economic welfare than that of working time […] the cost of a service like the theatre or a good like meat is generally simply said to be equal to their market prices, yet everyone would agree that the theatre and even dining take time, just as schooling does, time that often could have been used productively*". This approach has influenced subsequent research, which has for instance compared use of time to the use of money (Jacoby et al., 1976; Leclerc et al., 1995; Okada and Hoch, 2004): indeed, workers' salary is calculated in relation to the number of working hours (i.e. hourly wage). Following this logic, time savings are a key objective of projects addressing value of time because implying higher efficiency and productivity.

In the transport context, research and applications on value of time are firmly grounded on the concept of Value of Travel Time (VTT), defined as the cost of time spent on transport, including both waiting time and actual travel time[4]. VOT includes costs to consumers of personal (unpaid) time spent on travel and costs to businesses of paid employee time spent in travel (see Figure 1 for a Danish example of VTT for various types of modes, and also Wardman & al., 2016 for a European review).

Travel time values for travellers for the year ***2018*** ***2018*** prices

EUR per person-hour	Commuting	Business	Other private	Average
Public transport travellers				
Travel time	12.14 €	51.64 €	12.14 €	15.12 €
Delays	36.42 €	154.91 €	36.42 €	45.36 €
Waiting Time	24.28 €	103.27 €	24.28 €	30.24 €
Hidden waiting time (frequency)	9.71 €	41.31 €	9.71 €	12.10 €
Change time	18.21 €	77.45 €	18.21 €	22.68 €
Change penalty (DKK per change)	1.21 €	5.16 €	1.21 €	1.51 €
Car drivers				
Travel time	12.14 €	51.64 €	12.14 €	16.51 €
Delays	18.21 €	77.45 €	18.21 €	24.76 €
Cyclists				
Travel time	12.14 €	51.64 €	12.14 €	13.02 €
Delays	18.21 €	77.45 €	18.21 €	19.53 €

Figure 1: *Travel time values from the Danish ministry of Transport*[5]

[3] When time is referred to without any other connotation, it means "clock time". However, other definitions of time (e.g. "perceived time") are as relevant when considering the idea of value of time.
[4] The time needed to plan a trip is generally not included although also relevant.
[5] http://www.modelcenter.transport.dtu.dk/Noegletal/Transportoekonomiske-Enhedspriser

Travel time values such as the ones described in Figure 1 can be estimated in several ways (e.g. stated willingness to pay based on travel survey, revealed willingness to pay based on actual choices, analysis of business costs). For instance, the traveller may be asked on the willingness to pay an extra cost for a faster trip (Worsley & Mackie, 2015).

Based on an anthropological hypothesis on human behaviour (Marchetti, 1994), the notion of personal "Travel Time Budget" (TTB) was introduced as a stable daily amount of time that people make available for travel. This means that based on the TTB, people (mostly, unconsciously) optimise decisions that lead to rather constant total amounts of time spent on the move. Research has found that people on average spend one hour per day in travelling (Zahavi & Ryan, 1980; Vilhelmson, 1999), although a review of studies on this issue revealed that this is true only at an aggregate level (Mokhtarian and Chen, 2004). In line with this consideration, VTT is also defined as the maximum amount of money that one is willing to pay to save a minute of travel time. In other words, the assumption is that people are willing to pay more to spend less time in travelling to receive in return more productive time. Although widely cited, TTB is still a quite controversial concept that may be even regarded as incompatible with the purely utilitarian view of VTT: to quote (Mokhtarian & Chen, 2004), "the TTB idea appears, at least at first glance, to clash with one of the most fundamental tenets of travel behaviour: that travel time is a disutility to be minimized". Without entering into any judgement, it is worth noting that both definitions of VTT presented so far are firmly grounded on two (interconnected) key variables, namely time and cost. Furthermore, these two definitions hint that VTT models generally assume that transport is a derived demand (Banister, 2008; Mokhtarian & Salomon, 2001) and a person aims at maximising utility by acting in a rational way. Such utility depends on consumed goods and time spent in different activities, including work and travel. Work or leisure time are often discussed differently in VTT literature: in the former case, VTT is a cost to employers for the time spent on travel by employees, while in the latter it is a cost for personal (unpaid) time spent on travel.

The association of value of time to cost is in line with the idea that "time is money" (Becker, 1965). A Transport Note by the World Bank (2005) clearly explains this logic: "*The conceptual model underlying the valuation of travel time savings is one of consumer welfare maximisation. It postulates that each individual maximises the satisfaction or utility he gets by consuming and by engaging in leisure activities. Consumption of goods and leisure activities is constrained in two important ways: first, expenditure is limited by income which must be earned by devoting time to working; and second, work, leisure activities and travel compete for an amount of time available strictly limited by the number of hours in the day*". In allocating time between activities, an individual must trade off the extra consumption that work earning against the foregone leisure. Also, the possibilities of extending the amount of working or leisure time available by spending extra money to save travel time should be considered. This may arise in the narrow context of choice between fast and expensive modes or routes and cheaper, slower, alternatives or in the broader context of choices of activity or residential location. By analysing the relative sensitivity of such choices to variations in money and time cost, the implicit value of time of travellers can be identified. Following this approach, projects having the goal of increasing value of travel time normally aim at achieving time savings. As such, the Value of Travel Time Savings (VTTS) is associated to the benefits of faster travel that saves time (Mackie et al., 2003). From this viewpoint, the enhancement of transport infrastructure to reduce road congestion could be an example of effort to increase VTTS. In reality, it has been observed that the enhancement of transport infrastructure does not reduce congestion, at least in the long-term period, but rather increases the use of cars (Metz, 2008; Mogridge, 1997). VTTS criteria have been also used to direct transport investments, based on the time needed to achieve key locations and activities such as "work", "school", "hospital" and "supermarket". Although not always explicitly mentioned, whenever linked to VTTS, travel time has a negative value because it is associated to non-productive time, while productive activities are assumed to be carried out at origin or destination.

The body of knowledge on VTT, developed since the Sixties, has been regarded as particularly valuable by decision-makers, transport planners, engineers, and economists in the context of projects aiming at enhancing transport infrastructure. In this respect, VTT is regarded as the most important concept in the domain of transport economics and cost-benefit analysis of transport implementations. Based on the idea that travel time has no utility and cannot be allocated to economically productive uses, the time spent by everyone on the move, in leisure or work activities, represents a significant economic cost for society. For this reason, the employment of a different conceptualisation and measurement of VTT demonstrating that travel time is not necessarily wasted time would represent a paradigm shift in the field.

1.2 Emerging perspectives on value of travel time

Although all above-mentioned considerations are still valid and relevant, in the last decade or so, alternative and more holistic conceptualisations of VTT emerged. Among others, the idea that travel time is "wasted time" without any intrinsic utility is increasingly questioned, especially when the traveller's perspective is considered. For instance, people can increasingly carry out a variety of productive tasks while on the move, particularly thanks to the increasing use of mobile devices connected to the Internet (Jain & Lyons, 2008). Furthermore, emerging conceptualisations of VTT stress the importance of acknowledging that travel time value should not necessarily be associated only to the "economic" dimensions of utility and productivity. In this respect, value may be rather referred to the ideas of pleasant, meaningful or worthwhile travel time (Wardman & Lyons, 2016). It is worth noting that worthwhile travel time does not exclude the idea that this may be productive, and multiple types of "value" may be associated to each specific journey. For instance, the time devoted to bike to work can be regarded as productive time producing benefits both to personal health and to the environment. Due to these benefits, which can be also described in economic terms, a person may consider it more valuable to spend 10 or 15 minutes more to go to work by bike rather than going by car or by public transport.

Recent research suggests the need to explore broader meanings to assign to the notion of value of travel time, which are however challenging to conceptualise, measure and interpret. Emerging approaches to VTT support the idea that investments and policies in transport infrastructure and services should support various types of requirements and objectives, not only of an economic nature. These requirements include, among others, accessibility, equity, empowerment, participation, environmental friendliness, individual health and well-being. With one word, these requirements may be summarised with the aim of supporting high-standards of quality of life, in which citizens and communities can increasingly take responsibility and influence the course of their lives. According to Duarte et al. (2010), "*research developments of the latest decades have strengthened the importance on the individuals' behaviour to understand, not only their choices, but also how can this be incorporated in the modelling tools that are used to picture present demands and future calls on society levels such as economy, transport and social policies, among other*". Traditional views of VTT are limited in incorporating knowledge on users' attitudes and choices with respect to travel time, reasons behind re-organisation of transport routes and schedules, as well as factors explaining preference for a slower transport option or a longer route increasing travel time. The acknowledgement of these aspects as central in VTT estimation determines a shift from the economic focus to a broader behavioural focus centred on what value of travel time means for the traveller, and how such value could be increased in the context of individual decisions. In turn, this knowledge would also allow macro considerations at the level of cities, regions and countries, with clear policy implications. The shift from economic to behavioural approaches to VTT has the potential to contribute to the development of information societies with a human face. Jana Carp (2014) explains well this concept by introducing the Slow City movement, a vision for sustainable cities combining pleasure and productivity:

> *Correlated with digital and transportation technologies, high speed can be an advantage in discrete situations, but it has significant secondary effects that reduce overall quality of life, inhibit personal and public relationship, and exacerbate injury to people and ecosystems. At a time when we face the unprecedented question of human sustainability, and cities increasingly invest in digital innovations to improve the efficiency of urban systems (the Smart City), certain aspects of speed hinder capacity-building*

for social and ecological resilience. […] Good quality of life, and better business results, depend in large part on strategic employment of fast and slow (Davis and Atkinson 2010). It is not about pace in itself but what pace affords. When fast people slow down, they experience other people, the incidental pleasures of life, the character of the land, the weather, sounds, smells, and tastes. This embodied awareness of place and people is part of what signifies the quality of life promoted by the Slow movement. It is not envisioned as a period of leisure outside work life, but as characteristic of the social and ecological environments in which people live their whole lives.

The considerations above are well-suited to be operationalised to explore the value of travel time from a traveller's viewpoint. As an example, a similar approach has been adopted by Warffemius *et al.* (2014) to explore the value of comfort in train appraisal. In this conceptualisation, VTT is decomposed into two dimensions representing respectively the "time" and "quality" components of VTT. This approach shows that the traditional view of VTT (time and cost savings) may be complemented by additional indicators quantifying other relevant VTT dimensions. In other words, the classic approach to VTT estimation may not be necessarily regarded in opposition to emerging perspectives and approaches to VTT. As the case of high-speed trains shows, enhancing the perceived VTT from the traveller perspective may imply an effort in both shortening travel times and in addressing other relevant dimensions of the travel experience (e.g. comfort, safety). Accordingly, factors influencing (negatively or positively) the VTT appreciation during a journey are associated to services and activities that can be carried out while travelling. In this respect, it is important to underline the significant potential that ICT have in shaping VTT, which is the focus of the next section.

1.3 Role of ICT in shaping and investigating VTT

It is acknowledged that digital personal devices have an empowering and emancipatory potential on individuals and self-organising communities (Lugano, 2010). Ubiquitous and high-speed connectivity to social networks and, more generally, to knowledge and services, is felt to have an intrinsic positive effect on VTT (i.e. to increase the marginal utility of travel time) since it allows carrying out productive activities while on the move. These activities are not only supporting orientation, navigation and wayfinding thanks to location-based technologies (e.g. journey planner), but also a variety of work-related or leisure activities during the travel time (e.g. reading a book or newspaper, chatting with family and friends, business emailing, media consumption). In short, when appropriately used they can enrich the travel time. As an example, the availability of free and wireless internet access may contribute to this enrichment.

On the other hand, digital personal devices also lead travellers to engage in "travel multitasking" (Circella et al., 2015; Keseru & Macharis, 2017), a complex and cognitively demanding task. To make best use of time, a category of apps functioning as personal trackers and often including a "coach" function has emerged. These apps often detect mobility patterns and collect user input on activities and other relevant aspects of everyday life. This data is processed to provide personalised feedback to the user, thus increasing self-awareness, self-reflection and optimisation of own decisions. While not directly associated to travel time, these tools generally pursue the general objective of enhancing value of time from the viewpoint of an individual user. To explain it differently, enhancing value of time in this context is not about doing more in less time, but rather in finding the right balance between quality and quantity of activities and their outcomes.

Thanks to digital devices, smartphones and wearables in particular, as well as open datasets, it is increasingly easy to "quantify" one's life and to obtain a visual representation of personal activities, including statistics, trends and comparisons to a specific population[6]. These statistics can be fairly simple, such as counting the steps walked each day and comparing them to individual targets (e.g. today you walked 8.500 steps) and past behaviours (e.g. this week you walked 1,7km less than the previous one). The same approach can be applied to more complex behaviours and processes, with significant societal implications. Abend and Fuchs (2016) provide a clear summary of the ongoing trend "quantified self and statistical bodies":

> *"Contemporary quantified self enthusiasts are tempted by the possibilities of the surveyed body. Thus, joggers can keep track of their accomplishments, snorers can monitor their sleep, and chronically ill patients can readjust their medication. "Self knowledge through numbers" became the mantra of the emerging communities of self-trackers, and quantified self, lifelogging, and personal informatics are the terms used to describe the use of digital technology to track physical activity, quantify bodily processes, and monitor one's own conduct of life".*

The needs and requirements for a more holistic multi-dimensional conceptualisation of value of travel time find an excellent opportunity in employing the Quantified Self (QS) approach (Abend & Fuchs, 2016; Epstein et al., 2015; Lupton, 2016) to follow, measure and interpret, at an individual level and for a prolonged period of time, personal mobility and activity behaviours. The QS approach is the foundation of a research and application area known as Personal Informatics (PI), the gathering of personal data for enhancing self-knowledge and self-awareness (Ayobi et al., 2016; Rapp & Tirassa, 2017). The transport and mobility domains are well suited to the application of the QS approach, which was adapted already in 2011 to introduce the idea of "quantified traveller" (Jariyasunant et al., 2011). The benefits of employing the quantified traveller approach were two-fold: on the one hand, it allowed to reach a higher level of detail and sophistication than travel surveys and travel diaries. On the other hand, by presenting personalised feedback and statistics to the user, it also enabled offering value to the user in the form of personal insight in exchange of the research data needed for the study (Runyan et al. 2013).

Traditional approaches to VTT estimation regard travel time as unproductive, thus separating "activity time" from "travel time". The MoTiV project acknowledges that travel can be an activity in itself (Mokhtarian & Salomon, 2001), and the possibility of activities within mobility, as well as mobility within activities. The same considerations made in the previous section are valid also in the context of ICT use (e.g. considering both time "well saved", and time "well spent" thanks to digital technologies while travelling). Accordingly, the project will demonstrate how the value of mobility patterns can go beyond economic cost considerations if considered in relation to personal attitudes, preferences and motivations that influence mode choice in leisure and work activities. Specifically, the project adopts the emerging behavioural perspective of "happiness economics" in transportation planning. As underlined by Duarte et al. (2010), "existing behavioural travel choice models should be enhanced with regards to their behavioural validity incorporating the impacts of travelling happiness/satisfaction". It follows that value of travel time as well should be investigated in relation to subjective wellbeing (Choi et al., 2013).

1.4 MoTiV objectives and expected contribution

Although the role and importance of motivational and behavioural factors in VTT research is well recognised, these factors do not usually represent the cornerstone of VTT projects. Indeed, economic evaluations of transport projects solely rely on monetary cost and time factors. Additional behavioural factors related to travellers' preferences and experience should be incorporated as well in the economic quantification of value attributed to

[6] Usually, individual results are compared to the average results of a user group to allow a person to have an idea of where he/she stands.

travel time, such as the ability to work or carry out other meaningful activities while travelling, the level of comfort, reliability, among others. The MoTiV project aims at identifying such additional factors and at exploring their impact on VTT across gender, generations and socio-cultural contexts, as well as across transport modes. To meet this goal, VTT is investigated from the perspective of a single individual with a unique combination of personality, preferences, and expectations.

In line with these considerations, the project will focus on what value of travel time means for the end users, in relation to their needs, expectations, and lifestyles. For instance, people do not always consider more meaningful or pleasant time that is spent more efficiently or productively. One's time valuation fluctuates, also for the same activity performed in different circumstances: time remains a largely subjective entity influenced by internal and external factors (Zakay, 1989; Galetzka et al., 2017). As perceived quality of time influences individual well-being (Mogilner & Norton, 2016), by understanding and reflecting on one's own time use allocation to activities and mobility, it is possible to adjust and optimise one's own behaviour and to consider alternative choices that would better fulfil one's needs, goals, and expectations – thus enhancing subjective time value. These general aims will be supported by the MoTiV app developed within the project: in addition to collect research data, by adopting the "quantified self" approach (see section 1.3) the MoTiV app is also expected to enhance self-awareness and self-reflection in relation to time use in mobility/activity decisions. The rich dataset of mobility and behavioural variables obtained via a "quantified traveller" approach is expected to enable achieving a broader and more interdisciplinary conceptualisation and understanding of VTT which emphasises its "behavioural" component. In this view, time savings are not necessarily the main objective of VTT projects, especially when these are focused on individual perception/use of travel time aiming at maximising individual happiness/well-being or, more generally, worthwhile use of travel time (Wardman & Lyons, 2016). The choice of the project acronym is in line with this perspective, as motive refers to "something that causes a person to act in a certain way". Accordingly, **the main goal of the MoTiV project is to contribute to advance research on Value of Travel Time (VTT) by introducing and validating a conceptual framework for the estimation of VTT at an individual level based on the Value Proposition of Mobility (VPM).**

Introduced by Lugano et al. (2018), VPM is a perspective on value of travel time that focuses on the "*promise of value to be delivered, communicated, and acknowledged to the individual traveller*" by a mobility system meant as a complex socio-technical environment[7]. This means that "*the value proposition of mobility is the subjective, dynamic and contextual valuation of available (or preferred) mobility options. This can be regarded as the value embedded in individual mobility choices. As such, the value proposition of mobility is focused on the individual traveller and his/her perceived travel experience*".

Within the VPM perspective, meaningful use of time as well as perception of wasted time should be assessed against multiple factors affecting the valuation process and playing a role in the overall travel experience. Building on Becker (1965), Festjens and Janiszewski (2015) observed that *"an hour spent on a meaningful activity is more valuable than an hour spent on a less valuable* activity". On this, Warffemius *et al.* (2014) concluded that *"the value of travel time is not only related to hours and money spent but also to the value of time as experienced by the passenger".* In economics terms, we could be tempted to define the VPM as the marginal utility not only of time and cost, but of all the relevant factors affecting travellers' satisfaction such as comfort or well-being. In relation to value of time. However, it is not obvious to regard the VPM as an extension of traditional economic VTT models, because not all these additional factors may be easily mapped to a monetary value. While the investigation of this mapping remains of interest for the project, the exploration of the VPM in MoTiV is primarily associated to the notion of subjective valuation of travel time. Knowledge on barriers and enabling factors playing a role in the traveller's choice is therefore key to meet expectations and expected travel experience.

[7] This includes travellers, transport infrastructure, means of transport, transport services and mobility solutions.

Even if focused on the individual dimension, the VPM should not neglect the social context (e.g. family, friends, community) that often plays a relevant role and sometimes, represents the main reason of mobility/activity decisions (e.g. picking up children from school, caring mobility). In the MoTiV project, the influence of the social context is considered by not focusing only on the variety and meaningfulness of activities performed while on the move, but also on destination.

This project introduces in this report an enlarged conceptual framework for the estimation of VTT grounded on the notion of VPM. This is based on the idea that each transport mode, or combination of transport modes, provides a different value proposition to the traveller in a specific mobility situation. Time and cost savings represent only two of these factors, not necessarily the one contributing the most to VTT. Depending on the situation, other factors such as increased comfort or well-being may influence traveller's choice as much as or more than time and cost, therefore considered more valuable.

MoTiV does not focus on a specific travel mode, but more generally on travel options, which may involve a combination of travel modes (i.e. the customer journey), each with different value propositions and characteristics of the mobility context influencing the overall travel experience (e.g. pleasant short walk to the railway station on a sunny day, then 30-min trip in a fast but crowded train, and finally rapid change to a comfortable bus with wi-fi).

Similarly, MoTiV acknowledges that each trip is not necessarily associated to a single purpose (e.g. commuting to work, accompanying children to school, shopping to the supermarket, or leisure trip on a week-end). Rather, it is recognised that mobility and activities overlap and that a rich understanding of how mobility and activity behaviours influence each other needs to consider the variety of available travel options, as well as the richness of opportunities for activities in a specific location and the possibility for flexible allocation of one's own time (e.g. not always tight to rigid schedules). Additionally, knowledge on the role that soft factors have (e.g. curiosity, comfort, safety & security, cost) is valuable to assess travellers' perceived value of time in a specific context.

Building on the observations made by Glenn Lyons (2008) on the "orthodoxy of travel time valuation", the MoTiV project focuses on the value of travel time itself (as perceived, experienced and reported almost in real-time via the MoTiV smartphone app) rather than on the value of travel time saved (as estimated based on survey data). In other words, quoting two key recommendations by Lyons (2008), "*investing in schemes to save travel time should be weighed against investing in schemes to make sure travel time is well spent*" and "*trend data are needed to better understand and monitor travel time use phenomena*".

By adopting this approach, the project aims at contributing to a richer understanding of VTT beyond (and yet possibly compatible with) the assessment of time and cost savings. In addition to cost and time, many other factors play an important role in decisions on travel and mobility choices, thus representing value for the traveller. Accordingly, the project introduces a new definition for "Value of Travel Time" as individual happiness/satisfaction for the time spent on door-to-door transport. The definition acknowledges the dimension of individual "well-being" and incorporates a variety of economic- and non-economic factors relevant to the individual traveller.

Through a European-wide data collection via the MoTiV smartphone app, the project aims at gaining an understanding of traveller's reasons for his/her travel choices in line with the perceived value proposition of mobility. In addition to collecting mobility-related variables, the MoTiV app will also allow users to enter qualitative input both to correct automatically collected data and to provide additional relevant details on the user (e.g. demographic and socio-economic information), time use and travel experience. The use of smartphones for collecting mobility and activity behaviour over a rather long period and from a large number of subjects, allows in-depth behavioural analysis that was not possible with traditional survey methods such as paper travel diaries or telephone surveys. One may argue that despite their limitations, these latter methods were more "inclusive". Additionally, although users without smartphone could be left out from a smartphone-based data collection, the penetration of this technology is constantly increasing, especially in Europe (Table 1) that can be considered widely accessible. Nevertheless, special care will be devoted during local data collection campaigns to reach and involve all relevant categories of users (including, for instance, senior citizens).

Table 1: *Smartphone penetration in countries targeted by MoTiV data collection (based on ITU, 2017)*[8]

Country	Smartphone penetration
Belgium	67%
Croatia	80%
Finland	153%
Italy	87%
Portugal	61%
Romania	73%
Slovakia	79%
Spain	87%
Switzerland	104%

Overall, the knowledge acquired within the MoTiV project is expected to be relevant both for the scientific community involved in studies on VTT, and for policy makers and solution developers shaping the value propositions of travel time.

2. Conceptualising the Value of Travel Time

2.1 Value, utility and human experience

Research on decision-making that has been conducted using economic decisions scenarios can also be used as a theoretical framework to better understand users' motivations and preferences in other contexts, including transport and mobility. But ''value'' from a traveller's perspective cannot easily (nor objectively) be quantified in monetary terms. In MoTiV we wish to quantify value beyond a purely economic assessment: it is therefore relevant to consider psychological rather than economic value, and in the case of this project, to consider specifically the psychological value of *time* (Galetzka et al., 2017). Kahneman et al. (1997) elaborate on the

[8] Active mobile-broadband subscriptions per 100 inhabitants. ITU ICT Development Index 2017, http://www.itu.int/net4/ITU-D/idi/2017/index.html

definition of subjective well-being (SWB) and the utility of an action in terms of the pleasure or pain obtained and propose a taxonomy of four types of utility:

Experienced utility (or instant utility): the moment-to-moment hedonic reward of an experience while it is being experienced, therefore measured in real time.

Remembered utility: the memory of the hedonic reward obtained from a past experience. Although intuitively one may think that the way we experience events when they are occurring and the way we remember them is quite similar, research has demonstrated that there are important differences between them. For instance, the hedonic value remembered from an experience is not the average hedonic value experienced during the experience, but it is commonly calculated as the mean between the most salient moments of the experience (i.e. the most pleasurable or unpleasant moments or *peaks*), which is called the *peak-end-rule*. Similar considerations may be also done for the pleasurable or unpleasant outcomes of the experience (Kahneman, 2003). This concept is well illustrated in Figure 2 .

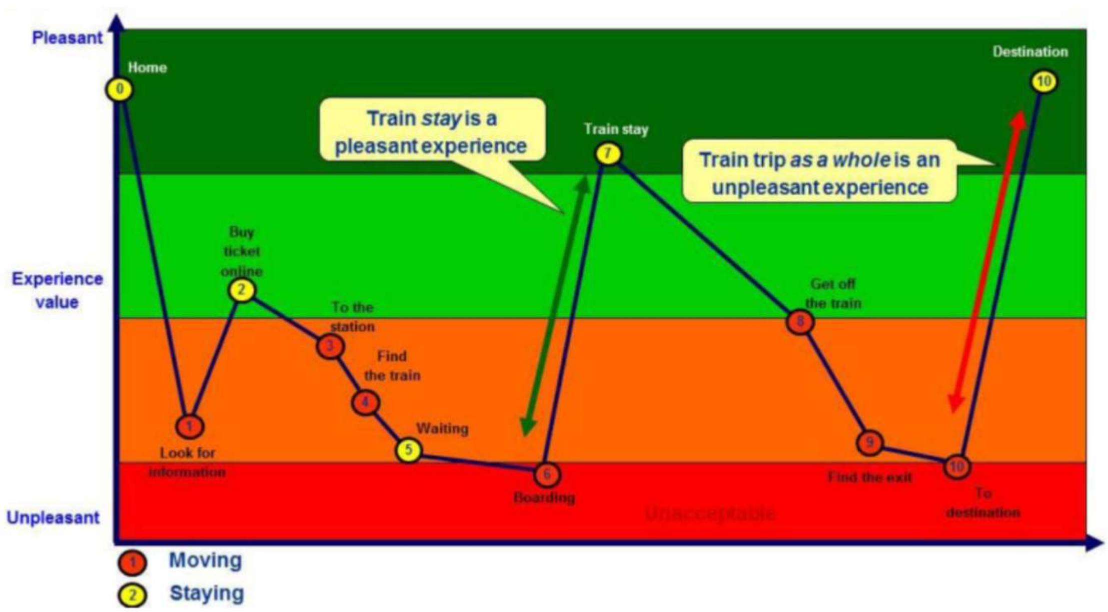

Figure 2: *How peak experiential value affects the overall traveller's experience (van Hagen & de Bruyn, 2012)*

Predicted utility: the expectation of how rewarding (pleasurable or painful) an experience will be. Research on social cognition shows that, when evaluating the hedonic properties of future experiences, we create mental simulations (or previews) of them, and we use such simulations to analyse how we would feel during experiences and to make our judgments on their hedonic qualities (Gilbert & Wilson, 2007; 2009). Such previews are not perfect simulations of future experiences, but they are constrained by limited cognitive capacity (Giguère & Love, 2013) and cognitive biases, and therefore tied to systematic sources of error. Specifically, previews of future events are essentialised, unrepresentative, truncated, and are also problematic when comparing dissimilar contexts (for details, see Gilbert & Wilson, 2009).

Another cognitive bias that may affect expectations about the value of future events is the different level of detail of the mental representation, as suggested by the construal level theory (Dhar & Kim, 2007; Trope & Liberman, 2009; Liberman et al., 2007). Broadly speaking, this theory suggests that mental representations of events or objects are more abstract as they are more distant to the subject (e.g. in time or in distance). This affects how future events are mentally represented, and therefore, the way we can attribute value to different aspects of the experience, since, depending on the type of representation, the individual may focus more on one or other aspects of the future experience.

Some cognitive biases that may also lead to inconsistencies in judgments about the utility or value of a future experience are loss aversion[9], framing processes[10], attribute substitution heuristics[11], or prototyping[12] (Kahneman, 2003; Kahneman, 2011). For instance, loss aversion may lead to overemphasise the possible negative aspects of future experiences compared to positive ones (Baumeister et al., 2001). Habits may also play a central role on evaluating the expected utility of a certain experience (Drolet & Wood, 2017).

Decision utility: the hedonic utility of a certain option as assessed during the decision. It is intrinsically connected to predicted utility (Berridge & Aldrigge, 2008; Kahneman et al., 1997). In the case of transport, decision utility usually refers to travel mode choice, whereas experienced utility refers to travel satisfaction (Vos et al., 2015).

The distinction between different types of utility is key, since there is empirical evidence that the predicted, experienced, and remembered utility of a same event may vary considerably due to the presence of diverse cognitive biases. In MoTiV all these forms of utility are of interest, but will be measured differently (e.g. experienced utility, with contextual notifications and user feedback; remembered and predicted utility, through user surveys to be filled at the beginning and during the data collection; and decision utility, through automated collection of mobility and behavioural variables associated to transport and mobility choices).

2.2 Reasonable Travel Time (RTT)

The term Reasonable Travel Time (RTT) originally appeared in Banister's (2008) paper about a shift of paradigm towards sustainable mobility. Subsequent articles by the same author that questioned the pursuit of higher speeds, suggest that there is a reasonable time that a travel should take, and reducing travel time should therefore not come at *any* cost (i.e. actual infrastructure investment costs or wider social or environmental costs).

RTT is a holistic conceptualisation of travel time, which is defined as the "*total (door-to-door) journey time that is acceptable to the passenger for reaching a particular destination (and its associated activities), given the conditions provided to turn 'forced time' to 'useful time' while travelling*" (Banister et al. 2016). It is essentially composed of three elements, to be seen as a set of combined decision factors to understand the traveller perspective on time:

1. **RTT is about the full *door-to-door* trip:** this puts emphasis on the total journey time and alternatives to the car, which usually involves a combination of modes and connections between them, all of which affect the traveller's experience. Door-to-door time therefore includes access, egress, the time spent interconnecting and waiting between modes, and the issue of the ''last mile'';

[9] In cognitive psychology and decision theory, loss aversion refers to people's tendency to prefer avoiding losses to acquiring equivalent gains.
[10] Frames are psychological lenses or assumptions that affect how people see and interpret the world around them.
[11] Attribute substitution occurs when an individual has to make a judgment (of a target attribute) that is computationally complex, and instead substitutes a more easily calculated heuristic attribute.
[12] In cognitive science, prototype theory refers to graded categorization where some members of a category are more central, or more perfect, than others. This means that although some things may belong to a certain category of elements, they still may be perceived as unequal.

2. **RTT comprises the full *experience* of the trip, beyond the concept of productivity**[13], with a view of the potential to repurpose ''lost'' or ''wasted'' travel and waiting time and turning it into ''free'' or ''usable'' time, therefore using this time for something ''worthwhile'' for the traveller;
3. **RTT is also about *activities at destinations*,** in the sense that the number of potential available activities and their characteristics at locations – the destinations a traveller travels to and through – also matter to travellers. This also implies that trips may consist of a number of activities and purposes at destination or on the way, commonly referred to as ''trip-chaining''.

Figure 3 illustrates the concept of RTT for a single origin-to-destination train journey, which emphasises the multiple ways in which travellers' use of time can be improved:

- By speeding up any segment of a trip;
- By improving the quality of time spent on any of these segments;
- By adding on new activities on the way or at destinations to reduce the overall need for travel, all of which improve the ''worthwhileness'' of travel time.

In this respect, in Figure 3 high VTT corresponds to the idea of worthwhile/useful time, while low time value to the idea of lost/wasted time.

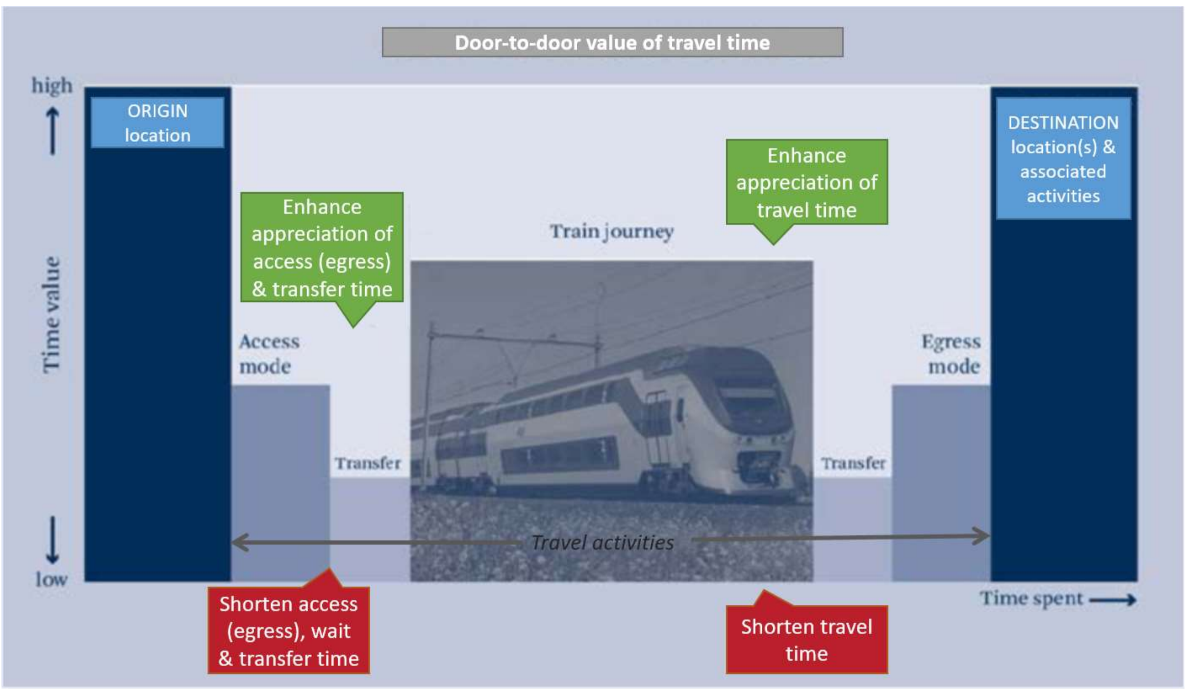

Figure 3: *RTT elements in train journeys. Inspired from van Hagen et al., 2017.*

Because RTT is an overarching concept relating to travel time that is both taking an explicit traveller perspective and is rooted in concepts of sustainable mobility, it is particularly well suited to the objectives of MoTiV. RTT is

[13] The term 'productive' is avoided to make clear that it is the value of time from the traveller perspective, as opposed to the value of time from for e.g. an employer perspective. This also acknowledges that travel time where the destination (or return) trip is work, if reclaimed, may not necessarily be reallocated to (productive) work activities. It is assumed in this approach that the traveller is best to decide on the use of his or her time, considering the universal constraint of 24 hours per day need to somehow be allocated to all necessary activities in some way or another, in or outside transport.

used in this document as a framework to which other concepts of travel time are connected (in the following sub-sections), each providing a unique lens from which hypotheses are then derived (in section 4).

2.3 Acceptable Travel Time (ATT)

For single mode and single trips, what is reasonable was well conceptualised from an economist perspective by Milakis et al. (2015) – what they termed Acceptable Travel Time (ATT). ATT explicitly acknowledges the inherent value of time spent travelling, which is represented by an intrinsic utility curve (see Figure 4). Displaying this as a curve implies that the level of utility is related to time, possibly rising at first (it takes a minimum time for the traveller to settle in before starting to benefit from the trip itself) and falling after a certain amount of time (trips that are too long bring tiredness or frustration which eventually offsets the initial benefits). The innovative aspect of this conceptualisation lies in juxtaposing the intrinsic utility curve with the more conventional derived utility curve (i.e. the value derived from the time spent at destination, which is the reason why the traveller undertakes the trip in the first place - in most cases, but not all - see also 3.4).

One contribution from MoTiV can come from validating to what extent, under which travel conditions, in what modes, and for whom, does the concave shape of the intrinsic utility curve apply. This could provide an opportunity to define various travel typologies, each with their own patterns of utility curves. This approach has the added advantage of potentially providing a representation of where the zone of reasonable travel time lies: assuming the shapes of the curves do apply, this zone could fall for example between ''Ideal travel time'' (the peak positive value derived from the time spent travelling) and ''Acceptable travel time'' (the peak total utility composed of both the intrinsic and derived utilities).

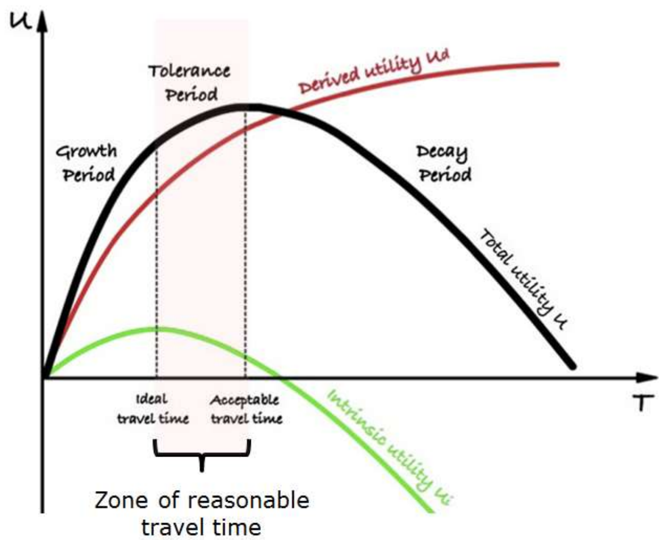

Figure 4: *Travel utility: ideal and acceptable travel time (Milakis et al., 2015)*

Although the concept of ATT brings a welcome conceptualisation of the value of time spent while travelling, it also uncovers several challenges when analysed through the prism of RTT. ATT is suitable for single trip legs. However, most journeys in a full door-to-door perspective are made of multiple trip legs. This is not a problem per se, as multiple ATT typologies could be lined up, one after the other, for representing the full journey. However, this approach still leaves intact the problem of the value of time spent *between* transport, i.e. in the various transfer and waiting locations that are an inevitable and important part of journeys, if not from travel time perspective, then from the perspective of the total experience of travel (e.g. a single ''bad'' experience such as an unsafe waiting space or a missed connection might very well ruin the full experience – see also Figure 3.

Another challenge may lie with the concept of ''utility'' itself, which is rooted in the Benthamite utilitarian ethical theory that assumes the ability to quantify, compare and measure individual happiness/well-being and has been criticised for, among other things, not necessarily leading to fair outcomes (Martens & Di Ciommo, 2017). One of the aims of MoTiV is to give a perspective on the human experience of travellers, which cannot necessarily easily be reduced to quantifiable factors (as opposed to goods transport for example). At a higher societal level, MoTiV also aims to provide empirical evidence to help address the structural inefficiencies and the risks of embedded unfairness of mobility systems (policy recommendations in this regard will be part of deliverable D6.5 – Report with Policy and Business Recommendations).

2.4 Travel Time Budget (TTB)

In relation to all three components of RTT, it is relevant to elaborate on the concept of travel time budgets (TTB) briefly introduced in the Introduction. Personal TTB is the daily amount of time that a person allocates to travel. Empirical data collected on TTB suggests that at aggregate levels across all populations, time periods, and geographical contexts, there exists a universal daily preferred travel time of 70±10minutes (Ahmed & Stopher, 2014). This ''constant'' is independent of distances or modes of transport, which has important implications for the concept of travel time, and more particularly for travel time savings (which are traditionally used to monetise the benefits for appraisal of transport infrastructure investments). In other words, speedier transport does not generate travel time savings in the longer run, as travellers will slowly adapt their travel patterns (by adding new activities or changing base locations such as home or work) so that overall, time spent in transport remains constant overall.

This has been one of the foundations for the recurring and long due recommendation to shift transport appraisal based on travel time savings to accessibility measures (Martens & Di Ciommo, 2017). Yet this also assumes locations to stay fixed in time, which is not the case, as studies on settlement densities and sprawl have shown. Although higher speeds in theory lead to a wider reach of activities, they can also lead to a dispersion of activities in space, as the choice of location for new jobs, services and housing adapt to this faster transport system. This land use and transport interaction was perhaps best explained by Wegener & Fürst (1999) (Figure 5), which therefore questions whether increased speeds lead to any accessibility gains in the long run at all.

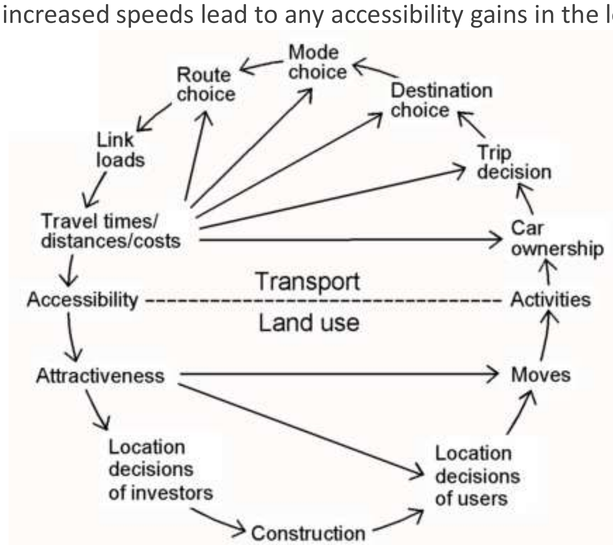

***Figure 5:** Land use and transport interaction as one explanatory mechanism for TTB* (Wegener & Fürst, 1999)

At a personal level, TTB is not necessarily constant across a period (week, month, year) as mobility patterns can differ much, for instance, when comparing regular working days to week-ends. Also, there can be ad-hoc events (e.g. a business trip) that are not part of one's routine activities and therefore imply a specific TTB. Furthermore, TTB estimation can be based on an objective measurement (i.e. based on Clock time) or on the perception or plan of the individual (i.e. based on Cognitive time). Both perceived and objective TTB are of interest for the MoTiV project. In particular, since MoTiV will collect data on travelled times, distances and activities in multiple geographical contexts across Europe, it will be interesting to assess under what conditions TTB holds true, as well as analyse multi-modal trade-offs that travellers make (which remain under-researched).

Another important implication for TTB based on MoTiV data collection is the aspect of time used while travelling. TTB assumes time to be earmarked for travel, and therefore dedicated solely to this purpose. In other words, does the daily preferred travel time average implies that humans are willing to ''waste'' this time budget as a kind of *maximum*, undesirable average amount of time per day spent moving about, or is it that humans find some intrinsic utility in spending this time as a *minimum*, desirable amount? There may also be interesting correlations with the quality of how this travel time is spent: 70 minutes driving a car in traffic, standing in a crowded bus, sitting comfortably in a high-speed rail, cycling in one's neighbourhood, or walking for pleasure are vastly different experiences for the traveller – which may or may not affect TTB. It is therefore expected for MoTiV to contribute to this topic – and if relevant to provide feedback to users about their own TTB.

Even considering the time savings perspective, the smartphone app may include, for a specific travel option (i.e. mode and route chosen), hypothetical time savings that could have resulted from the choice of different travel route and/or modes. A person could make use of this information to optimise TTB, which is expected to provide room for improving one's activity plans thus enhancing life satisfaction.

2.5 Activities and multitasking

According to Wardman & Lyons (2016), "The value of time savings may be influenced by the scope for activities which can be undertaken during the journey". Therefore, collecting all *possible* activities is relevant, either as a proxy for worthwhile time, or to prove the hypothesis that the more activities can be conducted, the more worthwhile the time. Which useful activities can be performed in the course of travel is particularly significant for business travel. Conducting structured observations of passenger activities onboard public transport can show how difficult collecting data on activities actually is, for the simple reason that people multitask, change task and their attention *level* all the time (Kenyon & Lyons, 2007; Keseru & Macharis, 2017). Therefore, to be comprehensive, collecting data on activities would require being able to report on any type of activity undertaken in parallel during the course of a journey (see Figure 6). This raises challenges for the quality of self-reported activities while travelling. For example, post-trip questionnaires (researchers ''catching'' passengers just as they descend from a train for example) have showed that businessmen overstate the amount of time they work in order not to appear lazy (see Wardman and Lyons (2016)).

Yet recent studies also show that smart device usage may have a mitigating effect in uncomfortable environments: "*passengers may use smart devices to reduce perceived discomfort (e.g. jerkiness) or to further isolate themselves from that environment*" (Ettema et al., 2012; Guo et al., 2015). This means there is a need to discriminate between *active time* and *worthwhile time,* and between which activities are more worthwhile. Doing ''something'' has become easier with ICT, but that something might not necessarily be useful (or productive). Wardman & Lyons (2016) concur: "*however, it is not sufficient to simply include as a covariate in a standard value of time model what activities are being undertaken in the travel time. This is because those who have more important uses of travel time or for whom the ''boredom'' of ''no activity'' is greater will be more inclined to ensure that they have such things to do on the journey. As a result of this ''endogeneity'', there is the confounding effect that those who are pursuing such activities might actually have higher values [of time]!*"

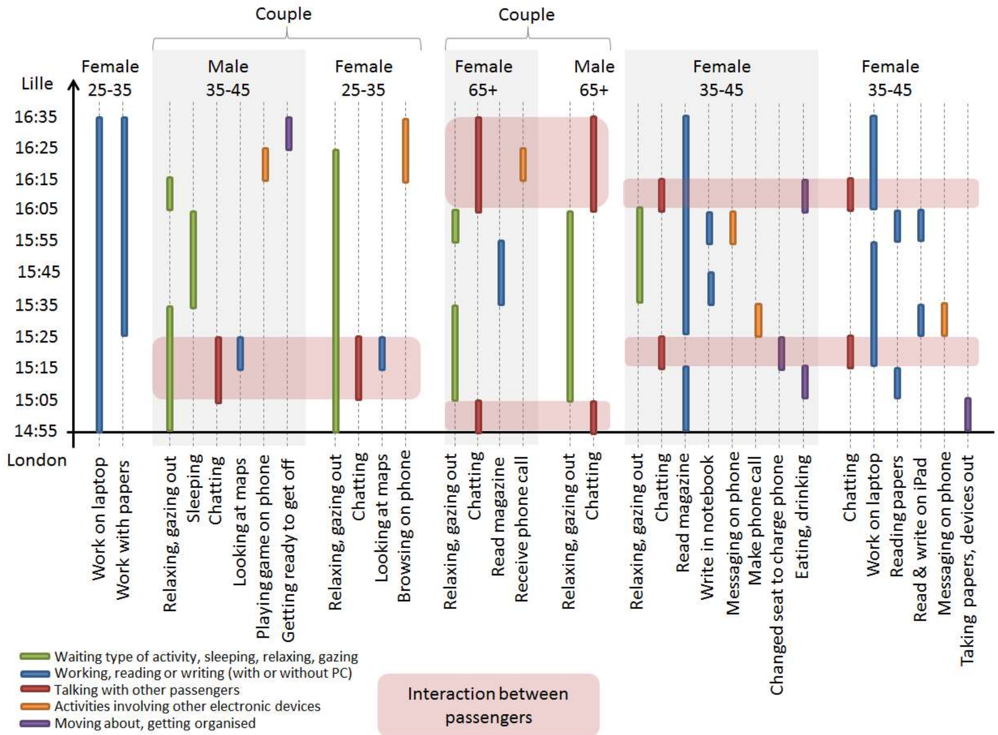

Figure 6: *Types of activities and activity multi-tasking while travelling* (Banister et al., 2016)

The propensity to engage in worthwhile activities (whether only one or many) depends on a number of factors, grouped along the following types of categories of variables (Keseru & Macharis, 2017), which are relevant to cover in the data collection:

1. **Socio-demographic variables** refer to the socio-demographic characteristics of passengers such as age, gender or access to car;
2. **Trip-related variables** refer to specific characteristics of the trips such as duration of travel, travel distance and travel mode;
3. **Attitudinal variables** include psychological characteristics of the persons travelling, their own expectations and expectations of other people towards them;
4. **Comfort-related variables** refer to variables related to the comfort and services provided during the trip mainly related to the vehicle, the infrastructure (e.g. stations) and the environment (e.g. weather);
5. **Equipment-related variables** refer to any personal equipment passengers carry with them during the journey (e.g. smartphone and books);
6. **Spatial attributes** refer to the area where the multitasking activity takes place or where passengers board or leave a vehicle;
7. **Time-use-related attributes** refer to the type of activities one spends his/her time with in general and how non-multitasking activities relate to travel-based multitasking.

2.6 Locations, destinations and travel purposes

The term ‘’trip purpose’’ (and most models in transport) assumes one single purpose to a trip, which in practice is not necessarily the case. A journey can often be justified by a number of purposes where, for example, one activity serves as an *anchor* to a number of other activities. Similarly, there may also be other activities undertaken ''on the way'', implying detours, transfers between modes, and waiting times. Susilo and Dijst (2009) provide a useful typology of these journey types.

This raises the question: when does a trip start and end? Susilo and Dijst (2009) talk of base locations, which they define as home or a fixed workplace. In MoTiV we do not aim to collect data when users are in these based locations (which would take the project too far into the private sphere and into activity diaries as opposed to travel diaries). But data of anything happening in between and beyond is relevant.

The following two cases illustrate the difficulty in defining trip purposes. Figure 7 illustrates two different ways to categorise the same trip from a hotel to a work office, with stops to the pool, a restaurant for breakfast and a short return to the hotel to pick up luggage. This trip consists of many legs (in this case walking) with the possibility of multiple main (anchor) purposes. This also has implications for determining trips along conventional variables such as ''business'' or ''leisure'' or ''commute''. In such cases, there is simply no uniform way to categorise where the work-related part of the trip starts.

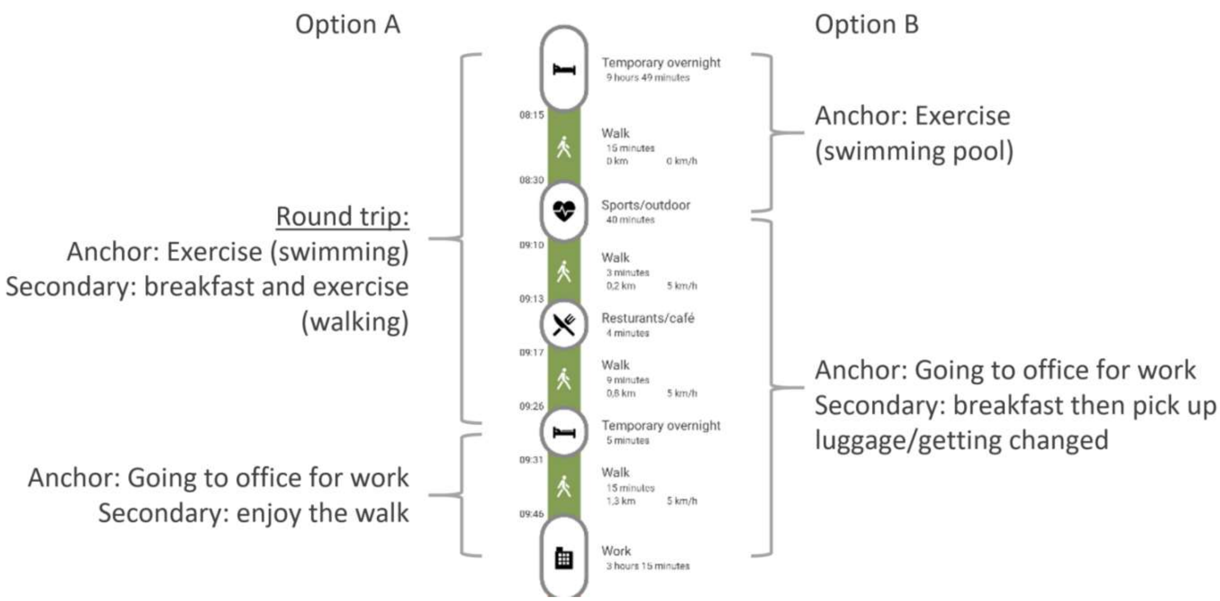

Figure 7: *Two possibilities for categorising a trip*

A second example is illustrated in Figure 8, which consists of a leisure trip to a neighbouring town. In this case, although the main purpose is clear, it is unclear when the trip starts or ends, since there is no specific target location (it consists of a mix of shopping, museum, and café locations, as well as walking in the streets). The most likely ''arrival'' is perhaps the moment when the traveller leaves the boat. The same problem arises for the return trip: it can start as soon as the traveller walks out of the last café, or when he/she boards the regional train.

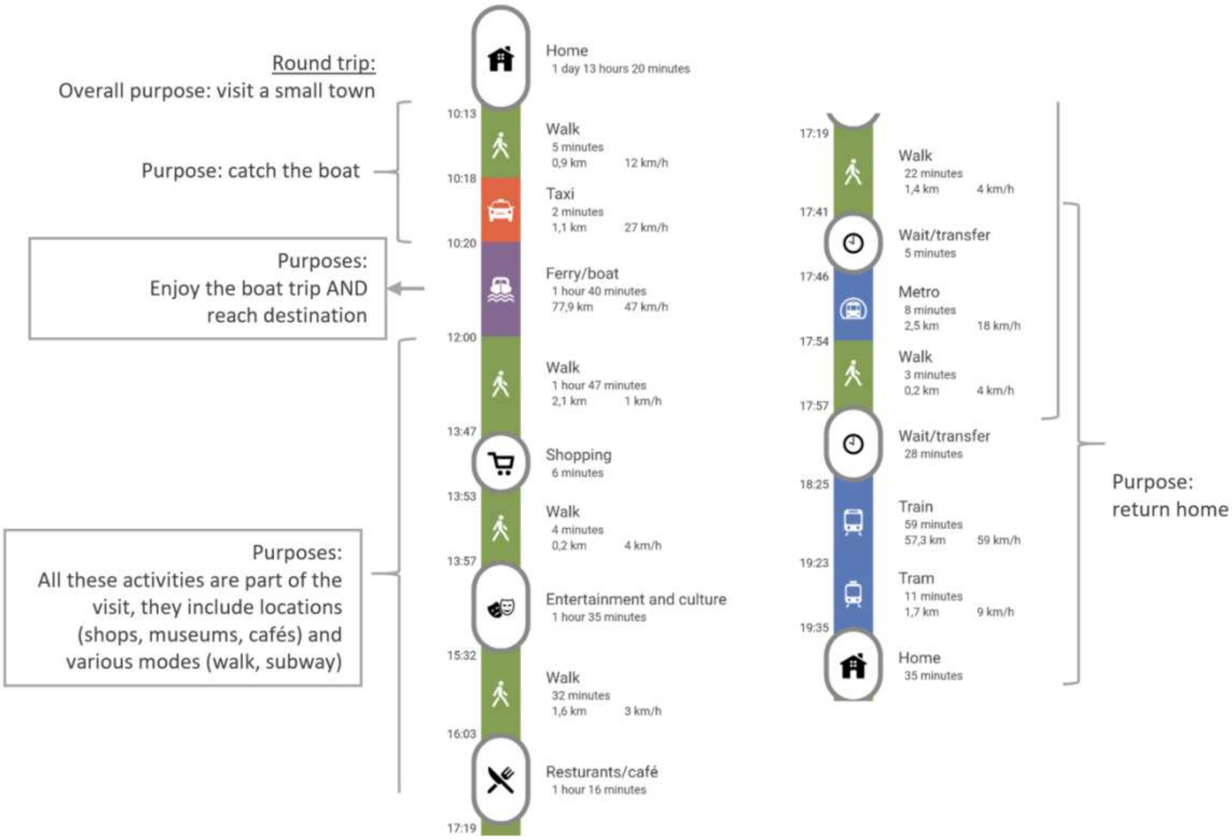

Figure 8: *Example of a leisure trip with multiple purposes*

To avoid the risk of simplifying bias from the start, one suggested approach for MoTiV is to talk of travel *purposes* (plural), and explicitly adopt the concept of ''primary'' or ''anchor'' activities, and ''secondary'' activities to determine which activities at destinations act as main drivers (and time constraints) for justifying a trip. Furthermore, activities at destinations need to be analysed and tracked insofar as the number and diversity of them will influence the traveller's decision to undertake a trip. It is therefore necessary to find out about the range and quality of activities at these locations – whether a shopping centre, a train station, or a bus stop – because they influence the experience of the full door-to-door trip.

In MoTiV, it is also important to focus on collecting all trip legs (consisting of a single mode) and locations (where some time is spent) as fundamental units of analysis. Establish ''trips'' and ''trip purpose(s)'' is an added layer of data, which can be inferred from locations or asked in real-time to the traveller – bearing in mind that transport can become purposes and justify a trip (such as walking for fun or taking a boat for the experience). Finally, both locations and legs can have time constraints, e.g. having to catch a boat or train at a specific time, or having to be at a work, shopping or school location at a specific time.

2.7 Measuring worthwhileness of time

The Hensher approach seeks to determine a value of travel time saving (for business travel) which accounts for some of the journey time being used productively for work. This approach also accounts for the relative productivity of working while travelling. Fowkes (1986) codified the concept described by Hensher into a formula (Figure 9) and an interesting paper by Wardman and Lyons (2016) highlighted the discrepancies in trying to collect data on the Hensher formula's two main factors, q and p. q is the relative productivity of work done while travelling compared with the office environment, and p is the average amount of time spent working while travelling. For an example of implementation of Hensher, see Fickling et al. (2008).

Expressing the above ideas mathematically let;

MP = marginal product of labour

VL = the value to the employee of leisure relative to travel time

VW = the value to the employee of work time in the office relative to travel time

r = proportion of travel time saved used for leisure purposes

p = proportion of travel time saved at the expense of work done while travelling

q = relative productivity of work done while travelling compared with in the office

MPF = value of extra output generated due to reduced fatigue.

Then the value of savings in (long distance) business travel time (VBTT) is given by:

$$VBTT = (1-r-pq)MP + (1-r)VW + rVL + MPF \qquad (1)$$

It is this expression which we would ideally like to measure, and which we call a synthetic value of time. Next we discuss, in turn, issues concerned with the measurement of MP, VL, VW, MPF, p, q and r.

Figure 9: *Hensher's formula (Fowkes et al., 1986)*

The Hensher formula was designed for the proportion of *work* p* done while travelling (to estimate the Value of Business Travel Time[14]), not for any other activity. If any activity is to be considered equally worthwhile, even the act of driving itself, then p* would be 100% for all modes, which is no longer providing relevant insights. Therefore, there is a need to understand the relative value (''worthwhileness'') of activities as well. The Hensher formula also requires the relative productivity (q) compared with home/office in the case of a work activity. But people do not always plan in advance activities they can be productive while travelling. Often, they adjust their behaviour and plans to optimise their time use. For this reason, this value is usually close to 1 and therefore less relevant to collect.

Lyons and Urry (2005) produced an illustrative figure of productivity by mode which is relevant to understand the concept proposed by Hensher (Figure 11). The figure makes two points.

- First, some modes are more likely to have higher p* factors. Wardman and Lyons (2016) later provided empirical data on the likelihood of productiveness where train obtained the highest values (with figures up to 57% in latest studies in the UK), followed by air travel, and finally bus and car at the bottom of the pyramid (see Figure 10).

[14] This is a simplified Hensher formula. To calculate a VBTTS (value of business travel time savings), the formula also requires an estimate of how much time saved from travelling would actually be used for working (which is assumed to be 100% in conventional Cost-Benefit Analysis (CBA). Because we do not aim to calculate new economic values of travel time saving, we focus only on the percentage of journey time spent doing something worthwhile.

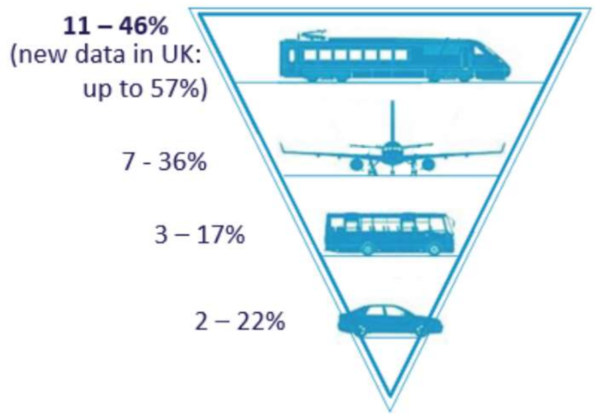

Figure 10: *Current values of worthwhileness of time, per mode* (Wardman & Lyons, 2016)

- Second, levels of productivity are not necessarily limited to the travel leg, but it may have ''spill-over'' effects outside travel, termed as ''counter-productive time'' and ''ultra-productive'' time. In other words, a particularly ''bad'' travel experience may undermine productivity once at destination (e.g. from stress or tiredness), and vice-versa (e.g. a healthy bicycle ride may be energising).

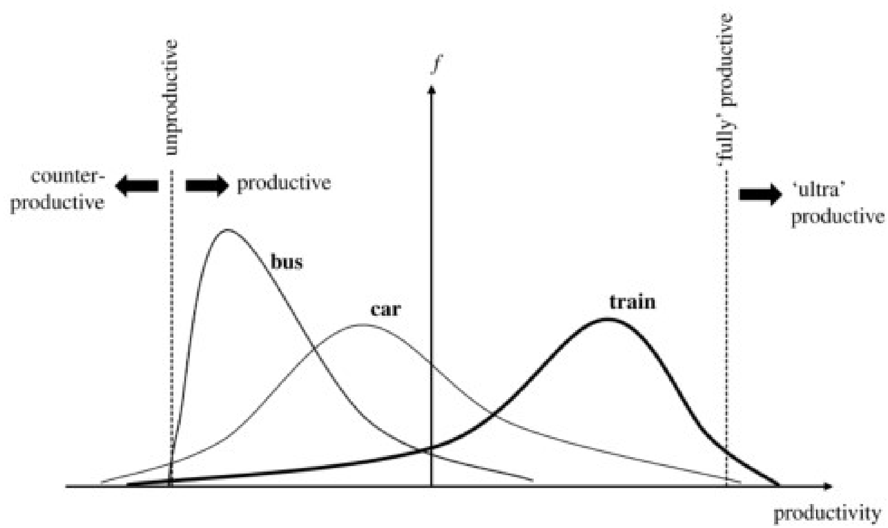

Figure 11: *Illustrative frequency distributions of 'productivity' of travel time by mode (Lyons & Urry, 2005)*

The concept of worthwhileness of time expressed by the Hensher formula has more recently been complemented with the concept of satisfaction with travel, itself derived from subjective well-being (SWB) introduced in section 2.1. In addition to the cognitive judgment[15], satisfaction is influenced also by the emotional state of the traveller. It is therefore necessary to capture the affective dimension of well-being, which can be obtained by scales using opposing adjectives, e.g. depressed/happy (Vos et al., 2015). The theory suggests discriminating between two main dimensions: activation (e.g. relaxed or excited), and pleasantness (from sad to happy) (see Figure 12).

[15] Cognitive judgement may be elicited from the Hensher formula, or similar approaches.

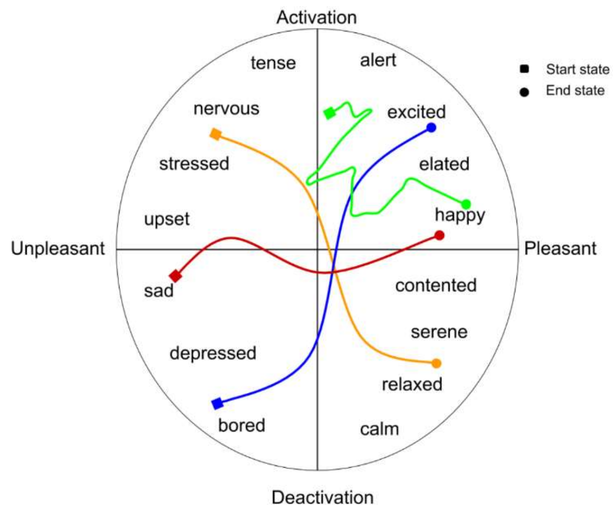

Figure 12: *Measuring traveller's emotional state across two main dimensions* (Kariryaa & Veale, 2014).

The above two concepts of cognitive judgments and emotional state as a comprehensive measure of worthwhile time has recently been consolidated into a transport-specific Satisfaction with Travel Scale (STS) (Ettema et al., 2011). The approach has reduced the questionnaire to scoring 9 components on a -4 to 4 scale, illustrated in Figure 13.

Positive deactivation–negative activation
Time pressed (−4) – relaxed (4)
Worried I would not be in time (−4) – confident I would be in time (4)
Stressed (−4) – calm (4)

Positive activation–negative deactivation
Tired (−4) – alert (4)
Bored (−4) – enthusiastic (4)
Fed up(−4) – engaged (4)

Cognitive evaluation
Travel was worst (−4) – best I can think of (4)
Travel was low (−4) – high standard (4)
Travel worked well (−4) – worked poorly

Figure 13: *The Satisfaction with Travel Scale* (Ettema et al., 2011)

In conclusion, collecting and analysing data on the worthwhileness of time by means of the MoTiV app aims at exploring an area that is relevant, but still rather under-explored. Wardman and Lyons (2016) summarise the importance of collecting this kind of data: "*the reluctant summary observation is that we still know very little with much confidence —especially once the variables of mode, journey distance/duration, location and change over time are accounted for*".

2.8 Travelling efforts

About the quality of the travel experience, Banister et al. (2016) suggest measuring the capacity to reclaim travel time by assessing the unwanted efforts spent towards the travel – as opposed to the ability to use the travel time for something worthwhile. Efforts that may prevent this worthwhile use can be physical, cognitive or affective. Banister et al. call this ''forced time'' – time that the traveller is ''forced to spend on an unwanted activity or effort. Unless such efforts are desired (e.g. exercising), they play against giving back the time to the traveller. However, what prevents the traveller from using their time for something desirable or useful is very personal and can also change depending on the time of the day, the purpose of the travel, expectations, habits and attitudes. Table 2 summarises these three types of efforts.

Table 2: *Unwanted travel efforts*

Effort type	Definition	Example	Intervention
Physical	Effort asked of and imposed on the body in undertaking travel	Standing in a crowded bus	• Reducing transport connections and '''smoothing'' them by integrating the transport networks • Improving comfort, e.g. seating, personal space, or by alleviating crowding or travel-sickness • Improving travel services, e.g. accessibility for the mobility-impaired, or younger/older people
Cognitive	Mental focus that is needed to execute the journey successfully	Noisy or attention-demanding environment	• Improving the familiarity with the transport system • Improving the ability to plan the journey effectively • Reducing unwanted distractions
Affective	Emotional influence of undertaking the journey	Stressful, unsafe or unreliable	• Improving the perceived security or pleasantness of travel • Improving reliability

The proposed worthwhileness measures and Unwanted travelling efforts are in a way complementary. In MoTiV, it is needed to assess whether both approaches need to be addressed and, if not, which method would be more suitable for the project implementation needs.

2.9 Attitudes and travellers' segmentation

One shortcoming of RTT is that it does not attempt to categorise how traveller characteristics or attitudes influence the three components of RTT. However, operationalising RTT for MoTiV data collection requires recognising the importance of attitudes in traveller profiles. This is particularly important since research shows that traditional socio-demographic factors have little bearing on the travel profiles (Anable, 2005). There is therefore a need in MoTiV to define names and sizes of market segments based on cluster analysis, as Small (2012) explains:

"It is striking that the more we learn about these topics, the more apparent it is that the behavioural regularities being sought are subtle and complex. It's not just a matter of measuring a single number, ''the'' value of time, or even a set of functional relationships showing how it varies with income, age, and so forth. Rather, we need to understand how these trade-offs are embedded within a complex dynamic decision-making process involving many choice dimensions, all within a context of habit, attitudes, and learning. (…) The importance of this topic is increased by our growing realization that the standard rational economic paradigm is an incomplete and sometimes highly inaccurate description of individual decision-making." (Small, 2012)

Segmenting means subdividing the public/broad audience into clearly identified/manageable groups based on the attributes they possess, e.g. their social status, their attitudes or their dominant behaviour. However, establishing such market segmentation via cluster analysis is difficult (e.g. one must achieve statistical validity and be sure the target groups are indeed represented). Difficult questions arising from this may be:

- Which attitudinal traits are both influential and stable enough to be useful for prediction?
- How much statistical efficiency is gained from incorporating attitudinal information?
- Does such information tell us more about behaviour or about how respondents answer surveys?" (Small, 2012)

There exist already many such segmenting studies. For example, Morton et al. (2017) defined different types of electric car users in the UK in this way: Environmental Cynics (24%), Weekend Drivers (20%), Keen Greens (20%), Early Adopters (18%), and Car Enthusiasts 19%. The SEGMENT project[16] has targeted groups based on life events, such as ''New employees'', ''Start/change school'', ''New residents'', ''University students'', "First baby day care'', and ''New foreign residents''. Their resulting attitudinal segmenting groups are: Car-free choosers, Public transport dependents, Car contemplators, Practical Travellers, Active Aspirers, Malcontented Motorists, Image Improvers, and Devoted Drivers, which the SEGMENT project proposes to use as a type of standard for future data collection in cities across Europe.

The limitation with reusing SEGMENT is that it is not representing fully the characteristics that matter to MoTiV. First, it is somewhat focused predominantly on car users and the methodology is biased towards bus as representative of public transport (a UK perspective perhaps). Second, SEGMENT says nothing about attitudes towards travel *time*.

In MoTiV, there is a need to understand travellers' attitudes to both mobility and travel time, jointly. Two conceptual frameworks may be useful for this exercise. First, the perception on the productivity of time presented above in Figure 11 suggests also that some travellers may have predispositions in terms of the potential for using their travel time for something useful. Some frequent long-distance high-speed rail travellers may have expectations for a special type of focussed time while travelling, where they are able to be ''ultra-productive'', achieving some tasks better than in other environments, thanks to the relative seclusion from disturbances and the passing views which may help concentration. Other travellers may be particularly sensitive to jerkiness and experience motion sickness in local bus transport or in a car for example. This may not only force them to be wasting their time by not being able to engage in any desired activity, but also potentially affecting their mood or physical state beyond that of a journey, therefore leading to ''counter-productive time''. These predispositions can be investigated by understanding for e.g. the travel factors important for the traveller.

A second useful concept is ''slow travel'' by Lumsdon & McGrath (2011), which distinguishes between tourist travellers preferring a slow travel experience against those preferring a fast travel experience (we note that the focus here is on tourism as the main purpose of travel, but the categories developed may nevertheless be relevant for attitudes towards travelling time in general). Lumsdon & McGrath (2011) identified three core defining categories: slowness, travel experience, and environmental consciousness (see Figure 14). Characteristics of the mode of travel and destinations (the sense of place) also played a secondary role for the meaning of slow travel.

''Slowness'' is characterised by a preference for an unhurried, relaxing and enriching travel experience where the destination may not be as important as the journey itself. ''Travel experience'' further relates to the opportunities for engagement with cultures or the landscape while travelling. ''Environmental consciousness'' is about

[16] : http://www.segmentproject.eu/hounslow/segment.nsf/pages/seg-1

recognising and valuing the advantages of slow travel, particularly in terms of carbon footprint. Travellers may also express a commitment to particular modes of transport or attachment to the special characteristics of a place.

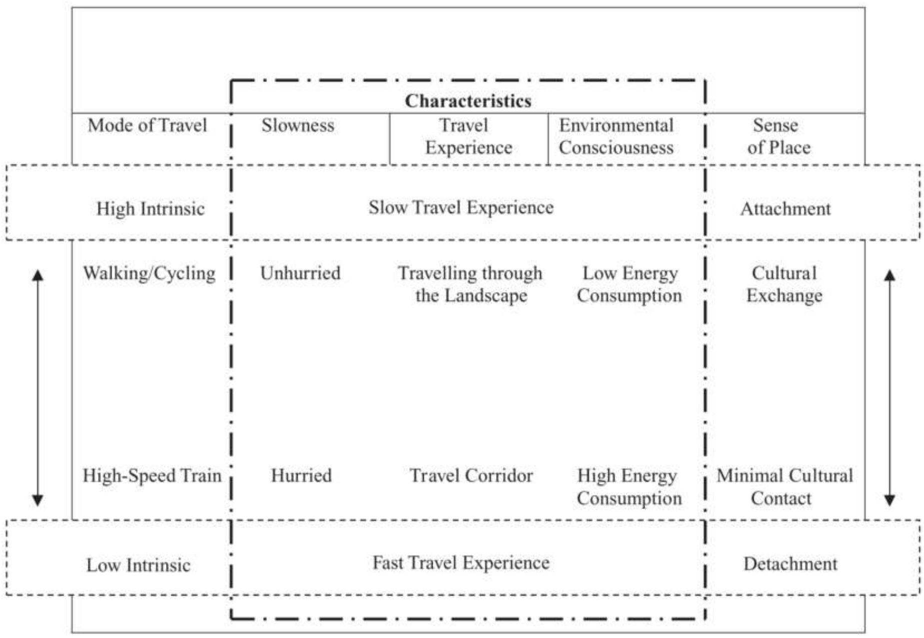

Figure 14: *Slow travel conceptual framework* (Lumsdon & McGrath, 2011)

To what extent the data on attitudes collected in MoTiV will allow travellers' segmentation will be determined during the dataset analysis.

2.10 Equity in the experience of travel

The literature on transport justice has in recent years examined how the conventional approach to transport planning tend to benefit the majority of the population at the detriment of other groups, in terms of accessibility, mobility choices, and health effects for example (Di Ciommo & Shiftan, 2017). More particularly, the current utilitarianist paradigm, its focus on maximising *net* satisfaction for society as a whole, and the associated monetary methods in calculating travel time savings introduce biases that are difficult to address other than by considering equity issues from the start, i.e. at every step of decision-making and planning in transport (Jones & Lucas, 2012; Martens & Di Ciommo, 2017).

Inequalities can take many forms. It is usually well acknowledged that lower income groups are disadvantaged in many ways: they collectively ''weigh'' less in cost-benefit assessments because they have lower willingness to pay; they often face additional barriers and constraints (multiple jobs, greater spatial imbalances between home and work and less mobility choices for example); they often suffer more from the externalities of transport (more affordable housing is more likely to have higher air and noise pollution); and finally they have less disposable time to spend filling travel surveys (something relevant to consider in MoTiV data collection campaigns) (Singleton, 2018).

Although there is no clear-cut difference in the total time spent travelling between low or high income groups (see also section 2.4 on TTB), research showed that higher income groups tend to travel at higher speeds over longer distances, and lower income groups for shorter distances and at lower speeds (Martens & Di Ciommo, 2017). Based on French long-distance trip data, Figure 15 shows how high-speed rail as well as car trips are significantly higher for higher income groups.

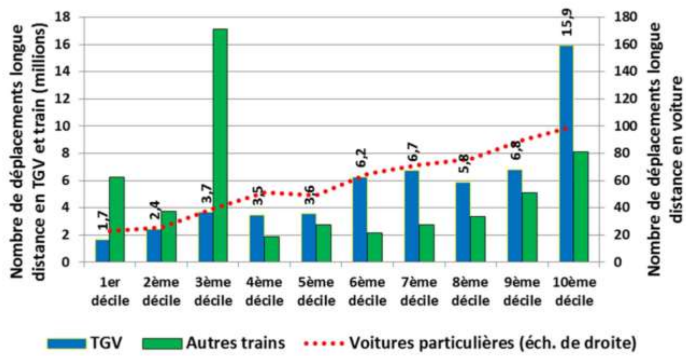

Figure 15: *Trips as a function of income deciles for long-distance travel in France*[17] (Cour des comptes, 2014)

Gender is also an important differentiator. Women have been shown to conduct more complex transport patterns, which typically includes more transport modes and particularly more walking, at more varied times of the day. Perhaps an outcome of remaining social differences, household roles and responsibilities often imply that women take on more care activities and household-related errands, which also means their needs may be under-evaluated in conventional transport assessments based on work commutes (Martens & Di Ciommo, 2017; Singleton, 2018). More particularly, women often report lower levels of satisfaction with their commutes, and are particularly likely to have more concerns regarding personal safety. Perception of fear and security depend in turn on factors such as time of the day or night, adequate lighting, cleanliness, reliability and the presence of security staff (or cameras) (Jones & Lucas, 2012).

Age and abilities also are often correlated with satisfaction with travel, where young people, older people, or people with disabilities being generally more fearful of crime and expressing lower levels of satisfaction with their commutes, particularly in terms of health and well-being (Jones & Lucas, 2012; Singleton, 2018). Finally, because of the importance of walking for some of these groups, evaluation of VTT cannot be dissociated from the characteristics of the places where walking occurs.

Overall, it is therefore suggested in MoTiV to shift away from utilitarianism by adopting an approach based on understanding the needs and preferences of individual travellers. Rawl's theory of justice provides the necessary conceptual underpinning, stating that "we should not favour the majority at the expense of the least well off" (Rawls, 1971)[18].

[17] Left scale: number of trips by train (HSR in blue, or conventional trains in green). Right scale: number of trips by car (red dotted line).

[18] See also Nahmias-Biran et al. (2017) and Pereira et al. (2017) for more detailed and updated reviews on theories of justice in transport.

3.MoTiV Conceptual Model

3.1 Key concepts and definitions

An important pre-requisite of MoTiV is to clarify the key concepts and definitions, not all self-explanatory or without ambiguities, that will be employed in the conceptual framework. These are listed below, with a brief description of their related meanings.

- **Trip, travel** and **journey:** these are regarded as synonyms and used in relation to the main concept of **door-to-door trip** (one of the RTT pillars). This includes both the time spent in transport ("moving") and the time spent at transfer locations ("staying", which covers waiting, parking, transferring).

- **Trip leg and trip route:** the trip leg is the fundamental unit of the door-to-door trip, which consists of one or more trip legs. Each trip leg is associated with one transport mode only. A trip route is a sequence of trip legs, which are followed by a traveller to reach destination based on personal criteria (trip duration, cost, or even mood, etc.).

- **Transfer locations and interchanges:** transfer between trip legs takes place at transfer locations, which can consist of any type of interchanges: bus stops, bus and train stations, car- or bike-share parking, hubs, airports, etc. Transfer locations and interchanges are used as synonyms. **Interconnectivity** refers to the ease of connecting between transport modes at transfer locations, which enables **multimodal** travel.

- **Activities:** it refers broadly to any type of human activity. In the mobility context, activities may be classified as travel activities or location activities**.**
  - **Travel activities** are activities that the traveller engages in while travelling, which includes both activities while in transport or at transfer locations. Some travel activities apply only to certain modes. For example, relaxing while in the train or getting exercise while cycling or waiting for the bus are both travel activities. Travel activities are potentially supported by a range of carried items, such as a book (reading), a mp3 player (listening to music or podcast), or food and drinks (eating and drinking). The traveller may be engaged in one or more travel activities in parallel, which is called **multi-tasking**, some of which may be more relevant than others (primary, or anchor activities).
  - **Location activities** are the range of possible activities available at locations, either while in transfer or at destination, like shopping or playing bowling. Location activities are therefore connected to a location's offering in terms of infrastructure and services, and constraints, such as opening and closing times. Location activities are usually the purpose of travel.

- **Travel or trip purpose:** a trip purpose is typically understood as an activity at destination (i.e. a specific location activity) that justifies the travel, such as work or shopping. Accordingly, a trip purpose applies to a whole trip and not to a single trip leg. If a specific purpose is the main reason for taking the trip, it is an **anchor purpose**. In other words, without this purpose, the trip would not take place. Other purposes may be added, they may be secondary or anchor (i.e. two or more reasons justifying a trip). **Secondary purposes** are activities added to a trip: they do not contribute to the justification for the trip itself. In MoTiV, a travel purpose can apply to both travel activities or location activities. When applied to travel activities, it acknowledges the travelling as a purpose in itself (e.g. this includes, among others, going out for a walk without any other specific purpose in mind). In other words, a traveller may choose to travel to enjoy the ride or to exercise, which is the value from the time spent in transport for a specific leg (also called intrinsic utility in economic terms). Or a traveller may choose to travel to reach a location to engage in an activity at destination, which is the value derived from the time spent in transport (or derived utility in economic terms). **Destinations** are a type of location marked by the traveller with at least one anchor purpose.

- **Clock time and perceived time:** each trip (and specific trip leg) has a specific measurable duration, called clock time. This differs from perceived time, which is related to the quality of time experienced from the traveller's perspective. Perceived time is quantified with the worthwhileness of time invested in **travel activities** during (any portion of the) trip. **Worthwhile time** is time that can be allocated to the most preferred activities by the traveller, hence with an intrinsic value. On the contrary, **wasted time** is time without an intrinsic value. This includes time spent on unwanted activities or time that the traveller, if possible, would have reallocated to other activities. We refrain from using productive and unproductive time, utility and disutility, to avoid connotations to the cost dimension, monetised time and seeing positive value of time as ''work time'' only[19]. Similarly, we avoid attempts at forcing a distinction between work and non-work purposes (it can be discriminating to define work only as paid employment. Indeed, care-taking of a family member or unpaid work for a community association for e.g. are also work)[20]. Worthwhile time encompasses multiple dimensions of travel time value from the perspective of the traveller, applicable to the whole spectrum of the value proposition of mobility (i.e. utilitarian, hedonic and eudaimonic value).

- **Travel experience, satisfiers and dissatisfiers:** travel experience is affected by multiple factors that can have different impacts under different circumstances, thus influencing the overall perceived value of travel time. In MoTiV, a strong focus goes to the factors influencing emotions and time perception, contributing to a positive or negative travel experience (satisfiers and dissatisfiers). Both satisfiers and dissatisfiers are part of the **comfort dimension** of the value proposition of mobility (VPM, see section 3.2).

- **Attitudes:** relevant pre-determined inclinations that influence travel choices and activities conducted while travelling. Investigating attitudes is done by segmenting the population into user groups based on certain characteristics.

3.2 Value Proposition of Mobility (VPM)

The Value Proposition of Mobility (VPM) is the core concept of MoTiV. Introduced as a basis for the MoTiV project (Kováčiková et al. 2018 - see also MoTiV public deliverable D2.1), it is defined as the subjective value embedded in individual mobility choices. It implies a range of expectations associated with mobility behaviour, which are tightly connected to motivational as well as attitudinal factors. The VPM is therefore regarded as a framework for "*achieving the objective of enabling lifestyles by improving mobility fit*", which combines both general sustainability aspects and subjective well-being.

The conception, development and deployment of mobility infrastructure, services and solutions from the perspective of individual motivations, needs and expectations defines and shapes a Value Proposition of Mobility. This represents a promise of value to be delivered, communicated, and acknowledged to the individual traveller.

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[19] Valuation of time in monetary terms is related to wage income and a host of other assumptions. MoTiV can contribute to this econometrics exercise by providing the factors (or weights) of worthwhile time e.g. at aggregate levels for various modes.

[20] In a full day or week, leisure time can displace work time and vice versa. We therefore do not explicitly ask the traveller to differentiate between work and leisure, but instead will collect types of activities and satisfaction levels.

A group of travellers with similar needs, aspirations, motivations, and expectations are likely to have also a similar general judgment of different transport options. The value proposition of mobility cannot be reduced only to the value proposition of a single product, technology, and brand (e.g., the Tesla Model S car), but it should be referred to a set of products, services and technologies used within a broad variety of human activities and mobility situations. Being a complex ecosystem, there is no single actor in charge of shaping the Value Proposition of Mobility. It is rather a joint outcome of actors co-creating meaning and value to transport and mobility options through policy, implementation, deployment, and participation. The concept of VPM is particularly relevant today, as Internet-based travel planners (e.g. single-mode vs. multimodal, local vs. national or international), peer-to-peer real-time mobility services (e.g. ride-sharing, Uber), crowdsourced micro-tasks, including delivery of small goods (e.g. PiggyBaggy) and, ultimately, Mobility as a Service (MaaS) are shaping and redefining the value of technologies, products, and services, and on the other hand introducing new actors in the mobility ecosystem.

The VPM, at the core of the conceptual model of MoTiV, addresses the need of allowing to capture the value of travel time, which cannot always be adequately assessed in terms of travel time savings (e.g. in cases where travelling is the purpose in itself). As shown by Mokhtarian and Salomon (2001), in the case of leisure travel under some circumstances people travel just for the sake of travelling, because it is “fun”. As described later in this section (Figure 16), this specific motivation is driven by the “curiosity” need. In this case, it is not the activity to be carried out at destination that represents utility, and therefore value to the traveller, but the journey itself. The authors of the study include several types of activities falling under this category such as driving an off-road vehicle, recreational walking, jogging, cycling, hiking. These activities are “undirected” in the sense that they do not necessarily have a specific objective or destination point. On the contrary, value of travel time is often associated to utilitarian travel, such as bringing kids to the kindergarten, going shopping or to a medical appointment. The study goes further, describing also utilitarian travel situations in which travellers may decide to travel further (therefore, not minimising travel time) because of intrinsic reasons, such as a “variety-seeking” orientation or just curiosity. These are not exceptional situations: a common decision as dining out instead of eating at home (although food is available and quick to cook) could be included under this category. In this sense, the VPM shall acknowledge both utilitarian and hedonic value, fulfilling up to the highest level of the hierarchy of travel needs, which deals with well-being.

The starting point for investigating individual preferences and motivations in travel choices is a classic study by Sheth (1975), who distinguishes between five utility needs corresponding to motivational dimensions:

1. *Functional motives:* related to the technical functions the product performs. The combination of product attributes forms the total functional utility of a product;
2. *Aesthetic-emotional motives:* style, design, luxury, and comfort of a product (class). These motives are not only important for the specific (brand) choice but also for the generic (product) choice. The product class is evaluated in terms of the fundamental values of the consumer in the emotive areas of fear, social concern, respect for quality of life, appreciation of fine arts, religion, and other feelings and emotions. Thus, it may be contended that individuals tend to select those product classes that match with their life styles and enable them to express their fundamental values;
3. *Social motives:* related to the impact that consumption makes on relevant others. Status, prestige, and esteem may be derived from the possession and usage of products and their conspicuous features. Some products are selected for their conspicuousness only ("conversation pieces"), sometimes in combination with aesthetic motives;
4. *Situational motives:* these are not motives in the sense of long-term desires to reach a certain goal. The selection of a product may be triggered by situational determinants such as availability, price discount, and/or accessibility. These situational factors apply usually for a specific brand or type. The brand choice is usually made in these cases without a careful evaluation of the product class;

5. *Curiosity motives:* motives that are supposed to prompt trials of new and/or innovative products. The consumer may try a new product; however, his repeat-purchase may be independent of such trials.

Although Sheth's model was conceived more than forty years ago, it is still current as it acknowledged both intrinsic and extrinsic motivations. A recent study by Mokhtarian et al. (2015) underlines that by "*focusing exclusively on the extrinsic motivations to travel runs the risk of substantially underestimating the demand for travel*". Building on Maslow's scale of needs (Maslow, 1943), Van Hagen & Sauren (2014) developed a pyramid of customer needs for Nederlandse Spoorwegen (NS), the principal passenger railway operator in the Netherlands. The pyramid of customer needs is designed to reflect the importance and perception of the quality of services for the traveller. There are three main types of needs identified: first, the basic needs of safety and reliability that represent the foundation of trust between the traveller and the transport/mobility provider, which must ensure that the traveller reaches destination safely. The dimension of time savings is incorporated in the middle level of the pyramid, which also includes a basic element of comfort: the low mental effort required to access and use the transport service. This includes, among others, suitable infrastructure and clear information. The third level of the pyramid covers other elements of comfort such as physical comfort and the feeling of valuable time spent while travelling is at the top of the pyramid. In this sense, the value of travel time from the viewpoint of customer needs shall incorporate also the emotional dimension of a pleasant travel experience, which requires an understanding of the factors influencing customer satisfaction and dissatisfaction, happiness and frustration.

The VPM proposes a refined model for describing motivational factors influencing travel choices (Figure 16), which should help understanding the expected determinants of utilitarian, hedonic and eudaimonic value linked to transport and mobility choices. The VPM builds on the model proposed by Sheth (1975) and it is inspired by the pyramid of customer needs (Van Hagen & Sauren, 2014) and the considerations on travel and subjective well-being (de Vos et al., 2013). Note that the choice of a pyramid representation does not necessarily imply a hierarchy in the importance of the dimensions of VPM, which are subjective and ultimately established by the travellers depending on the context. In this representation, additionally to the VPM dimensions, the cross-cutting dimension of influence factors (e.g. infrastructure, services, weather) is highlighted as they enhance or decrease the perceived value associated with all the VPM dimensions (in terms of satisfiers/dissatisfiers).

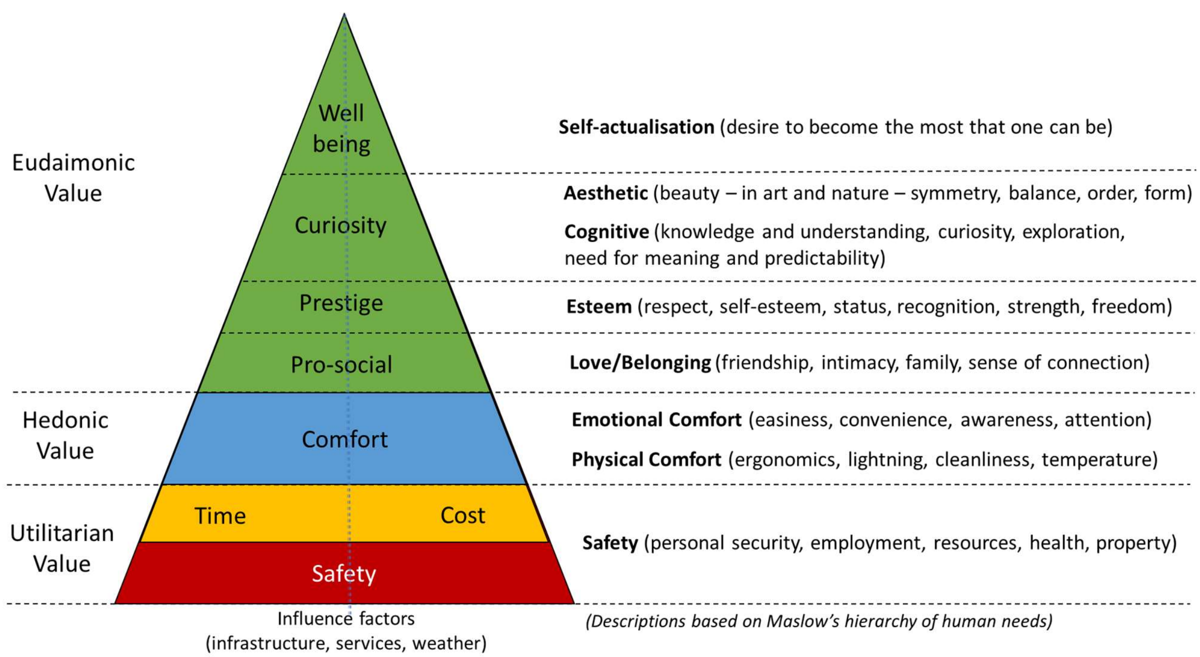

Figure 16: *Dimensions of the Value Proposition of Mobility*

The VPM suggests looking at travel time from the viewpoint of decision factors (well-being, curiosity, prestige, pro-social, time, cost, safety and reliability, and comfort factors and well-being) affecting mobility and activities. The better understanding of hedonic and eudaimonic value in travel time is at the core of the MoTiV project, which explores the role of these factors in VTT, under-researched compared to studies on the utilitarian components. Table 1 provides further considerations for each of these factors:

Table 3: *Value Proposition of Mobility - adaptation from Lugano et al. (2018)*

Decision Factor	Assumptions	Clarifications and further comments
Well-being	To be maximised in line with health and well-being aspirations and objectives. This includes also commitment to reduce environmental impact of transport (in terms of CO_2 emissions).	Subjective well-being is to be understood in terms of self-actualisation; this means connecting to higher aspirations and values relevant to the individual, a community or the whole society, such as personal health or environmental sustainability objectives (e.g., privileging active modes). Aspirations and values are connected to attitudes and ''persona'' (see D2.1), which may be used for segmenting groups of travellers. In MoTiV, well-being will be mostly addressed via attitudinal surveys, as well as from the emotional state during travel and the cognitive judgment of the experience of travel (Vos et al., 2015).
Curiosity	To be maximised in line with travel experience expectations.	Curiosity is a type of travel condition as well as an attitude of the traveller towards life and discovery. It refers to aesthetic and cognitive elements of the experience, such as enjoying the scenery that can be viewed or the sense of exploration and acquisition of knowledge about travel, places and people. This refers to a desire of continuous self-development, learning and search for meanings. These meanings may address the adventurous approach to the unknown (e.g., the travel as a purpose in itself), or simply support more informed decisions. Overall, mobility services and information (often accessed through digital devices) support this dimension of the travel experience.
Prestige	To be maximised in line with social status aspirations.	Prestige is an attitudinal factor expressed by travellers in terms of images or discourses towards certain types of transport modes, comfort preferences, etc., that also play a role in determining identity. The dimension of prestige could be further determined by feedback mechanisms that are typical of social media (e.g., ''likes'', following/followers, and other social recognition measures). In MoTiV only the individual aspect of prestige is considered and not the social one. This is to be obtained through qualitative feedback about transport and services preferences.
Pro social	To be maximised to maintain and/or extend personal social relationships	Pro social addresses explicitly the part of the travel experience involving other people, stressing the sense of connection to the world, e.g. a rich experience by travelling with a friend, colleague or family member (ingroup), and/or interaction with strangers (outgroup). This is addressed

	(e.g., it may involve volunteering, charity or caring activities).	in MoTiV by specifying companionship during travel, the type of activities, and other aspects of the social context.
Comfort	To be maximised in line with travel service expectations.	Comfort is a crucial factor affecting the travel experience, which in turn may be influenced by: 1) external influence factors, such as quality of service (convenience), availability of travel services, weather, time of the day; 2) internal factors, such as mood or attitude. Comfort factors are varied and include seating space, crowdedness, personal space, air quality, noise, levels of vibration/shaking, temperature, trip reliability and infrastructure accessibility (for older or less able people, or in some countries, for women-only). Travel services include for e.g. availability of toilets, food/drinks, Wi-Fi, entertainment such as newspapers and entertainment systems, travel information such as arrival time or connections, garbage containers, etc. In MoTiV, comfort is addressed at a general level with satisfaction with the travel time (i.e. worthwhile time) and at a more specific level with the description of satisfiers/dissatisfiers influencing the ability to carry out meaningful activities. In general, the lack of comfort will have a direct incidence on the increased unwanted travel efforts (physical, cognitive and emotional).
Time	To be optimised in relation to time savings strategies.	There is a universal intention to save travel time, understood as the freedom to decide how to spend one's time and to claim ownership of one's time. In other words, the latent intention to save travel time exists because there is an opportunity cost, i.e. one loses the opportunity to use time in something else which has value. Personal strategies for saving time can include: 1) reducing absolute travel time, by either increasing speeds or reducing distances; 2) increasing reliability, therefore reducing the time necessary to plan trips before or while travelling; 3) increasing the amount of free, usable time when travelling to conduct desirable activities (including the possibility for multi-tasking[21]); 4) reducing the amount of time needed to carry out one's activities at destinations; or 5) removing the need to travel in the first place (out of scope in MoTiV). In line with the multiple time savings strategies, this dimension is addressed in MoTiV from several perspectives and in particular with a focus on locations (e.g., amount and diversity of possible activities) and

[21] Time savings are obtained when a suitable strategy for multi-tasking is followed, i.e. choosing suitable activities not resulting in cognitive overload, stress or fatigue.

		the use of ICT and smartphones in relation to activities while travelling (e.g., use of journey planner, use of smartphone apps to carry out a variety of work-related and/or other tasks) as well as time constraints such as schedules.
Cost	To be minimised (as personal expenditure) in relation to service expectations and personal budget.	Personal travel costs should be minimised, in relation to the expected level of service, as well as the personal available budget and resources. Cost estimation may not be straightforward, as real cost of a transport choice may be higher than the perceived cost of going from A to B. For example, the cost of a trip by owned car shall consider e.g. its purchase, maintenance, yearly insurance and tax costs. In some cases, cost may be also maximised such as in the case of personal mobility plans compatible with the possibility of earning by transporting people or goods. In MoTiV, the relevance of cost as a decision factor for travel choice is investigated, as well as the "good value for money" judgement, based on the feedback on the travel experience.
Safety	To be maximised to reach destination safely.	Safety is a fundamental quality singled out because it is often a precondition for travel. For example, the presence or absence of appropriate infrastructure such as protected cycling lane or footpath with adequate lighting will determine whether cycling or walking are considered as options in the first place. There are two types of safety: 1) measured safety (actual numbers of injured or dead, which can be used as a measure of travel risk). This data is not collected within MoTiV; 2) perception of safety, which can differ significantly from actual data and greatly vary between travellers. In MoTiV, the relevance of perceived safety as a decision factor for travel choice is investigated.

By using the terminology adopted by Van Hagen et al. (2017) in relation to the "perfect train experience", the VPM focuses on both "satisfiers" and "dissatisfiers".

One way to quantify to what extent different factors of the VPM shape the travel experience is to collect satisfaction and importance scores (Brons et al. 2009; Brons & Rietveld, 2009) (see Figure 17). Although these greatly vary with context and users surveyed, Bernardino & Gama (2013) found that travellers "*tend to point issues which are contributing to dissatisfaction and to forget issues with a very high quality*". For rail, there is some evidence that travel time reliability and comfort (e.g., seating availability and crowdedness) are particularly relevant to shape the worthwhile use of travel time (Wardman & Lyons, 2016).

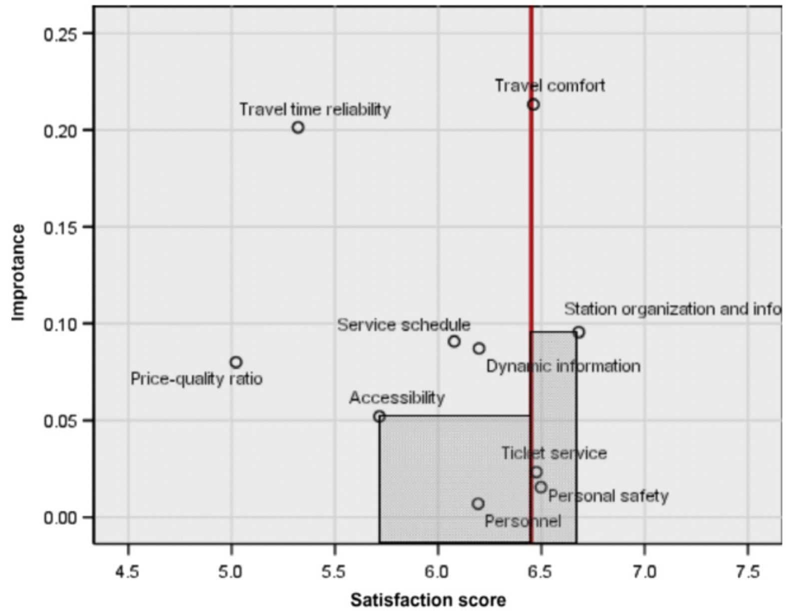

Figure 17: *Satisfaction and importance factors (rail travel in the Netherlands, all passengers) (Brons et al., 2009)*

3.3 Model overview

Research on value of travel time has for a long time focused on time and cost savings related to specific types of trip purposes, namely work-related and leisure trips (Figure 18 presents a simplified view of the classic scope of VTT). Transport planning was the research area closely associated to the conceptual aspects and applications of VTT.

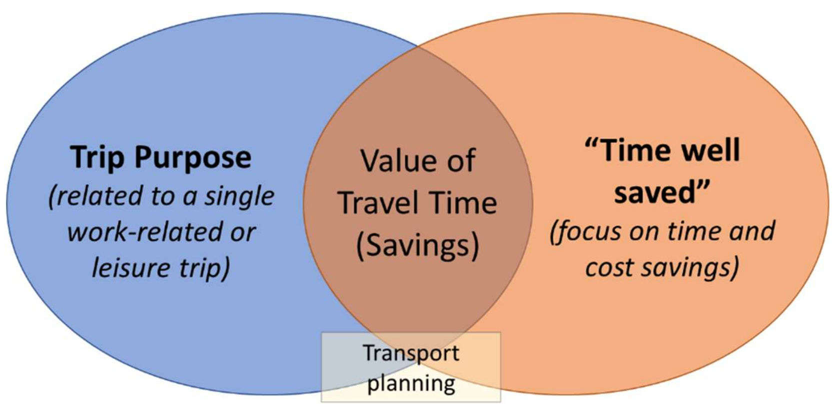

Figure 18: *Simplified representation of the classic scope of VTT*

In MoTiV, the emerging views and approaches to VTT and its societal impacts are investigated. These are more complex to model and understand: the enlarged scope of the area of investigation acknowledges the "time well spent" while on the move in addition to the "time well saved" (Figure 19). This means that other relevant areas such as quality of life and well-being planning are considered in addition to transport planning. Furthermore, the broader scope implies a shift of focus from "trip purpose" to the broader idea of "location activities" that justify and/or influence mobility choices. The significant link between locations, mobility and human activities calls for a stronger acknowledgment of the perspective of land use planning.

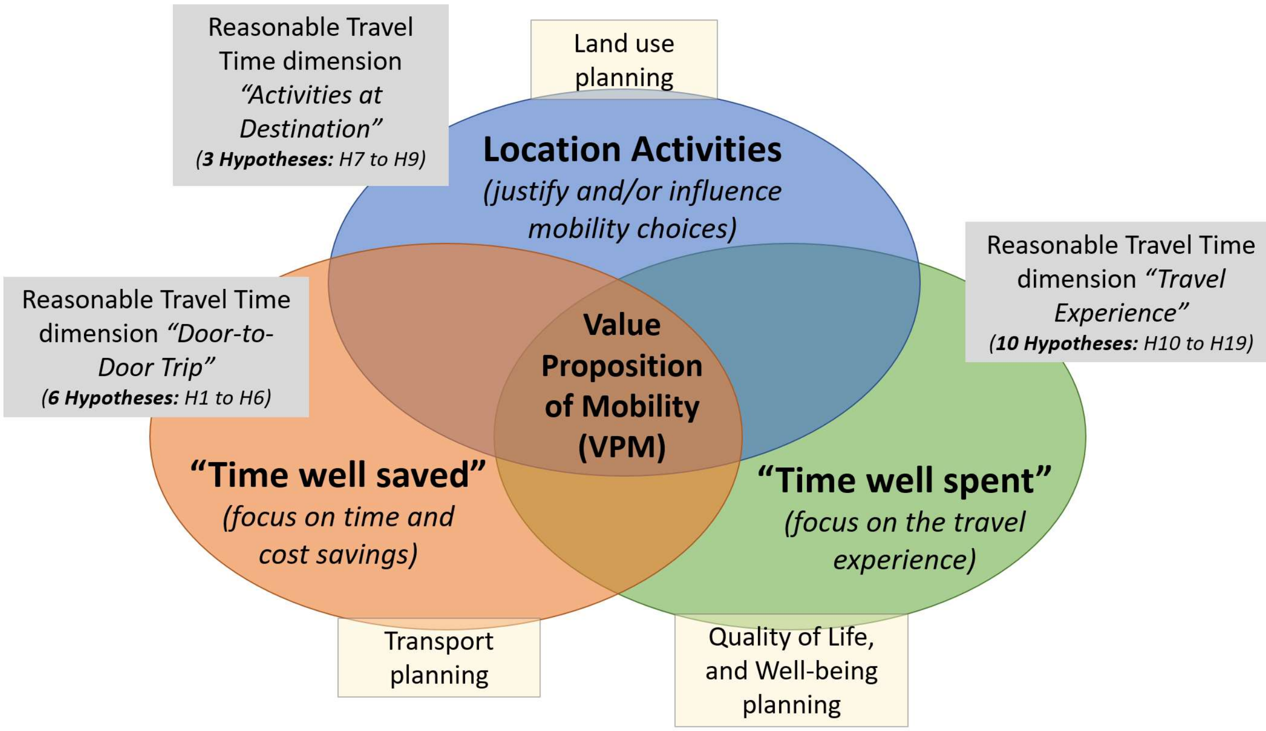

Figure 19: *High-level view of MoTiV conceptual framework*

As the previous framework described in Figure 18, also this one does not wish to be complete, but rather to show the broad and complex area of investigation. In MoTiV, the perspective of RTT was considered as suitable to investigate the relationships between the three areas (i.e. location activities, time well spent and time well saved) and their influence on changing value of travel time in a systematic way. In general, VTT is fully realised when mobility systems allow travellers to reconcile time savings with travel experience, allowing carrying out travel and location activities. In this project, this area corresponds to the dimensions of the VPM, which conveys the idea of perceived value associated to the travel and the associated activities.

In MoTiV, a total of nineteen hypotheses covering all the dimensions of RTT and VPM were generated and are described in Section 4. A detailed investigation of all them is beyond the scope of the project. However, the expectation is that the project, through its European-wide data collection, will shed light on relevant behaviours, patterns and factors to further investigate and incorporate in future VTT models, analyses and applications.

3.4 Data to be collected

There are six main types of data to be collected: mobility data, experience (satisfaction) data, activity data, profile data, attitudes data, and insights data.

- **Mobility data** consists of a mobility timeline layer with travel data to be collected semi-automatically by a mobility tracker module. This consists primarily of locations, times, and modes (see Figure 7 and Figure 8 for an example of mobility timeline). Purposes can be added by the user or inferred by the locations;

- **Experience data:** based on the mobility data layer, the key contribution of MoTiV is on collecting soft experiential data from the user consisting of satisfaction levels, satisfiers, and dissatisfiers. This is collected mostly in real-time, or to be confirmed at the end of the day (see Figure 20[22]);
- **Activity data**: this data consists of the type of activities the user engages at each segment of the journey as well as the type of equipment the user carries, and can be entered by the user for each leg or location;
- **Context data**: this data consists mostly of external data about the mode of travel (e.g., provided by routeRANK or similar transport schedule databases), locations (e.g., online meta-data), infrastructures or weather;
- **User profile data** consists of socio-geodemographic data collected either at the user registration stage (basic user characteristics) or at various stages of the campaign to prevent overloading the user. Data like home and work base locations can be inferred semi-automatically;
- **Attitudes data** is more demanding and requires filling separate surveys to determine attitudinal characteristics towards mobility (transport modes), time saving and scheduling, the environment, and money;
- **Insights data** is feedback data that is provided to the user, such as the user's own travel time budgets and comparisons to group averages or other normative metrics (e.g., carbon budgets).

Figure 20 provides an example of the kind of multidimensional data collection that could be employed in MoTiV. In this example, there are three dimensions: trip legs of a door-to-door trip, human needs similar to those described in the VPM, and a simple satisfaction rating system.

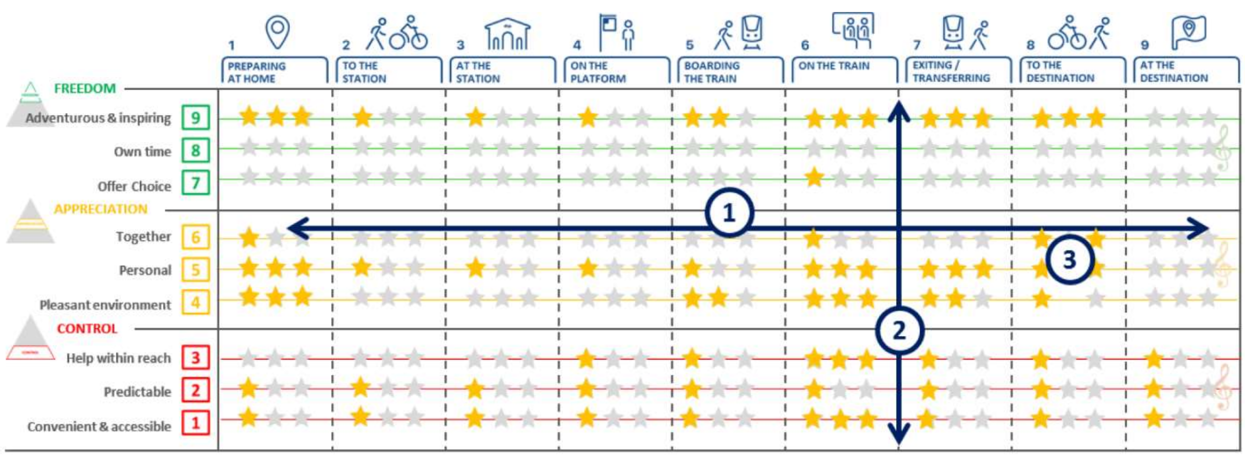

Figure 20: *Example of qualitative data collection used for 'Pinkpop Express' travellers (van Hagen et al., 2017)*

3.5 Worthwhileness ''Index''

Worthwhile time is a critical and multidimensional aspect to assess in MoTiV. One of the main design exercise for MoTiV is to provide a ''measure of worthwhileness'' as a kind of metric for the new value of travel time for each trip. The approach will not attempt to establish monetary values of time based on utilitarian assumptions (e.g.,

[22] Include short description of 1) Mobility timeline, consisting of preparation, access, wait, transfer, main trunk, and egress time 2) Pyramid of needs dimension 3) Simple rating system *(van Hagen et al., 2017)*.

willingness to pay to avoid inconveniences or unforeseen event). Although for this type of research, it is probably best to leave all factors disaggregated and produce a more descriptive, qualitative assessments of the findings. We do envision building a type of index, composed of multiple factors and their associated weights, as a way to synthetise results. This index could take the form of a weighted average based on an assessment of ''worthwhileness'' for each trip leg. Worthwhileness for each trip leg can be expressed by the following five options (see Figure 21):

1. Rating on a scale (Likert or direct weight) by the traveller for the trip leg as a whole
2. Disaggregated rating per time period = $\sum_{p\ time\ periods\ e.g. every\ 5\ minutes}$ worthwhileness rating / p
3. Based on actual activities (including smartphone activities) = $\sum_{a\ activities\ engaged}$ (relevance of activity x activity duration / trip leg duration) / a
4. Based on all satisfiers = weight of comfort factors x $\sum_{c\ comfort\ factors}$ (importance weight x satisfaction rating) / c + weight of travel services x $\sum_{s\ travel\ services}$ (importance weight x satisfaction rating) / s
5. Based on unwanted efforts = (level of physical effort + level of cognitive effort + level of emotional effort) / 3 → assuming equal weight for all the types of effort. This is a measure of wasted time. The normalised figure need to be inversed to give a measure of worthwhile time

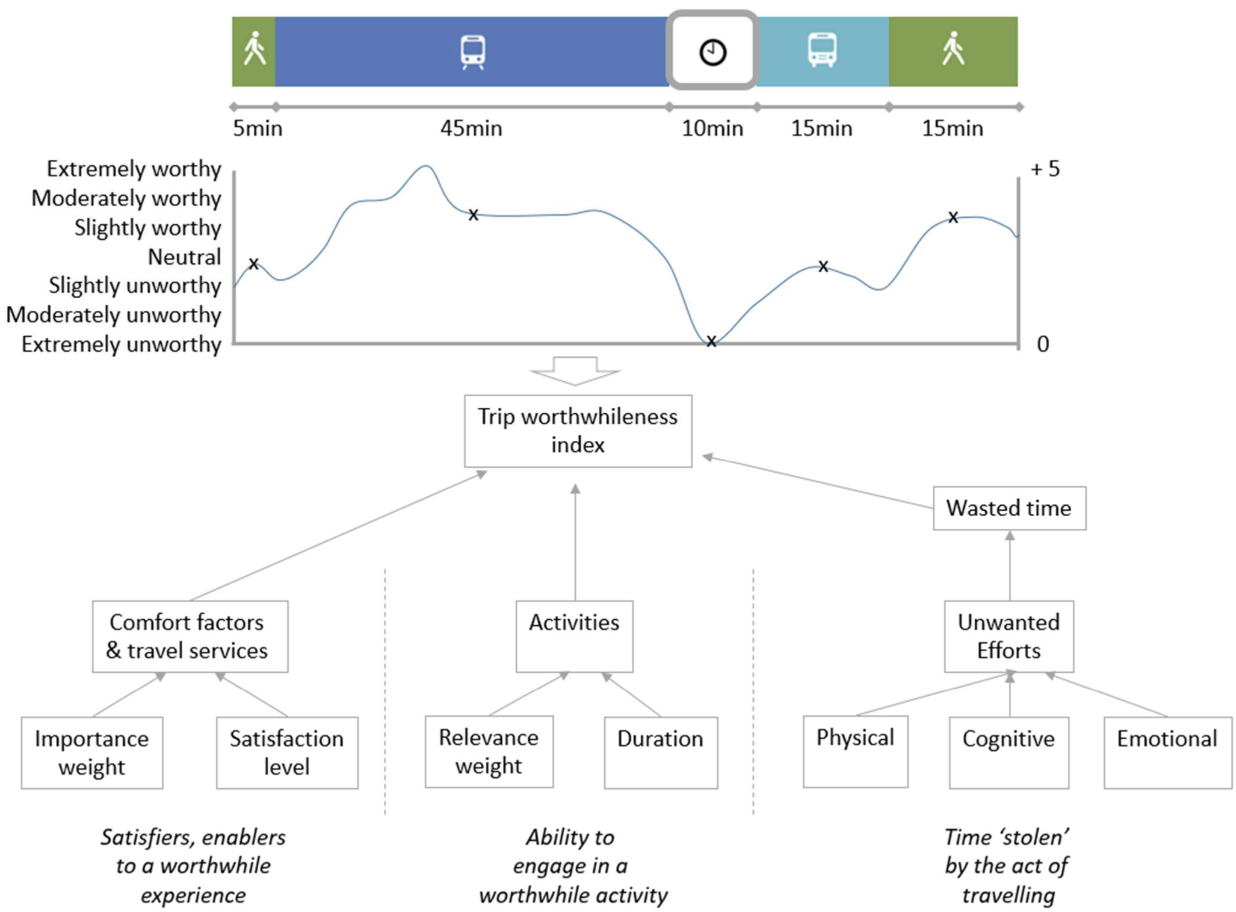

Figure 21: *Five different but complementary ways to measure the worthwhileness of a door-to-door trip.*

As an example, for the single train trip leg above (45 min):

1. Overall Worthwhileness rating (0 to 5) = 4; 80% worthwhileness or 36min worthwhile time.

2. Per 5 minutes period: 2, 4, 4, 5, 4, 4, 4, 4, 3 = 34 / 9 periods = 3.8; 76% or 34min.
3. Useful activities: writing (25min, 100% relevant), relaxing (10min, 30%), reading (10min, 50% relevant) = 25 x 100% + 10 x 30% + 10 x 50% = 25 + 3 + 5 = 33min worthwhile time or 73%.
4. Top comfort factors and services: seating (most important = weight 55%, highly satisfied rating = 5); table space (second important = weight 30%, satisfied rating = 4); quietness (third important = 15%, not very satisfied rating = 2); 55% x 5/5 + 30% x 4/5 + 15% x 2/5 = 85%. Note in this case importance weights for each factor and service should add up to 100%. Rank Order Distribution (ROD) weights can be used for this purpose if the traveller ranks factors in his/her order of importance.
5. Unwanted efforts = physical (none, 0/5), cognitive (just to keep track of travel progress, 1/5), emotional (e.g., some stressful and noisy announcements, 2/5) = (0% + 20% + 40%) / 3 = 20% wasted time on unwanted efforts, therefore 80% worthwhile time.

All options above should in practice be proxies for measures of worthwhileness of time for a single trip leg (and there may be more options or factors – see hypotheses in next section). The final measure will depend in practice on how much data can be collected. If all five were to be made available, it is also possible to consider building an overall (weighed) average.
As for computing an overall measure for a whole trip, it then becomes:

- Worthwhileness of trip = $\sum_{l\ trip\ leg}$ (trip leg duration / total trip duration) x worthwhileness of the leg

One limitation of the aggregation based on duration is that a very bad experience (e.g., worthwhileness level 0% on a percentage scale) will be only valued according to its duration. In other words, the weight used for the weighted average across all trips legs is clock time. It is worth considering improvements on the weights and scales to account for counter-productive (extremely unworthy) or ultra-productive (extremely worth) time (see Figure 11). Each trip leg (or the trip as a whole) can then be visualised by providing a type of spider graph where all normalised factors entering the overall value of worthwhileness are represented.

4. Hypotheses on changing VTT

Research hypotheses are useful for synthesising the concepts from the previous section and clarifying the explanations MoTiV will seek to obtain for various phenomena. Value of travel time is complex, as seen from the variety of concepts surrounding the topic. The fact that VTT cannot easily be reduced into parts implies that no single hypothesis can provide a comprehensive understanding. The many facets of VTT therefore require many hypotheses, each of them shedding light from one specific angle of the problem. Hope for clarity can therefore be obtained only if these are taken – and analysed – together, with all the richness of their interdependencies.

Although the complex systems approach is theoretically promising, it raises the challenge for data collection, which can easily fall in the trap of excessive reductionism. Can any app be expected to collect both passive data (from sensors, user interaction and internet) and active user data (from pre-set or dynamic surveys) on the quality of the time experienced by a traveller, at small time intervals, on any mode of transport, at any location, for any purposes, within a number of time constraints (which may change day by day) as well as the type of activities one is engaging in, their relevance, and the type of equipment one carries along? This is obviously challenging, both technically and in practice, since even if it were possible to prompt travellers about all these elements, it would require significant time to do so, which would in turn interfere with the ‘’normal’’ activities and time use of the traveller and therefore introduce a (potentially significant) measurement error.

With this in mind, the long list of hypotheses below does not represent formal software requirements. Not all of them can or should be implemented in MoTiV. However, it is expected that they could, in time, inform further data collection efforts and contribute to providing a more complete picture about VTT to the planners of sustainable transport in the future. For MoTiV, the main requirement and focus should therefore be on automated data collection and automated learning, prioritising the implementation of the research hypothesis into features that minimise user input to prompting for simple confirmations as much as possible. This is not to say however that automated measurements are necessarily more accurate representations of a phenomenon of interest. Reducing a problem to a single measurable variable in order to reveal traveller preferences risks hiding the subjectivity of the methodological choices and the assumptions made to devise such specific numerical values. In other words, there is no exact way to accurately reflect the perception of value to the individual, although various methods to ''measure'' this kind of subjective experiences and emotions have already been tested in transport and can inspire the MoTiV efforts (see for example van Hagen et al., 2017).

A related implication to address the inherent complexities of the value of travel time is the possibility to design new measures that, instead of trying to collect *all* possible factual data possible, focus on collecting more simple, user-friendly, holistic data. This can take the form of qualitative scales (e.g., from frustrating to delightful experiences), relative choices (e.g., choosing between two choices as a measure of preferences) and other types of ''top-down'' – qualitative yet quantified – data. Although this approach is likely to fall short of the expectations of traditional economics/statistical methods that focus on establishing some level of confidence in dependencies between a few selected factors, it might very well help to gain insights into the travelling stories as experienced by travellers, and therefore clarify the bigger picture. In turn, this can help challenge and revise the (sometimes hidden) assumptions behind the simplistic understanding of the bigger picture that perhaps still too often drive today's transport planning practice. This notion of sense making as a fusion of ''sufficient complexity of thought with simplicity of action'' has been termed ''simplexity'' (Colville et al., 2012).

Overall, an important aspect of MoTiV will be to find the right trade-off between automation and user inputs, and between qualitative and quantitative data. This is likely to require some level of pilot testing before rolling out the data collection campaigns.

4.1 Main hypothesis

The high-level hypothesis to be investigated in MoTiV is that the traveller's choice of modes and routes depend on the journey's Reasonable (or Acceptable) Travel Time, defined for the purpose of this project as the *door-to-door journey time that is acceptable to the individual traveller for reaching a particular destination and its associated activities, given the conditions provided to turn wasted time into worthwhile time while travelling*. The value of travel time (VTT) therefore depends more specifically on the three main components of RTT:

A. door-to-door travel time;
B. activities at the destination; and
C. the full experience while travelling.

These elements contribute in different ways according to age groups, gender, location, and mode choices. What is acceptable and worthwhile is subjective to the traveller and it is directly connected to the satisfaction levels for each of the travel characteristics, which in turn provide the insights needed to assess the "Value of Travel Time" – defined in this document as individual happiness/satisfaction for the time spent on door-to-door transport.

To explore the potential impacts of megatrends on VTT and to identify hypotheses for testing the MoTiV conceptual framework, the recommendations of the deliverable 2.1 (Outlook on Value of Travel Time: Futures Study and Related Hypotheses) have been considered. The D2.1 report provided an insight on people's needs, behaviours and difficulties in relation to mobility and travel time. The hypotheses generated in D2.1 were considered as an input for the development of the refined MoTiV conceptual framework on VTT. In particular, the D2.1 futures report on the value of travel time has raised the awareness on reliability, information, connectivity, equity and accessibility benefits in the context of travelling. The multi-dimensional "value proposition" will be validated based on the collection of travellers' mobility and behavioural experience through the MoTiV smartphone application.

The list of hypotheses below unpacks the dimensions of RTT across the various factors expected to contribute in different weights to VTT. It is worth noting that unless otherwise noted, all hypotheses are thought as travel mode independent and geo-demographics independent, i.e. they should apply across all modes, geographical contexts and socio-demographic parameters and not focus on any specific ones. However, some variables to be collected can be mode-dependent, for example, comfort factors to be asked to users will vary depending on the mode.

#	RTT	Name	Purpose	VPM
1	Door-to-door trips	Door-to-door time	To explore how the choice of modes and route is influenced by the door-to-door travel time and experience.	Time
2		Reliable door-to-door time	To explore how VTT is influenced by the reliability of the planned travel choice.	Time
3		Trip planning time	To explore how time spent on travel planning and preparations impacts travel choices and VTT.	Time
4		Time constraints	To explore how VTT is influenced by perceived hard time constraints.	Time
5		Acceptable travel time	To explore how VTT is influenced by the acceptable travel time.	Time
6		Travel time budgets	To explore how closely the Travel Time Budget (TTB) matches with a constant 70+-10 minutes per day after factoring in time considered worthwhile.	Time
7	Destination activities	Trips purposes	To investigate the urgency and importance of activities conducted at destination.	All dimensions
8		Diversity of location activities	To explore how the amount of worthwhile time is influenced by the range and diversity of activities at the destination or locations on the way.	Comfort
9		Modal distances	To explore how many urban trips are short distances.	Safety, Well-being
10	Travel experience	Proportion of worthwhile time	To explore how VTT is influenced by the share of worthwhile travel time out of total travel time.	Comfort
11		Unwanted efforts	To explore how VTT is influenced by physical, cognitive or emotional effort related to the travel.	Comfort

#	RTT	Name	Purpose	VPM
12	Travel experience	Travel activities	To explore how VTT is influenced by the range and diversity of activities while travelling.	Comfort, pro-social
13		Smartphone-based activities	To explore how VTT is influenced by smartphone apps and the time spent on them.	Comfort
14		Value of travel activities	To explore how VTT is influenced by the perceived worthwhileness of a trip leg.	Comfort
15		Travel comfort factors	To explore how VTT is influenced on the perceived comfort of the locations or while travelling.	Comfort
16		Jerkiness as a proxy for comfort	To explore how comfort while travelling is influenced by vibration, jerkiness and shocks.	Comfort
17		Transfer and waiting experience	To explore how comfortable transfer and waiting times are.	Comfort
18		Traveller needs and equity	To explore how the choice of travel speed is influenced by the user's demographic characteristics.	Cost, safety
19		Attitudes towards mobility and time	To explore how VTT is affected by the traveller's attitude about transport modes and time.	Well-being, curiosity, prestige, pro-social

For each hypothesis, initial assessments of **priorities** are provided according to the following criticality legend: High = Must (minimum viable data), Medium = Important; Low = Nice to have. Different sets of **indicators** are proposed to determine the needed data to be collected to shed light on the hypothesis. Wherever required, lists of factors to consider and known standards from existing surveys are provided. Finally, **insights** to be reported back to the user are suggested. These can consist of the collected raw data, ratios, comparisons with averages and other types of numerical values that contribute to the "quantified self" aspect of the MoTiV app. Alternative insights can also include suggestions, e.g. alternative routes, which contribute to the "personal coach" feature in the MoTiV app. Where relevant, **useful references** are listed. When referring to another hypothesis, the notation Hx is used (e.g., H9 refers to Hypothesis #9).

As a final note, the hypotheses below do not imply any particular method of analysis. While the use of the term "hypothesis" hints on the adoption of a quantitative methodology grounded on statistical analysis, this is not necessarily the case. In MoTiV, we aim at exploring factors shaping the value proposition of mobility, and contributing (positively or negatively) to the value of travel time. As such, we do not expect to "test" the hypotheses in a strict statistical sense, but rather to discover associations and interactions among factors (e.g., through multiple methods including exploratory-descriptive analysis (EDA), correlations and multivariate regression analysis as well as content analysis in the case of open questions). This approach is more aligned with the description of the conceptual framework, which points to both qualitative and quantitative methods of analysis.

4.2 Hypotheses related to "Door-to-door trips"

4.2.1 Hypothesis 1: Door-to-door Time

Summary
From the traveller perspective, the choice of modes and route is influenced by the door-to-door travel time and experience, which includes access, egress, transfer/parking and wait time as well as travel time.

Description
The focus for this hypothesis is on efficiency of connectivity, and therefore on the improvement of integrated transport to decrease *connection time.* This requires a measure of time spent in movement vs. time spent in access, egress, transfer and wait. The *experience* of travel and interchange time are addressed separately in hypotheses related to the travel experience (see section 4.4, hypotheses H10/H11, H15, and H17).

This hypothesis requires accurately detecting and measuring trip legs, modes, and locations. The hypothesis also requires collecting information on alternative modes from the travel planner and comparing it with the actual trip legs.

Priority
High. This is the basic mobility data layer of MoTiV.

Indicators

- Actual transport and non-transport time, including access, egress, wait, transfer/parking time;
- Speed for each leg;
- Time spent at locations (transfer or destinations);
- Number of connections in a trip;
- Time (travel, access, egress, transfer) and number of connections for alternative routes.

Insights

- Connectivity ratio: amount of time spent on access, egress, wait, transfer/parking compared to main trunk time, per trip;
- Show the speed for each leg compared to ideal/average speeds per mode to give a sense of time effectiveness;
- Suggest alternative faster routes, including with other modes;
- Calculate time ratios between modes: e.g. show % faster or slower had the user chosen to conduct the door-to-door trip using other modes (e.g. cycling vs. driving would be % faster or slower).

Useful references
(Brons et al., 2009; Krygsman et al. 2004)

4.2.2 Hypothesis 2: Reliable door-to-door time

Summary
VTT is influenced by the level of reliability.

Description

Reliability is an important factor that influences the selection of modes on a door-to-door trip, which is perceived more in terms of lateness relative to the timetabled travel time (in case of public transport) or to the free flow travel time (for car-based transport during congestion).

Priority
Medium

Indicators
- Traveller’s satisfaction and importance for travel time reliability of a specific leg or trip;
- Actual congestion/traffic levels (for road) and delays from operators (for public transport);
- Frequency of service (for public transport).

Insights
- Provide alternative options and travel choices;
- Display real-time information on the trip.

Useful references
(Brons & Rietveld, 2009)

4.2.3 Hypothesis 3: Trip Planning Time

Summary
Time spent in planning a trip and general activities related to travel preparation (e.g., ticketing, wayfinding) may have an impact on travel choice and overall VTT.

Description
This hypothesis focuses on exploring traveller’s habits and effort invested in travel preparations. This requires investigating how much time and effort is spent on tasks such as searching a location, buying tickets, as well as the related hassle/perceived difficulty, and the traveller’s preference towards shared mobility (bike-sharing, car-sharing, carpooling) or types of ticketing (paper, e-ticket, automated payment or subscription options). This information can be collected by measuring the time spent on the multimodal travel planner module. The mental effort can be collected in connection with H11.

Priority
Low

Indicators
- Time spent on travel planner + time spent on activities related to preparing and conducting a trip;
- Mental effort, or perceived difficulty, in planning a trip;
- Type of trip in terms of recurrence, i.e. routine trip (planning just to find exact schedules) or new destination (planning to determine travel options).

4.2.4 Hypothesis 4: Time Constraints

Summary
Not all people can use their travel time for something useful, some people have more time constraints than others, which has equity implications.

Description
In some circumstances, perceived time matters more than clock time; when there are time constraints, clock time matters more than perceived (travel) time.

Priority
High

Indicators

- Time constraints during the week, e.g. work start time, dropping/picking up kids at school time, doctor visits, any activities that are fixed in time;
    - E.g. asking "What activities do you have that are fixed in time in your daily or weekly schedule?"
- Category of travellers (or workers), i.e. equity differentiators;

Insights

- Produce a daily time-space prism, visualising time spent on travel and activities against a geographical map.

4.2.5 Hypothesis 5: Acceptable Travel Time

Summary
VTT varies with journey distance / duration, therefore there is also an "acceptable travel time" (ATT).

Description
This hypothesis can also be formulated as "not every marginal minute of travelling has the same value". This may require dividing up the travel time and measuring worthwhileness of time (as in H10) in smaller segments, e.g. 10 minutes. ATT could be associated with any of the other collected data during the analysis to obtain deeper insights.

Priority
Medium

Indicators

- Acceptable travel time, e.g. asking "Is there a travel/commute time that you would consider as closer to your sense of acceptable travel time?";
- Minimum travel time in order to be worthwhile to start an activity, i.e. settling down time before activities start;
- Maximum travel time, where no more activities can be undertaken, i.e. preparing to arrive/disembark time;
- Trip purpose(s) and desirability/relevance of activities at destination taken from H7.

Insights

- Report on the average acceptable travel time for the traveller, compared to attitudinal groups.

Useful references
(Milakis et al., 2015; Milakis & van Wee, 2018)

4.2.6 Hypothesis 6: Travel Time Budget

Summary
Travel Time Budgets (TTB) of 70 +- 10 minutes per day are expected to stay constant at aggregate levels, after factoring in time considered worthwhile.

Description
The TTB is constant at an aggregate level and independent from distance or mode. There are two options: including only the proportion of work time, or extending to all worthwhile time, which is more in the spirit of the MoTiV project. The related hypothesis to test for is whether using travel time for something useful induces further travel (measured in distance). A second related hypothesis to test is whether TTB corresponds to acceptable travel time, i.e. the peak intrinsic utility curve by Milakis et al. (2015). Finally, this has implications for carbon emissions. There may be a similar rebound effect of reclaiming travel time for worthwhile activities than simply saving time by travelling faster. In other words, if TTB holds true, then those who travel further are likely to have higher carbon emissions.

Priority
Medium

Indicators
- Same data as H1 + distances;
- Proportion of worthwhile and wasted time spent in transport (data collected in H10**).**

Insights
- Report back the traveller's daily TTB, computed as the total travel time (time spent in movement) per day;
- Report back the traveller's daily TTB factoring in the proportion of time used for something worthwhile while in movement, or simply report the total daily travel time that was repurposed for something useful;
- Calculate the daily carbon emissions which result from the traveller's mode choices.

Useful references
(Ahmed & Stopher, 2014; Milakis et al., 2015)

4.3 Hypotheses related to "Activities at Destination"

4.3.1 Hypothesis 7: Trip Purposes

Summary
Purposes of trips depend largely on the urgency and importance of activities conducted at destination and on the way (trip-chaining).

Description
For this hypothesis, it is necessary to collect data on activities carried out at locations (destinations or on the way) (see H8), as well as qualifying these activities in terms of importance (anchor vs. secondary activities, see 3.4) and urgency. It should be possible to highlight which activities have a specific time constraint (start or end, see H4). Trip purposes can also be inferred from the locations reached, but will require input from the user to confirm the

trip purposes, correct or add new ones, and select which one is primary (anchor). This hypothesis also tests the conventional assumption that most trips can be reduced to a single purpose such as work, school or visiting friends.

A related hypothesis is the idea that the willingness to travel (including the willingness to "waste" time travelling) depends not only on the importance of the activities at destination, but also on *the time spent* for these activities (concept of travel time ratio).

Priority
High

Indicators
- Anchor activities and additional, secondary activities (at all locations, destinations or "on the way", e.g. interchanges);
- Importance of the location activity (anchor or secondary);
- Urgency of the location activity: identify time constraints for planned scheduled activities (start or end) (H4).

An initial list of trip purposes:
- Home
- Work
- Community work
- Care
- School/education
- Business (meeting, trip)
- Personal business (bank, authorities)
- Drop-off/pick-up
- Restaurant/café/bar
- Shopping
- Healthcare
- Visit friends or relatives
- Exercise/sports/outdoor
- Entertainment and culture
- Hotel/temporary overnight
- Time-off/holiday/vacation
- Parking
- Other: Please specify

Insights
- Calculate user's travel time ratios, i.e. proportion of time spent travelling for each activity time;
- Produce an activity "heat map" showing visually on a map where the user spends most time (in transport or at locations).

Useful references
(Susilo & Dijst, 2010)

4.3.2 Hypothesis 8: Diversity of Location Activities

Summary
Worthwhile time is influenced by the range, diversity and worthwhileness of activities at locations, which applies both to destinations and transfer locations (bus stops, stations, airports).

Description
This hypothesis refers to the availability of worthwhile activities at locations. The range and diversity of activities at locations depends on the geographical context, and therefore contributes to an integrated view of transport and land-use planning (see Figure 5), i.e. if activities are denser, there is less need to travel in the first place. Destination characteristics can be collected for e.g. from location meta-data from internet (opening time, rating, other social apps data, etc.).

Priority
Medium

Indicators
- Density of potential activities (within a short walking range) at locations (destinations or on the way to destinations);
- Level of density, urbanisation and sprawl (urban form), and general geographical context characteristics of the traveller's home-base location (urban/suburban/rural);
- Measure of the relevance/desirability of activities at a location.

Insights
- Propose additional popular activities at locations the user visits or passes through;
- Calculate the user's average distances travelled for all anchor activities, and how that compares to averages.

Useful references
(Geurs & van Wee, 2004; van de Coevering & Schwanen, 2006; Wegener & Fürst, 1999)

4.3.3 Hypothesis 9: Modal Distances

Summary
In urban context, most trips could be shifted from motorised transport to active modes, e.g. walking or cycling.

Description
This hypothesis is related to the hidden potential in cities of shifting from carbon intensive modes to low-carbon and active modes for a majority of trips. A related assumption is that the lack of appropriate infrastructures (safe and direct routes for walking or cycling) acts as a barrier to changing travel habits towards more sustainable modes. Collecting data on actual distances can provide visibility to infrastructure planners on this issue. This hypothesis complements H1, but focuses on distances instead of door-to-door travel time. This hypothesis can also be combined with H12 (desirable activities) and H15 (comfort factors), to investigate why users chose less time or carbon efficient modes for short distances. A related hypothesis is that active modes result in higher satisfaction levels than people using other travel modes.

Priority
High

Indicators

- Modes and distances;
- User reported quality of the infrastructure for active modes (see H15);
- User reported preferred activities while in transport (see H12);
- User reported levels of satisfaction for the time spent during the trip (see H10 and H14).

Insights

- Show to the traveller the trips that could have been walked (e.g. less than 2km), cycled (e.g. less than 5 or 10km), or e-biked (e.g. less than 15km). Note: walkable or bikeable distances can be more accurately calculated by multiplying the average speed for user(s) with the average daily TTB (i.e., if a user is on average willing to travel 60 minutes per day, and cycles at an average 15km/h, then reachable distance by bike for a commuting trip is 7.5km);
- Show potential carbon savings in shifting modes.

4.4 Hypotheses related to "Travel Experience"

4.4.1 Hypothesis 10: Proportion of Worthwhile Time

Summary

The travel experience can be quantified by calculating the proportion of travel time used on any worthwhile activity, accounting also for the traveller's emotional state and cognitive evaluation of the trip.

Description

A related hypothesis: "Worthwhile time" differs by mode, from least to highest experience of productivity: car, bus, air, and train. Hypothesis 10 is based on the main factor p* of the Hensher formula (see section 2.7). p* is likely to be affected by different travel conditions and comfort factors, which are collected in H15.

Priority

High

Indicators

- Proportion of time spent (p*) on doing something worthwhile or pleasurable while travelling. Note: the measure should ideally be a time-weighted average, i.e. given by total minutes spent on a worthwhile activity / total minutes trip leg time. Alternatives are:
  - Asking "What proportion of the time spent on this trip leg did you conduct any of the activities selected?" or, "All in all, how would you rate the time spent to go to (location)?": 0% = wasted time, vs. 100% = worthwhile time;
  - Asking "Thinking about the time you spent travelling, which one of the following statements do you most agree with?" a. I made very worthwhile use of my time on this trip leg today b. I made some use of my time on this trip leg today c. My time spent on this trip leg today is wasted time (note this measure is rather weak);
- Cognitive evaluation based on STS measures: a. Travel was worse – best I can think of b. Travel was low – high standard c. Travel worked well – worked poorly. This measure can be tested against seating availability (e.g., 25% seats occupied, 50% seats occupied, 75% seats occupied, 90% seats occupied-nobody standing, 90% seats occupied-a few people standing, 100% seats occupied), crowding levels, outbound vs. inbound trip, distance (time travelled for e.g. time bands <45min, 45-89min, 90-149min, more than 150min), comfort factors (e.g., type/class of vehicle).

- Emotional state of the traveller and cognitive evaluation by the traveller based on STS (see section 2.7), “Select the choice that best corresponds to your overall travelling experience” (scale from -3 to 3) for the following pairs:
    - “I was very…” 1. distressed/content, 2. tense/ relaxed, 3. sad/happy, 4. tired/energised, 5. bored/enthusiastic;
      “My trip…” was 6. displeasing/enjoyable, 7. went poorly/smoothly, 8. was the worst/best I can imagine; and 9. “I was worried I wouldn’t/confident I would arrive on time.”

Insights

- Produce a graph similar to that of Figure 10 for the location of the traveller based on other users’ evaluations of worthwhile time, per mode

Useful references
(Singleton, 2018; Wardman & Lyons, 2016)

4.4.2 Hypothesis 11: Unwanted Efforts

Summary
Travel experience is impacted by external, unwanted efforts imposed on the body and mind.

Description
This is based on the assumption that many people regard as highly desirable “an effortless world”, free of all work and pain, in which all desires would be satisfied immediately, *and* where they are free to engage only in efforts and personally meaningful tasks in which they find purpose and/or enjoyment. This approach complements H10 by analysing unwanted physical, cognitive, or emotional efforts. Instead of focusing on worthwhile time, it focusses on the stimuli and external stressors that prevent engaging into worthwhile activities, therefore contributing to a sense of wasted time.

Priority
Medium

Indicators

- Level of unwanted physical effort required by the trip, e.g. having to stand or go upstairs;
- Level of unwanted cognitive (mental) effort required by the trip, e.g. unwanted distractions, difficulty to plan trip or know where to go;
- Level of unwanted affective (emotional) effort required by the trip, e.g. stress, fear (for safety or to be late).

Useful references
(Stradling, 2002; van Hagen, et al., 2017)

4.4.3 Hypothesis 12: Travel Activities

Summary
VTT is influenced by the scope of worthwhile activities which can be undertaken during the journey.

Description

This hypothesis builds evidence to the possibility of engaging in desirable activities at any part of a journey, both in transport or at transfer locations. For testing this hypothesis, the user should be presented with a list of default activities with the possibility to tick (select) for e.g. a maximum of three activities spent most time on. The set presented to the user should be narrowed down depending on the mode of travel (e.g., sleeping while cycling is rather unlikely), the type of locations, or dependent on a habit survey (e.g., what the user prefers to do while travelling). This hypothesis should be evaluated in connection with the worthwhileness of activities (see H14).

Priority
High

Indicators
- Types of worthwhile activities conducted while travelling, including both in transport or at transfer locations;
- Whether the activity is considered work-related or not – this can also be inferred as part of the activity description;
- Whether the activities the traveller could do were the ones the traveller wanted to do (this is connected to the appreciation of travel activities in H14);
- Option to provide free text for any missing activity.

An initial list of activities:
- Sleeping/snoozing
- Relaxing/daydreaming/doing nothing
- Reading for leisure
- Working/studying (reading/writing/thinking)
- Talking to companion/other passengers
- Enjoy the view/Window gazing/People watching
- Listening to music/radio/podcast
- Watching a film/video
- Text messages/phone calls – work
- Text messages/phone calls – personal
- Checking emails
- Internet browsing
- Accessing social networking sites
- Eating/drinking
- Caring for someone travelling with you (including children)
- Playing games (electronic or otherwise)
- Exercising
- Personal maintenance and hygiene
- Being bored
- Being anxious about the journey (e.g., delays or where to get off)
- Planning onward or return journey
- Other: Please specify

Insights
- Present a chart on the proportion of time spent on favourite types of activities (e.g., % of time spent for each or top 10 activities while travelling).

Useful references
(Keseru & Macharis, 2017; Lyons et al. 2013; Steg, 2005; Wardman & Lyons, 2016)

4.4.4 Hypothesis 13: Smartphone-based Activities

Summary
The smartphone is ubiquitous and contributes to shape the daily activities we carry out. The type of apps and the time spent on them can provide insights into the nature of the activities and the related value of time.

Description
This hypothesis is a subset of H12 and is concerned with the growing availability of ICT having significant (positive and negative) impacts on VTT as experienced by travellers. The concept of "ICT equipped time" focuses on the activities carried out on mobile devices (relevant both in travel and at interchanges). While the omnipresence of technology is impacting the amount of activity time while travelling, it is also important to understand the value of those activities (covered in H14), for e.g. activity for killing time against boredom, or searching travel information to reduce stress. This hypothesis is not taking for granted that positive impacts (on VTT) necessarily outweigh negative ones.

Priority
High

Indicators
- Apps used
- Type of carried items

An initial list of carried items:

Electronic	- Laptop
	- Mobile phone
	- Portable DVD player
	- MP3 player/personal stereo
	- eBook/iPad
	- Games console
Non-electronic	- Newspaper
	- Reading book
	- Textbook
	- Magazine
	- Paperwork
	- Games/puzzle
	- Food/drink

Useful references
(Lyons et al., 2013)

4.4.5 Hypothesis 14: Value of Travel Activities

Summary
Not all activities are necessarily equally worthwhile: the travel experience (VTT) depends on the relative perception of their value / usefulness / pleasantness / relevance / "worthwhileness" related to a trip leg.

Description
This hypothesis is concerned with the quality/relevance of the activities a traveller is able to engage while on a journey, both in transport or at transfer locations. It is important to discriminate the worthwhileness per mode and comfort characteristics, which may differ, e.g., "accessing social networking sites" while standing in a bus. Considering that a trip leg can consist of several activities, it may not be practical to ask for each activity separately: H10 is therefore addressing the general worthwhileness of time for trip leg as a whole.

Priority
Medium

Indicators
- Quantification of worthwhileness as a property of the activity (rating scale);
- Comfort characteristics (in H15).

Insights
Provide feedback on which activities other users find most worthwhile when travelling on specific links or modes, which could be particularly relevant for user groups who find it difficult to use their travel time for something useful

4.4.6 Hypothesis 15: Travel Comfort Factors

Summary
VTT is largely influenced by the level of travel comfort and availability of services.

Description
For public transport, the two most important comfort factors are seating availability and crowdedness. Travel comfort for cyclists is very much related to (perceived) safety. Importance for these factors changes according to user characteristics e.g. infrequent public transport users, car availability, age, presence of a travel companion. Comfort factors and related travel services are the causes affecting the ability to conduct activities while travelling (H12). This hypothesis complements a similar hypothesis related to comfort and services factors in transport interconnections (stations, interchanges, bus stops, hubs) addressed in hypothesis H14.

Priority
High

Indicators
- Travel comfort, assessed both by the *importance* of each comfort "dimension", and a *satisfaction* score;
- Qualitative data: offer the possibility to upload pictures or videos of the environment the traveller is in while doing their main activities (providing snapshots for checking crowdedness, cleanliness, colourful environments, design of furniture etc.).

Initial list of comfort and services availability factors:

Comfort factors	-	Cleanliness – inside
	-	Cleanliness – outside
	-	Maintenance (upkeep and repair, condition of seating, walls, tables etc.)
	-	Seating availability – onboard
	-	Seating availability – benches
	-	Personal space
	-	Crowdedness
	-	Privacy
	-	Pleasantness – ambiance
	-	Pleasantness – design
	-	Pleasantness – views/scenery
	-	Air quality – ventilation
	-	Air quality – temperature
	-	Air quality – pollution
	-	Noise
	-	Smoothness – jerkiness, motion-sickness
	-	Smoothness – pavement, floors
	-	Accessibility (for people with special needs or disabilities)/ease of being able to get onboard
Services availability	-	Availability of staff
	-	Helpfulness and attitude of staff
	-	Space for luggage
	-	Space for bicycle
	-	Space for prams
	-	Toilet facilities
	-	Food/drinks
	-	Shopping/retail
	-	Entertainment (magazines, TVs, entertainment system)
	-	Power sockets
	-	Tables
	-	Silent area
	-	Provision of information
	-	Signage
	-	Access infrastructure (escalators, lifts)
	-	Parking (all modes)
	-	Car charging

Useful references
(Brons & Rietveld, 2009)

4.4.7 Hypothesis 16: Jerkiness as a Proxy for Comfort

Summary
Travel comfort and the (in)ability to engage in worthwhile tasks can be associated with vibration, jerkiness and shock levels while travelling.

Description
Jerkiness is known to induce motion-sickness for many travellers, which prevents some activities such as writing or reading. This can apply to all modes e.g. abrupt stop-and-go, sharp turns, or bad pavement surface (while cycling or driving) and is a measure of comfort. This should be correlated with modes, with other comfort factors (e.g., seating availability) and with the number and types of activities conducted during transport, particularly mobile phone use, which goes up in jerky, uncomfortable environments (presumably because it is the only activity one can engage into).

Priority
Medium

Indicators
- Abrupt stop-and-go, sharp turns, or bad pavement surface (while cycling or driving)
  - There is the possibility to use passive data by recording the accelerometer data to record the number of shocks during a trip[23]. Shocks can then be converted into a scale, e.g. A. Detectable only by instruments B. Very slight vibrations felt by only some people C. Feeling moderate shaking D. Strong shocks E. Sudden and very strong shocks
- User-reported feedback on ability (or inability) to conduct activities and feeling of motion-sickness;
- Number and type of activities that a traveller was able to conduct on a specific leg (from H12);
- User sensitivity to motion-sickness (as part of the user preferences for comfort factors).

Useful references
(Guo et al., 2015)

4.4.8 Hypothesis 17: Transfer and Waiting Experience

Summary
Transfer and waiting time is a kind of time that is considered frustrating, undesirable, and a particular source of “disgruntlement” by most travellers, which may impact the overall experience.

Description
Particular instrumental, attitudinal or affective factors matter for the experience across interchanges. Waiting places in transport interconnections (interchanges, or hubs) are somewhat considered at the edge of transport planning, and a policy hypothesis is that there remains great potential in improving such locations. In other words, improving the quality of interchanges can substitute improvements elsewhere in the transport network system. The comfort and services factors to be used are similar to those experienced while in transport (see

[23] However, for the collection to be valid (and not due to the vibrations measured from the user moving, using or shaking his/her mobile phone), this could be the focus of a special survey, asking the user to confirm whether they held their device stable (on table, in hand or pocket) for the whole duration of a leg.

hypothesis H15), but may be called differently for locations, e.g. seating availability (benches and public furniture), smoothness (of pavement or floors). It is important to note here that it is interesting to capture the effect of frustrating transfer time on the rest of the trip (as a kind of counter-productive time, see Figure 11).

Priority
Medium

Indicators

- Satisfaction and importance of relevant comfort and services characteristics of transport interconnections.

Useful references
(Hickman et al., 2015; Watts & Urry, 2008)

4.4.9 Hypothesis 18: Traveller Needs and Equity

Summary
Some social groups may be disadvantaged by design in their use (or non-use) of particular modes, which influences VTT.

Description
Traditionally transport planning has focused on commuting trips for work, which has been to the advantage of male travellers compared to women who conduct more complex trips. Gender is an important differentiator: women have different expectations in terms of transport characteristics for e.g. during the day or at night time (see section 2.10), which impacts mode choice and their value of travel time. Other social groups, such as low-income groups, the young, older or disabled people or people with disabilities may also value satisfiers and dissatisfiers of transport differently, which leads to different mode choices as well as different satisfaction levels with travel. A mode-specific hypothesis is that high-speed rail is used mostly by higher deciles of income and city dwellers, which brings important issue of fairness in transport investment. It is therefore relevant wherever possible to explore the characteristics that make some groups of travellers feel that the transport system was not designed for them, in other words, where they are more likely to be wasting their time, spending too much unwanted cognitive, physical or emotional efforts on transport. For all these cases, travel data can be analysed from the perspective of gender, level of net yearly income, home-base location (urban vs. rural or in-betweens), age and personal abilities.

Priority
High

Indicators

- Socio-geodemographic characteristics of the traveller, gender, home-base location, net yearly income;
- Personal abilities (related to young/older population, people with disabilities, or possessing a driving licence or not);
- Choice of modes, use of car and high-speed rail vs. public transport or active modes;
- Preferred characteristics of locations and transport (see H15 and H17), and experience of worthwhile time (H10) or efforts (H11) by time of the day, including a focus on safety and ease of access factors.

Insights

- Gender-based modal split, e.g. who is driving, who is walking.

4.4.10 Hypothesis 19: Attitudes towards Mobility and Time

Summary
Travel experience and mode choices can be affected by travellers' attitudes e.g. towards a specific travel mode and towards the passing of time.

Description
Attitudes, values, societal norms and general preferences towards certain transport modes and lifestyles play an important role in determining both mode choices and the potential for "enjoying" travel. These characteristics and preferences in turn serve as a basis for habits formation. Furthermore, such preferences cannot be inferred from the user characteristics such as residence location or whether or not a person owns a car, which may not be their preference (location or mobility dissonance).

Priority
High

Indicators
- Reasons for choosing a specific mode linked to the dimensions of the VPM;
- Willingness or previous experience in using travel time for something;
- Preferences towards slow versus fast travel experiences;
- Attitudes towards the environment, society and well-being;
- Socio-geodemographic characteristics of the traveller.

Insights
- Inform the traveller about his or her segment.

5. Pre-testing the MoTiV framework

5.1 Exploring travel choice in a European-wide multi-modal journey planner

In this section, the main results from an analysis performed on two datasets provided by RouteRANK are presented and discussed from the viewpoint of implications for the MoTiV framework.

The aim of the analysis was to identify mobility and behavioural variables relevant to VTT that could be collected on the basis of queries to the routeRANK multi-modal journey planner (i.e. address the question "What are the regular patterns and trends in the behaviour of users of routeRANK?") and which other variables addressing relevant dimensions of the MoTiV conceptual framework are not available within the journey planner and should therefore be collected within the MoTiV app. Intuitively, it was expected that the analysis of the journey planner dataset would have revealed some insight on the dimension of "door-to-door travel planning". On the contrary, no expectations were related to obtaining an insight on travellers' activities and travel experience, which is typically not covered by journey planners (including the routeRANK one).

The analyses performed had an exploratory nature and concerned the investigation of the relative weight that decisions factors (e.g. cost, travel time, CO2 emissions) have in distinct types of travel plans, across transport modes, journey types and trip purposes (e.g. commuting).

For privacy and data protection reasons, routeRANK does not collect any personal-identifying information related to its users. Therefore, the datasets provided by routeRANK do not contain any socio-demographic information associated with travel queries. While this would have allowed a more fine-grained analysis of the factors influencing travel decisions, we consider the findings still relevant for the objectives of the task.

5.2 Description of the routeRANK journey planner and dataset

The routeRANK journey planner consists of an online interface to search for journey options by inserting basic journey details such as origin and destination, and travel date and time (Figure 22). It is worth noting that routeRANK supports door-to-door journeys, meaning that location input can be given both in a generic form with the name of a city, or more specifically as an address.

A study[24] from 2009 found that the routeRANK journey planner decrease travel planning time by two and a half hours as well as allow finding the most convenient offers. Although this result may no longer be as prominent due to the availability of similar online services, the study demonstrates the innovative solution implemented by routeRANK with the goal of enabling users finding the fastest and most ecological route, while saving money and trip planning time.

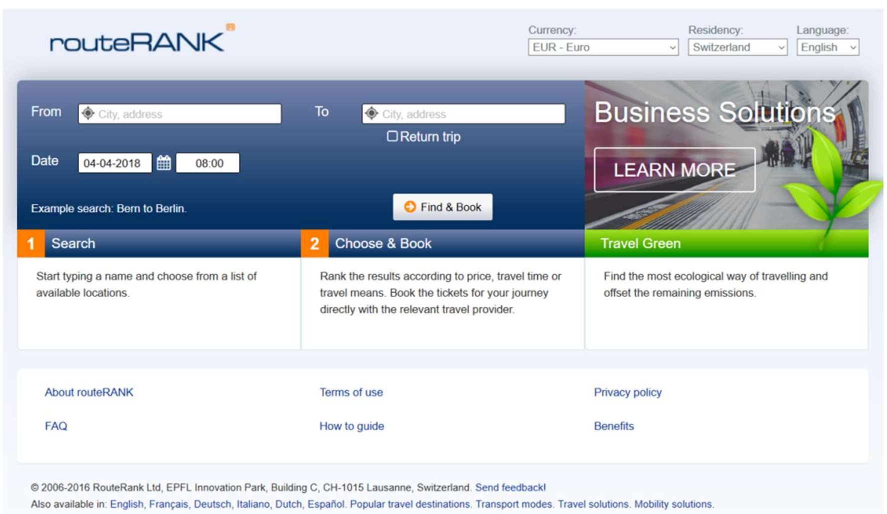

Figure 22: *Interface of the routeRANK journey planner*

Journey planner results are displayed to the user combining all the possible transport modes, which are found[25]. Results are then sorted according to multi-criteria ranking, which describes the relevance of the journey option to the user (Figure 23).

[24] Davidson, A. (2009) "How much time, money and CO2 emissions could routeRANK save a typical travel planner?". Master's thesis. Univ. of Cambridge (UK).

[25] The amount of journey options heavily depends on the availability of data that feeds the routeRANK journey planner.

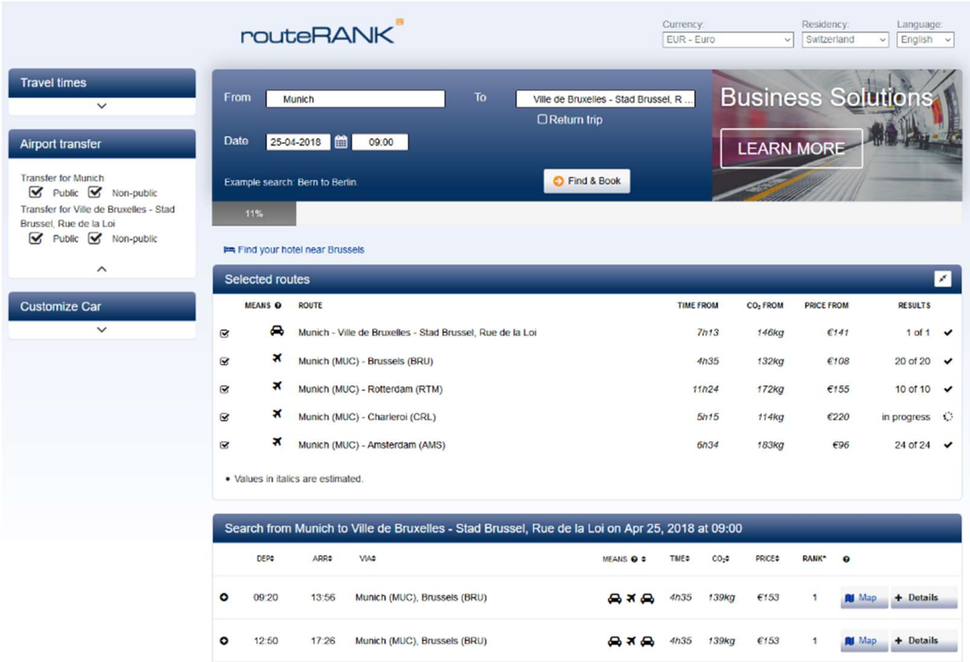

Figure 23: *Results of routeRANK search from Munich to Rue de la Loi in Brussels*

Typically, publicly accessible versions of routeRANK, targeting normal / leisure travellers use the following default weights for trip properties to rank the recommended journey options[26]:

- Travel duration: of highest importance;
- Travel cost: high importance;
- CO2 emissions: medium importance;
- Amount of changes / available time for changes: medium importance;
- Travel productivity (usable time): medium importance;

Business versions of routeRANK, the data of which are not included in this dataset for data privacy and confidentiality reasons, may use different (non-public) customer-specific settings for the above criteria suitable for business travel, and users have the option to adjust these weights themselves.

Users can filter and sort results according to the following criteria:

- Travel duration;
- Arrival time;
- Departure time;
- CO2 emissions;
- Travel cost;
- Rank (number linked to relative ranking of travel options generated by multi-criteria ranking algorithm defined by customer);

26 Weights are assigned by routeRANK, based on an internal review of relevant literature.

- Means (travel modes);
- Via (possibility to travel via specific locations);
- Travel productivity (described in the user interface as “Available time”, available in Swissplanner.ch only): this parameter represents the productive time for a user to allocate to activities such as e.g. preparing material for business meetings or reading a book.

Additionally, when the ticketing option is available, routeRANK provides information on the ticket price and the service provider, offering users the function to redirect to the transport service provider web-site for the purchase of the tickets (i.e. “forwarding” function).

For the MoTiV project, two datasets were made available by routeRANK: the first one included data from worldwide searches made from the public version of the online journey planner available on Routerank.com web-site. The second dataset contained searches made from Swissplanner.ch (Figure 24), another version of the routeRANK journey planner with additional sorting and ranking parameters[27].

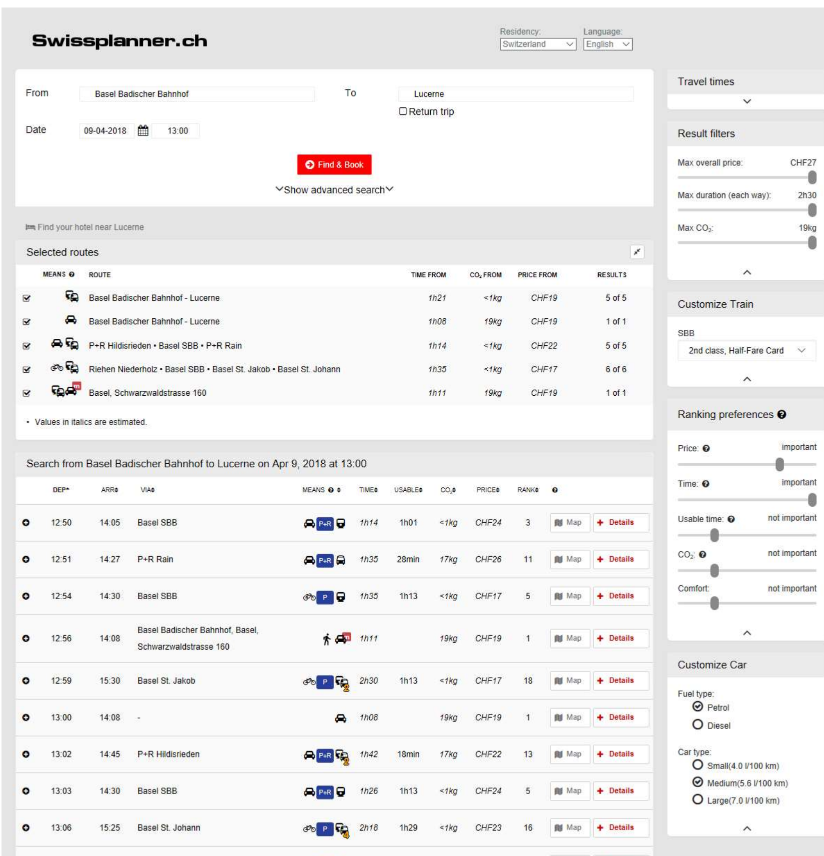

Figure 24: Interface of the Swissplanner.ch journey planner

[27] https://swissplanner.ch

The datasets are representative of two different and relevant customer groups, namely International and national non-business travellers. Specifically, international travellers (mostly from Europe) are the focus of routeRANK, while the Swissplanner primarily addresses Swiss travellers. It is worth noting that, just like routeRANK, also the Swissplanner supports international queries (e.g., searching travel options from Paris to Brussels) and it is available worldwide. However, its visibility and promotion are mostly limited to Swiss users, therefore it is assumed that it is largely used by Swiss travellers[28]. Since routeRANK business does not only cover Swiss and European but also the international level, its business is oriented towards an international context and therefore we will refer to the routeRANK dataset as representative of international non-business travellers (independently on the nationality or residence of the customer). The two datasets, with different characteristics in terms of user groups and travel searches, were considered useful to allow the comparison of the results.

The two datasets, altogether, contain a total of about 50,000 search logs randomly selected from those recorded in the period from June 2017 and January 2018. The size of the datasets is similar: the one related to international travellers included 26,064 logs and the one focused on Swiss travellers has a total of 24,065 logs. As raw data logs in the routeRANK system have a different structure, some pre-processing was required to prepare the dataset for the analysis. Pre-processed logs consist of log entries for searches performed on the above mentioned routeRANK tools.

The two datasets included information on the users' journey searches (start/end location, date and time), sorting behaviour (e.g. selection of travel factor such as travel duration or cost) and forwarding statistics (i.e., redirection to ticketing service in transport provider web-site). This kind of information provides an insight on users' choices and attitudes towards journey options and sorting according to the perceived relevance to their own travel plans. The datasets did not contain any information directly identifying a person such as the personal details (i.e., age, gender) or geographic location of the users.

5.3 Methodological approach to dataset analysis

The objective of the analyses was to explore the relationships and dependencies of users' travel planning behaviour, patterns and preferences with respect to sorting journey options and forwarding behaviour (i.e., redirect to transport service provider to purchase ticket). The analyses that were carried out on the datasets primarily focused on parameters related to the travel time, namely travel duration, arrival time and departure time.

For our purposes, the quantitative analysis in exploratory data analysis (EDA) was used (Tukey, 1977). This approach summarises the main characteristics of a dataset with charts and visualisations, highlighting relationships and dependencies among data parameters. EDA is often the first step in data analysis, implemented before any formal statistical techniques are applied, to find out what the data represent: specifically, EDA was chosen to characterise the behaviour of the users with respect to sorting journey options and forwarding behaviour and infer patterns and references, because it allows to summarise the characteristics of a dataset without making any assumption on the data. If we contextualise this activity inside the project, EDA becomes a natural choice, given that this task was one of the first of the project and no strong assumption could be made on the user behaviour.

[28] Information about IP addresses of journey planner queries was not available to discard non-national queries.

The data were divided into two broad groups, each of them associated with several variables and parameters. The first group concerned user behaviour related to the nature of travel search queries (e.g. travel distance, travel modes, geographical parameters), while the second was related to the user (click) behaviour in further inspecting the search results (i.e. sorting results, forwarding statistics). Overall, the journey query and the processing of the results visualised by the journey planner provide a good account on the travel planning behaviour, and in particular on travel choice (relative interest towards one or another travel option).

More specifically, to analyse search behaviour, several analyses were performed – each related to a different parameter of the dataset. The main types of analyses and related classifications are summarised below:

Travel distance in searches: to evaluate the nature of journeys entered into the journey planner, we categorised travel distance into two types, based on a standard classification (JRC, 2013; Christensen, 2014):

- *Short Haul*: up to 50 kilometres (up to 60-minute travel time);
- *Long Haul*: more than 50 kilometres.

For each of these types of journeys, their frequency was calculated by dividing the number of searches of each type of journey for the total number of searches. For the most frequent type of journey we plotted the Empirical Cumulative Distribution Function (ECDF). The ECDF reports, for any given number, the percent of individuals that are below that threshold. The choice of measuring and presenting the ECDF was made because it allows us to understand the distribution of the data from the data from the observations we made (hence the name "empirical"). Since our purpose is to characterize the behaviour and preferences of the users, this curve is an effective mean to do so.

Recurrent travel searches: the amount of times a specific travel search (i.e. same pair of origin and destination) appeared in the dataset that was analysed. Although this could not be linked to a single individual, the occurrence of the travel searches gives an insight on recurrent search behaviour. As in the other analysis, the results were visualised with ECDF.

User (click) behaviour: several analyses were performed on user click behaviour. The travel cost was kept as a constant element in all the analyses and correlated to the other available search parameters that the user could act upon (i.e. click):

a. *Travel cost:* we considered the prices (in EUR) associated to the selected results and plotted the ECDF to show the price distribution of the planned journeys;
b. *Travel cost by type of journey:* we looked for the correlation between the travel cost and the type of journey (i.e. Short Haul and Long Haul), taking into account also the travel planning behaviour of users speaking different languages (i.e. based on the selected language of the routeRANK user interface);
c. *Travel cost by service provider:* the correlation between the price of a specific journey and the transport service provider was also considered. In addition to the simple correlation between these two variables, an extended analysis considered also the type of journey users searched for (i.e., Short Haul and Long Haul).

Overall, results from users' click behaviour were expected to give an insight on travel preferences towards available travel options.

5.4 Results of the routeRANK dataset analysis

In the datasets, the number of searches in which the users further inspected the search results and the number of searches in which the user decided to sort the results are similar. This shows that international and Swiss travellers have a similar clicking behaviour.

Travel distance in search queries: in both datasets, long-haul travel searches represented by far the most frequent type of travel (83.2% in the international dataset, and 72.9% in the Swiss one).

Given that long-hauls represent the majority of searches, we explore them in more detail. In Figure 25, the x axis reports travel distance in kilometres and the y axis the probability that a travel distance in the dataset is lower than or equal to the value reported in the x axis. Generally, international travellers look for longer travel distances. When characterising the individual behaviour of the users, Swiss travellers are interested in longer trips. Indeed, in 60% of the cases the distance of a journey is below 200 km, while in the Swiss-based a similar share of searches is lower than 600 km. Moreover, while the curve of Figure 25 on the left strongly increases as the distance gets higher, in the Swiss-based dataset the probability to cover a distance between 250 and 600 km is almost equal. Hence, international travellers plan for long-distance journeys via routeRANK, but it is the Swiss travellers who are more likely to perform longer journeys.

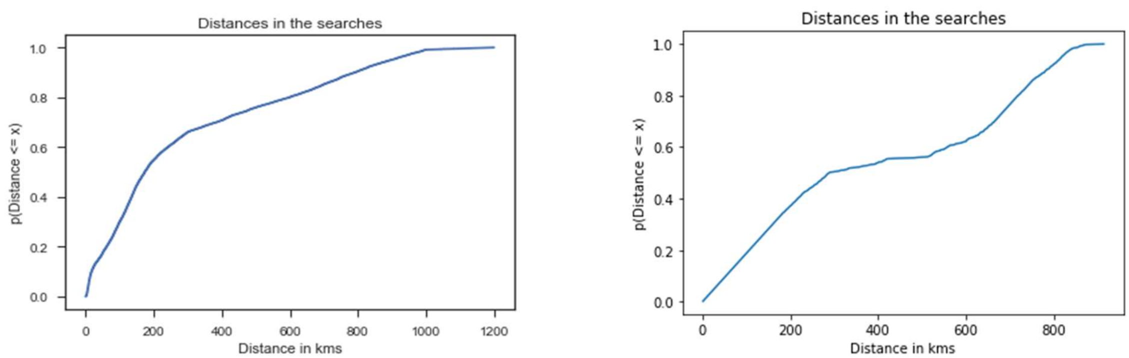

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Figure 25: *Travel distance searches (international customers and Swiss customers)*

If we consider travel searches related to urban/sub-urban contexts, the ones more likely to appear in the MoTiV dataset, we observe that less than 20% of the searches (both in the international and Swiss customer groups) are related to a radius of 30 to 50 km. The explanation, to be further verified, may be that the usefulness of journey planners, described by the amount of travel searches, decreases with the familiarity of the travel context. In other words, users who are familiar with a city and regularly follow similar routes (travel habits), already know how to get from desired origin to destination and therefore are less likely to use a journey planner as a supporting tool. A notable exception concerns the use of the journey planner to check public transport schedule.

Recurrent travel searches: when comparing the two datasets on this aspect, Swiss travellers looked for the same origin and destination many more times than international travellers. Apart from that, the behaviour shown by the users in the two datasets is the same and it is very rare for them to look for the same origin-destination pair more than once. Indeed, in almost 80% of the cases, the international travellers did not look for a pair more than once, while the Swiss travellers showed the same behaviour in more than 60% of the cases.

User (click) behaviour: as described earlier, user travel preferences are described by the click behaviour related to sorting journey planner search results. Interestingly, the large majority of users seem to be happy with the default results of the routeRANK algorithm sorting results by relevance[29]. Indeed, in 91.88 % of logs, results were not sorted. When results were sorted, travel cost, travel duration and arrival time were the most important factors respectively with 3.43%, 1.91% and 1.54% (Table 4).

Table 4: *Factors influencing sorting available travel options (international and Swiss-based dataset)*

International	Share	Swiss-based	Share
No additional sorting[30]	91.88%	Rank[15]	34.64%
Travel cost	3.43%	Means[14]	24.02%
Travel duration	1.91%	Travel Duration	13.26%
Arrival time	1.54%	Travel cost	12.60%
CO_2 Emissions	0.55%	Departure time	7.74%
Means[31]	0.32%	Arrival time	5.16%
Departure time	0.26%	Available Time	1.11%
Via (locations)	0.06%	Via (locations)	0.74%
Rank[32]	0.06%	CO_2 Emission	0.74%

A different situation is shown when analysing the Swiss dataset: in this case, no information is available on the user behaviour related to "not sorting". This is not because the sorting option is not available for Swiss travellers, but rather because the dataset shows that it was not used. Quite surprisingly, Swiss travellers seem to give more importance to the Rank (34.64%) and combination of means of transport (24.02 %). Perhaps this is due also to the peculiar nature of the Swiss transport system and its geographical configuration. These are followed by travel duration (13.26 %) and cost (12.60 %). In the Swiss dataset, there are also additional sorting criteria such as "Available Time" (i.e. describing expected travel productivity) that does not seem to be used much (1.11%).

Travel cost: international travellers searched for more expensive travel options than the Swiss ones: for international travellers, the maximum travel cost reaches 7,000 EUR, while for the Swiss traveller group it reaches 600 EUR. It should be noted that the two datasets did not report major differences in terms of travel distance. Hence, by crossing this result with the previous one, we can derive that international travellers are willing to spend more than the Swiss ones for their journeys.

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[29] This is in line with knowledge on the "inertia" associated to default options/settings: https://www.behavioraleconomics.com/mini-encyclopedia-of-be/default-optionsetting

[30] The search results provided by routeRANK are already sorted by rank. If a user does not perform additional sorting, it means that the default sort-by-rank given by routeRANK is followed.

[31] Number of changes in means of transport

[32] Ranking is based on clustering and visualising available travel options by relevance

Travel cost by type of journey: to deepen the knowledge on how the prices are distributed, in Figure 26 we report the prices spent for each type of journey by the international travellers (the results for the travellers are reported here but not in the figure due to space constraints). As expected, the amount spent for a journey increases as the distance to cover increases.

Travel cost by service provider: When comparing traveller groups, international travellers are interested in longer journeys and more expensive travel options: for both groups, the plane journeys are the most expensive (on average around 450 EUR for international travellers and 250 EUR for the Swiss ones). Travel costs by train are on average around 100 EUR for international travellers (with obvious differences depending on the country of the operator) and around 50 EUR for Swiss travellers. Additional travel options such as car sharing seem to interest both groups of travellers: however, no information on expenditure is available for international travellers, while for the Swiss group the cost is in line with that of the trains. Hence, we can derive that Swiss travellers are willing to embrace new transport modes such as shared mobility, even when these are not cheaper than the cost of other traditional transport modes.

The behaviour associated with each provider was also analysed by type of journey. International travellers employ all the means of transport for both short and long hauls, with the exception of the Austrian (ÖBB), French (SNCF), Spanish (Renfe) railway companies, which are only employed for long hauls. Also, Swiss travellers employ all the means of transport regardless of the type of journey[33].

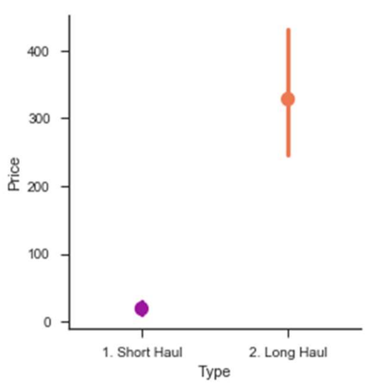

Figure 26: *Travel cost by type of journey (international customers)*

Combining the distance and sorting criteria: we have also investigated the relationship between the trip distance and the sorting criteria according to the modes or other parameters. The sorting criteria are the only parameters which reflect the travellers' behaviour. We can see that the average distance varies according to the sorting criteria. For instance, the average trip length for sorting criterion "Arrival" is 2,824 km and for "Duration" is 2,780 km, while for "Price" is 2,339 km. Trip length related to sorting criterion "Emission" is much lower (i.e. 1,040 km). Interesting findings show a comparison between the Arrival and Departure. The average distance for "Arrival" is 2,884 km, but for "Departure" it is only 853 km. The other criteria have following average distances: "Means" 783 km, "Rank" 1,267 km and "Via" 3,559 km.

[33] Obviously, with the exception of planes – considered only for long-hauls.

Table 5 shows how Swiss customers use the sorting criterion in relation to different factors: for instance, “Duration” is used for trips with an average distance of 991 km. The criteria “Arrival”, “Available Time” or “Departure” are used for much shorter distances.

Table 5: *Average trip distance with sorting criterion (Swiss-based dataset)*

Sorting criterion	Average distance in km
Arrival	95
Available time	24
Departure	43
Duration	991

5.5 Implications for MoTiV framework

The analysis of the routeRANK dataset allowed us to carry out an initial investigation of some elements of the MoTiV conceptual framework, focusing mainly on travel planning behaviour.

The analysis provided some interesting findings to be further tested during the MoTiV dataset analysis:

- Travel plans typically concern long-distance travelling. Therefore, within urban/sub-urban contexts, the journey planner may not be systematically used due to people’s familiarity with the area and locations in which they spend most of their time;
- The main factors according to which travellers rank their decisions are (in order of importance) travel distance, travel cost, and general time consideration factors (Travel duration, Arrival Time). Travel duration seem to be a key factor for travel choice, in particular for long distance journeys. As far as short-trips are concerned, arrival and departure time seem more critical that the actual travel duration

One of the aims of the analysis of the routeRANK dataset was to better understand “*what kind of data should be collected in the MoTiV project”*. The studied Journey planner data is useful, but very limited in relation to the scope of the hypotheses to be tested in the MoTiV project. Indeed, it does not adequately cover the dimensions and underlying factors of RTT. Knowledge about travel plans and attitudes towards the dimensions of the value proposition of mobility (e.g., cost, time, environmental impact) are important, but should be complemented by a set of additional variables such as socio-economic and demographic variables, mode choice, mobility behaviour, activities carried out while travelling and in meaningful locations, value judgement on use of time in relation to activities and in specific mobile contexts/locations, and the influence of external contextual factors.

From a methodological point of view, the approach adopted for the analysis of the routeRANK dataset was suitable for an initial exploration of the associations between variables. This may be adopted as well for a first analysis of the dataset collected through the MoTiV app. However, it will need to be complemented by a range of additional methods allowing to find associations between factors and VTT, and interactions between such factors. Such methods may include exploratory-descriptive analysis (EDA), correlation and multivariate regression analysis (e.g. ordinal logistic regression) as well as content analysis in the case of open questions.

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