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Personal Aerial Transportation Systems

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Executive Summary

This report presents results of phase 2 of WP7 of the myCopter project package which is dedicated to obtaining deeper insights into the socio-technological context and the infrastructural environment of a potential personal air transportation system (PATS). It describes and analyses mode choice behaviour (MCB) of commuters in the U.S. and Europe and uses this information to develop a heuristic for design requirements for future personal area vehicles and related infrastructures as well as for a first quantitative assessment of a PAV implementation scenario for a European model city. In addition, it briefly introduces the concept of narrative scenarios that are a key element for user group discussions to be performed at a later stage of this project and presents two draft scenarios developed on the basis of information gathered from deliberative exercises.

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Objective of the Report

The purpose of this document is to present further findings of the work package 7 (WP7) “Exploring the socio-technological environment of PAVs” of the myCopter project. The main goal of this work package is dedicated to obtaining deeper insights into the socio-technological context and the infrastructural environment of a potential personal air transportation system (PATS). The operation of personal air vehicles (PAVs) raises plenty of questions about their potential impacts on society, and it is not clear what the expectations of society regarding PAVs actually are and how they will be met. As PAVs are not a part of everyday life for most people in Europe, we do not know what the demand for this form of transportation might look like and what design of PAVs and their associated infrastructure people would prefer. By applying the methodology of technology assessment in an early stage of technology development of PAV, the myCopter project wants to contribute to a reflexive pioneering work in the field of individual future transportation and help to avoid technological lock-ins.

This report builds upon the results of the scoping phase of WP7 in which the socio-economic environment of this new transport form was mapped and challenges and issues surrounding an actual realisation of a PATS were identified. It describes and analyses mode choice behaviour (MCB) of commuters in the U.S. and Europe and uses this information to develop a heuristic for design requirements for future personal area vehicles and related infrastructures as well as for a first quantitative assessment of a PAV implementation scenario for a European model city. In addition, it briefly introduces the concept of narrative scenarios that are a key element for user group discussions to be performed at a later stage of this project and presents two draft scenarios developed on the basis of information gathered from deliberative exercises. By doing that, it expands the contextual information for PAV/PATS implementation scenarios already available from the scoping phase (Del. 7.1) by adding a transportation demand-related user-oriented perspective and prepares work to be performed within year 3 of the project.

1 Recap: What is the PATS vision of myCopter? – The Reference Scenario and Reference PAV

As pointed out in the project proposal, the myCopter project consortium's vision

> *"… encompasses PAVs typically designed for travelling between homes and the work place, flying at low altitude in urban environments. The envisioned PAV will be capable of short or vertical take-offs and landings (STOL/VTOL). It should be fully autonomous and allow for user input without necessitating any ground-based air traffic control centre facilities. This PAV concept could operate outside controlled airspace while current air traffic remains unchanged and could be integrated into the controlled airspace upon completion."*[3]

This more general vision has to be defined further in order to establish a common discussion basis for the project and to coordinate the (often implicit) assumptions of its various tasks, to be able to go deeper into issues seen as problematic, and to consider challenges associated with the design of the vehicle itself and the mission it shall enable. This process has been started by WP7 with the development of a reference case for the vehicle which was introduced in Deliverable 7.1 and is briefly summarized below.

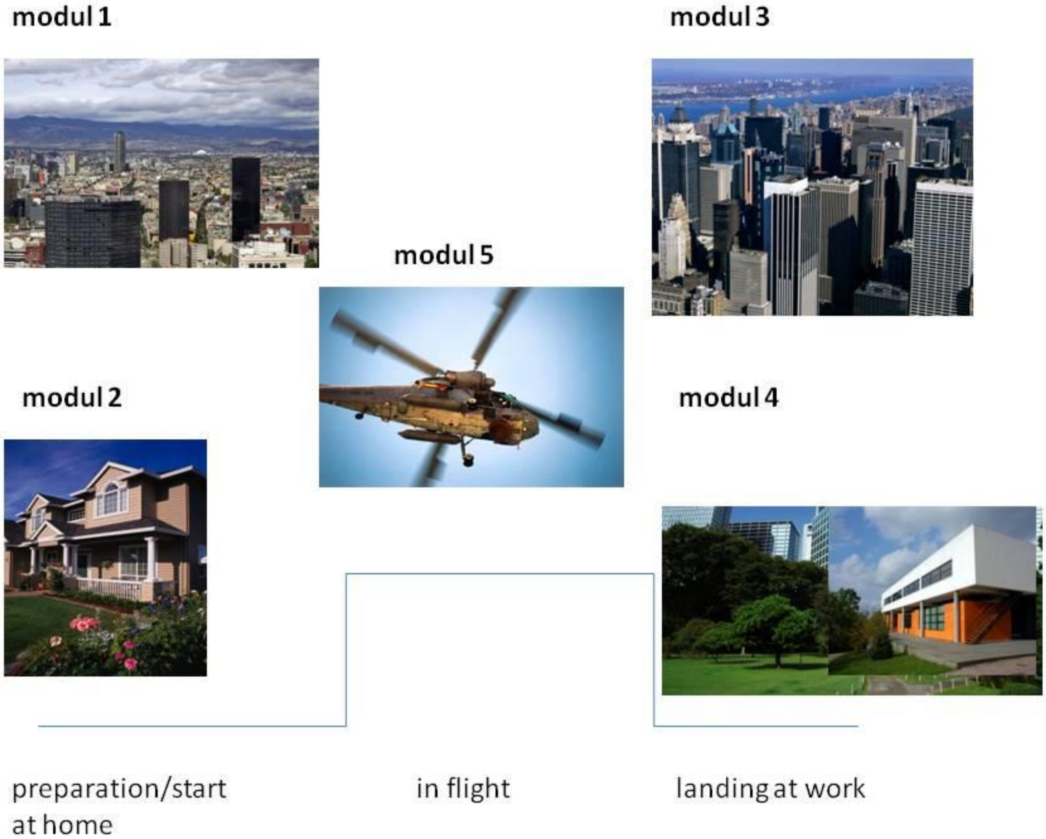
As a first step, potential application examples, in the following called "travel scenarios", were developed and discussed within the consortium. Starting with the settlement structure and the existing traffic system in Europe today, a discussion was initiated on the requirements which would become obvious from this outer framework for a future personal air transportation system serving daily commuters. Under consideration of the two opposed possible settlement structures (either densely or sparsely populated areas) and in combination with the commuting context the project is embedded in, four different combinations of start and landing modules were defined.

Origin
dense
sparse

Destination
dense
sparse

As several different requirements may exist for start and landing, the whole procedure was further divided in three main phases (preparation + start; in-flight; landing). The start and the landing phase were further divided by the settlement structure leading to five modules which are used to guide the discussion.

[3] myCopter Proposal, (2010)



Every module is characterised by its position in the flight procedure: start, in flight or landing, and the settlement density in which it occurs. Below follows a short description of every module.

Module 1: Starting from Your City Block

Here the concept is that the PAV user lives in a densely populated urban district and wants to start from there to commute to work. Questions arise, such as how the user gets to its PAV, if the PAV is able to drive on streets (to get to a take-off area for example), and how communication with other flying vehicles in the air and to the target location is accomplished. Further key aspects are the location, the organisation, and the equipment of the take-off sites.

Module 2: Starting from a Suburb /Property

The idea in this module is that the user lives in a sparsely populated neighbourhood. The PAV could be parked in the user's own garden, the question would be if he can and is allowed to start from there. The own property would probably be less well equipped than take-off areas in module 1: Therefore, refuelling and getting information could be tricky. The advantage would probably be less traffic in the take-off area and in the air.

From these two modules, questions arise, for example, regarding the size of the PAV itself (implication for storing options), its ability to manoeuvre actively on the ground or to be moved, and regarding the big issue of noise disturbance.

Module 3: Flying Phase

During the flight the autopilot would probably be in charge and the main task for the PAV or the system would be navigation, the avoidance of mid-air collisions, and, optionally, joining other PAVs to form swarms. Alternatively, the user could be in the loop and could control the PAV, but assisted by the system.

This module shows that different levels of automation are thinkable, one level representing full automation and another one representing partial automation where the user still has some control and needs pilot skills with all its resulting consequences in terms of cockpit design, training requirements, etc.. Additionally, this module illustrates the need for communication or data exchange between different vehicles and gives a hint on what requirements might exist in terms of navigation and sensors.

Module 4: Landing in CBD

In this module the user prepares to land in a densely populated inner city area. The challenge here could be plenty of traffic in the air and many obstacles around the landing site. The approach corridor could be narrow due to the fact that buildings tend to be very close together in inner city areas. As many users would have the CBD as their destination, the landing areas could be full and parking space also could be scarce. One option to handle the restricted parking space could be that the PAV drops the user off and moves on alone (autonomously) to a place where parking space is more easily available. Advantages of this landing situation in CBD would be a good connection to other modes of transport and well-equipped landing sites assuming that landing sites used by many PAVs would make it attractive to develop special service facilities. In this module the collision avoidance not only with other vehicles but also with obstacles on the ground plays a major role, and this interrelates with the requirements regarding the sensor technology and the whole performance of the navigation system. If non-skilled users are envisioned, the feature of automatic landing is added to the list of requirements.

Module 5: Landing at an Office Park

In opposition to module 4 the user in module 5 prepares to land in a more open environment which could be a business park located on the outskirts of a city. Questions connected to this landing situation are what the user has to decide during the landing procedure and how automatically the landing approach works. After landing, a solution to park the vehicle or to hand it over to another user must be considered, additionally, formalities might have to be handled by the user such as to register or to pay service fees. As it cannot always be expected that the landing site is also the final destination the question emerges of how far away the workplace is and of how this distance is bridged.

This module points out the questions associated with the infrastructure for PAVs, the storage of the PAVs when not in use, and the connection of PAVs to other modes of transport.

It is clear that these stories could be modified in any direction and questions of one module often also apply to other ones. Nevertheless, they help to imagine how PAVs could be used in daily live and requirements for the layout of a future PATS and the PAVs operating in it can be derived from them.

When looking into air traffic that is serving short trips to inner city destinations you have to consider either vehicles which land on airfields close to the city and then drive on the roads to their final destination or air vehicles that can land on comparably smaller spots in the city itself. This means that the performance abilities of the PAV have to be adjusted to the mission it shall enable. Other factors such as speed, total range, payload, and take-off weight of the vehicle are also connected to each other and cannot be examined separately.

Based on the understanding that a decision for one performance requirement, for example the seating capacity of the PAV does have an influence on other requirements of the PAV (internal dependency) and that some requirements are also strongly connected to the mission the PAV shall provide for, it is necessary to consider these requirements not separately but to be aware of these interactions.

This means that, regarding the design of a PATS, internal dependencies of “performance requirements” of the PAV exist and that dependencies exist between the PAV requirements on the system and the desired mission that the single vehicle shall allow for.

1.1 The Reference PAV of myCopter

As mentioned above, the travel scenarios were used as a tool to find categories of requirements which would be useful to discuss and frame in order to further clarify the idea of commuting via personal air vehicles and to “design” a Reference PAV as a conceptual basis for the further work in the project.

Around twenty requirements (like the dimensions of the PAV, its weight, cruising speed, etc.) regarding the PAV itself, its performance, and its overall design were identified by thinking through these scenarios. These requirements were developed and discussed by all project partners during an internal workshop in May 2011 and subsequently reiterated at the myCopter consortium meeting in Lausanne in June 2012. Specification characteristics and requirements of the Reference PAV which the consortium agreed on can be found in the table below.

It should be noted that these discussions – in a consortium with partners that deal with various enabling technologies for PAV – have not been without controversies, since decisions for or against certain parameter sets and specifications open up and support certain technical configurations and close others, and hence might influence the research strategies of individual partners. Such a situation is not uncommon for broader enabling technologies projects which are aiming at developing and investigating a wider set of techno-economic options. Experience, especially in a research context, shows that the discussion of these choices and its respective consequences finally leads to more robust knowledge and consistent parameter sets. It also allows for the introduction of an additional element of institutional learning in the design process. Consequently, the “preliminary and incomplete” status of table 1.1 is intended, the table represents a “rolling document” that will be adapted and developed further during the course of the project.

Table 1.1: Preliminary Specifications of the “Reference PAV” in myCopter as defined at internal workshops (as of June 2012)

physical specifications	
number of seats	1+1
dimension of PAV	“garageable”: size of a large/mid-size car
kind of propulsion technology	preferable electric
max. take-off weight of PAV	450kg
performance	
manoeuvrability on ground	yes, but only for short distances, no “roadable aircraft”
ability to come autonomously to the user	included in the “full level of automation”
Take-off capability	VTOL required
ability of IMC (Instrument Meteorological Conditions)	yes
ability to fly in darkness	yes
ability to fly in clouded environment	in degraded visual environment, probably not into clouds
av. cruising altitude	< 500 m above ground level
total range	100 km
cruising speed	150 - 200 km/h
max. speed [km/h]	t.b.d.
climb rate at MTOW [m/s]	t.b.d.
level of automation	two different levels (“fully autonomous” and “augmented flight”)
capability of automatic collision avoidance	Yes
capability of automatic landing/start	yes
further requirements:	
usability over the year	90 % per year

As traffic statistics state that the average car used for commuting is only occupied by 1.1 to 1.2 persons (see chapter 1), it was seen as reasonable to choose a seating capacity of 1 - 2 persons for the myCopter Referene PAV.

The chosen 1 + 1 seater gives the option to transport either one person with some luggage located on the second seat or to provide transport for two persons. As the PAV shall compete with the private car and shall be capable of being integrated into the existing ground transportation system, it would be good to have similar dimensions of the PAV as of today's cars in order to be able to use existing infrastructure for parking, etc..

Although myCopter is not dealing with the development and construction of an actual PAV and no work package is looking into propulsion technology specifically, it is clear that the propulsion technology should have as low emission as possible and, therefore, the intention is to have an electric powered vehicle. The weight limit of 450 kg maximum take-off weight was chosen following the definitions stated in Annex II of the Basic Regulation of the EASA from 2008 which defines two-seater planes or helicopters with a MTOW of 450 kg as not being regulated by the EASA itself but falling under the responsibilities of the national authorities.[4]

With regards to the performance criteria of the Reference PAV the question was whether the PAV would also be able to manoeuvre on the ground or even be driven around. This question is substantially interrelated to the question how the user's whole trip from door-to-door in an urban environment could look like. As the Reference PAV is assumed to have VTOL abilities, the necessity of manoeuvrability on the ground was seen as less important and the agreement was, to have a PAV which can be moved for a limited distance into storage facilities, etc. but not to have a vehicle for road use. This decision for a limited ground manoeuvrability means that the Reference PAV can be described as a one mode (air mode only) vehicle with VTOL ability referring back to the classification scheme introduced in chapter 1.

A few requirements in Table 1.1 are connected to the question of how automated the PAV shall operate. These questions refer to the abilities of autonomous flying and performing tasks such as automatic collision avoidance, landing, and starting. The consortium decided to go for different levels of automation including the "full automation" level.

Other performance parameters, such as cruising speed and total range, are first approaches to produce a mode of transport which would have clear time advantages compared to the car and would fit into the travel demand of today's commuters. Future findings or calculations in myCopter could reshape these numbers and lead to higher or lower requirements.

It was seen as necessary for the PAV to provide more options than flights following visual flight rules (VFR) which rely on good weather conditions and daylight. Therefore, the requirements for the Reference PAV were formulated so that flights in darkness, in clouded and degraded visual environments must be possible. As the PAVs are thought to replace car trips on a regular basis, it was seen as crucial the PAV to be used most of the time. It is clear that air vehicles have a high dependency on weather situations and that there will be times where the weather conditions inhibit flights. Although no reliable data exists on how many days weather phenomena inhibit commuter car trips, the impression is that cars allow quite reliable transportation and, generally, car trips are not inhibited that often by weather conditions.

[4] European Union, (2008)

Therefore, the consortium has set the 90 % usability benchmark[5], a figure which is probably below the figures related to the usability of cars but seems still to be challenging for a small air vehicle.

Some requirements from the table are still open and might be specified later on, others, as mentioned, might be changed dependent on new findings. It should be noted that the Reference PAV is one main vision which can always be employed when a concrete idea on the PAV is needed for the project work. The reference is flexible though, and changes and additions as well as other PAV concepts are possible.

[5] The impact of weather conditions on the availability of PAV and resulting requirements on technology and systems design have already been discussed in Del. 7.1

2 Congestion and Commuting in European Metro Areas. Some Considerations

Congestion is an area of growing concern, especially in the densely populated urban areas and regions in Western and Central Europe. The overuse of transportation networks leads to increasing journey times, reduced reliability of the transportation system and adverse environmental impacts since congestion results in increased air and noise pollution and higher fuel consumption. Transportation economy scholars who discuss (and sometimes quantify) the economic impact of congestion – which, according to CEC data costs Europe about 1% of Gross Domestic Product (GDP) every year – have identified time cost as the dominant factor of the overall congestion cost. In the Reference Scenario of the European Commission's "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" of 2011, congestion costs are projected to increase by about 50%, to nearly 200 billion € annually, by 2050.

As mentioned above, one of the key ideas of myCopter is to explore the potential of PATS/PAV to open the third dimension for commuter traffic and thus to reduce the negative impact of congestion in European metro areas. A general assessment of the overall impact of PATS on European road traffic will be difficult for methodical reasons. The regional impact of PATS may differ considerably, depending on the respective local situation, since all cities / metro regions differ with regard to a number of factors like spatial structure, structure of the local economy, socio-demographics, and many more. In general, one could imagine conducting site specific studies for all relevant metro areas within the EU but this would be far too complex for this project. In addition, a data availability problem could occur. The data quality on local transportation in general is quite high throughout Europe, but not all data are publicly available, some are considered proprietary by local (city) planning authorities and public transport operators. In addition, some surveys, especially those dealing with user behaviour, are done only sporadically and are not necessarily comparable between different sites.

To deal with this situation, we decided to draw our arguments from a set of good estimates and heuristics (‚rules of thumbs') that will be based on characteristic data obtained from case studies. Although the majority of these data will be based on German cases, we will make sure that these data can be considered as "within in reasonable range characteristic" for most European metro areas.

2.1 General approach

Our considerations follow the classic urban transportation planning (UTP) sequence (see figure below, upper level). Based on a set of structural data for the respective region (also sometimes called "land use scenario"), a travel demand model is applied and its impact on transportation and environment-related data is analysed.

For a first assessment of the impact of future PATS, we assume the structural data as remaining constant and the travel demand model as being influenced by the availability of PAV. For the changes in travel demand ("travel forecast"), we apply the so-called four step model (FSM) (middle level in figure below). FSM sequentially consider four elements: (1) trip generation (How many trips will there be, and for what purpose?), (2) trip distribution (Where do the trips origin, and where do they go to?), (3) mode split (How will people travel?) and (4) traffic assignment (What routes will be used?).

As a consequence of the myCopter consortium's decision to focus on commuter scenarios for PATS/PAV, steps (1) and (2) can be considered as remaining unaltered[6]. Existing commuting trips by car or public transportation will be substituted by commuting trips by PAV; neither mobility patterns nor origin-destination relations will change. For the purpose of this study, the question therefore can be reformulated as follows: How does the (hypothetical) availability of PATS / PAV influence the mode choice behavior (MCB) of potential users and what is the impact of this altered mode choice on transportation and environmental indicators?

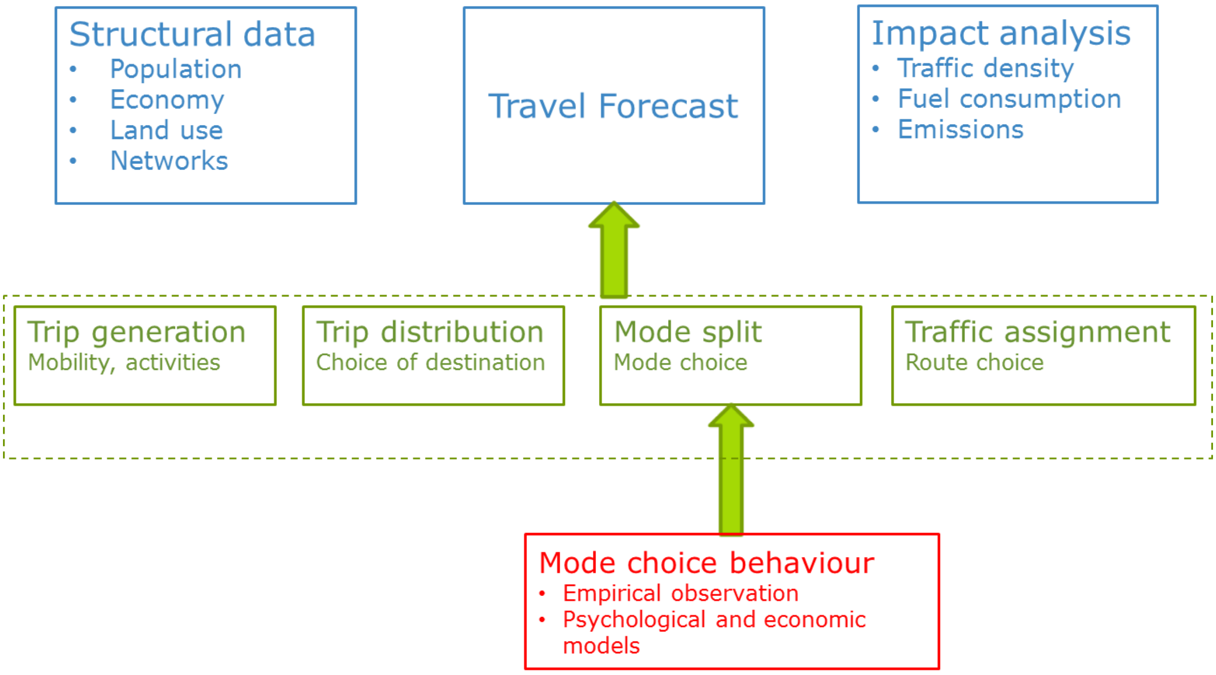


Figure 2-1: General approach to PAV/PATS implementation scenarios impact analysis

2.2 On Mode Choice Behaviour

Travel mode choice behaviour (MCB) is a matter of scientific investigation in different communities for several decades. Since it plays an important role, as described above, in analysing, describing and forecasting transportation-related decisions of individuals and its impacts, a significant body of research has emerged, especially in the context of urban transportation planning and public policy research. Various models have been developed, but no "standard methodology" has been established to date. Even basic assumptions are

[6] This is, of course, a reduced perspective. In the long term, the availability of PATS might also change the O-D-relations in commuting and mobility patterns as well as land use structure (similar to the availability of automobiles in earlier decades). But statements about nature and scope of these effects are currently purely speculative.

controversial between scientific camps. While the rational model of travel mode choice assumes that the optimal decision is to maximize individual utility subject to time and budget constraints (which requires the availability of sufficient or even full information about the relevant factors, a correct processing of these data and the absence of cognitive biases), psychological studies indicate that decision makers underlie bounded rationality, use choice heuristics and are affected by perceptual and cognitive biases.

On the empirical side, numerous case studies have been published. A comprehensive review of these results lies beyond the scope of this report. The most important characteristics of earlier research efforts investigating travel mode choice decisions have been summarized by Eluru et al. (2012) in a recent paper:

- Earlier research has clearly shown that individual and household socio-demographics exert a strong influence on travel mode choice decisions. Specifically, gender, income, car ownership and employment status affect travel mode decisions.
- Researchers have identified that tour complexity influences mode choice substantially. Individuals with more complex commute tours (possibly with multiple stops) prefer to employ the car mode of transportation.
- Residential location, neighbourhood type and urban form play a prominent role in determining the favoured travel mode for commute. At the same time, individuals with inclination to commute to work by public transportation locate themselves in neighbourhoods with adequate access to transit.
- There has also been extensive focus on evaluation of the willingness to pay (i.e. the amount of money paid for reducing travel time). In more recent research studies, reliability of travel time is also incorporated within the framework to compute the value of travel time.
- Other attributes that influence travel mode choice include travel distance, and household constraints such as picking up or dropping a child.
- Earlier research has also highlighted the importance of attitudes, personality traits and awareness of transportation alternatives on travel mode choice decisions.

Obviously, mode choice behaviour is influenced by numerous factors. While some of them can be considered being “objective” factors because they can be easily measured with established procedures (like socio-demographic factors: household size, employment status, age, income, education, car (PAV) availability, availability of transit passes, …; travel purpose: work/education, shopping, leisure, …; and characteristics of the existing transport system: travel times (door-to-door), prices/cost, way complexity…), other factors are largely subjective. This is especially relevant for attitudes and habits (social status, individuality, privacy, risk, fun, …); the perception and evaluation of the respective mode or trip (safety, punctuality, reliability, travel times (door to door), cost, environmental impact, predictability, …) and for customer acceptance and satisfaction in general.

A number of these factors are related to and influenced by the availability of PAV (similar to the role that car availability plays in mode choice decisions) and actual PATS design (including both the vehicle and the supporting infrastructure). While an assessment of the impact of subjective factors on PAV-related MCB would be highly speculative at the moment[7], a deeper understanding of a subset of the objective factors could help to identify selected requirements and potential design criteria for a PATS. Of special importance in this context are typical commuting distances and door-to-door travel times

2.3 Patterns of current commuter behaviour

The general, internationally agreed metric for travel times related to work are the so-called commute times which is all the time spent travelling to (but not from) work by any means. It is important to keep in mind that here only travel in one direction is counted. Travel times back home might in individual cases might differ considerably, however, twice the commute time is a good estimate for the daily time budget spent in commuting.

Individual commute times might vary to a large extent – among countries, settlement structures, between cities and even within metro regions. The challenge for assessments in the myCopter project therefore is to find a good and representative estimate for assumptions to be used in the commuter scenarios.

Time use surveys currently provide the most reliable data about the daily time spent on commuting. The OECD family database[8] collects these data which are based on national time use surveys. It should be noted that because of different base years of the various surveys and a number of other methodical issues, cross-country comparability between these data is limited. On the other hand, the quality is good enough to allow for the description of a few broader trends:

- In most European countries, male workers spend approximately one hour on commuting per working day. The figure is higher for the U.S. and Canada, and lower for Sweden and Finland.
- In most countries, men spent more time on commuting than women, but there are significant cross-country differences. While in Japan, the U.S., Germany and the U.K. men spent far more time commuting than (commuting) women, there is hardly any difference in Finland, Spain, Sweden or Slovenia.

[7] We hope that the analysis of the focus group discussions planned in Task 7.3. can provide first validated insights into the role of these factors later in this project.

[8] http://www.oecd.org/els/soc/oecdfamilydatabase.htm

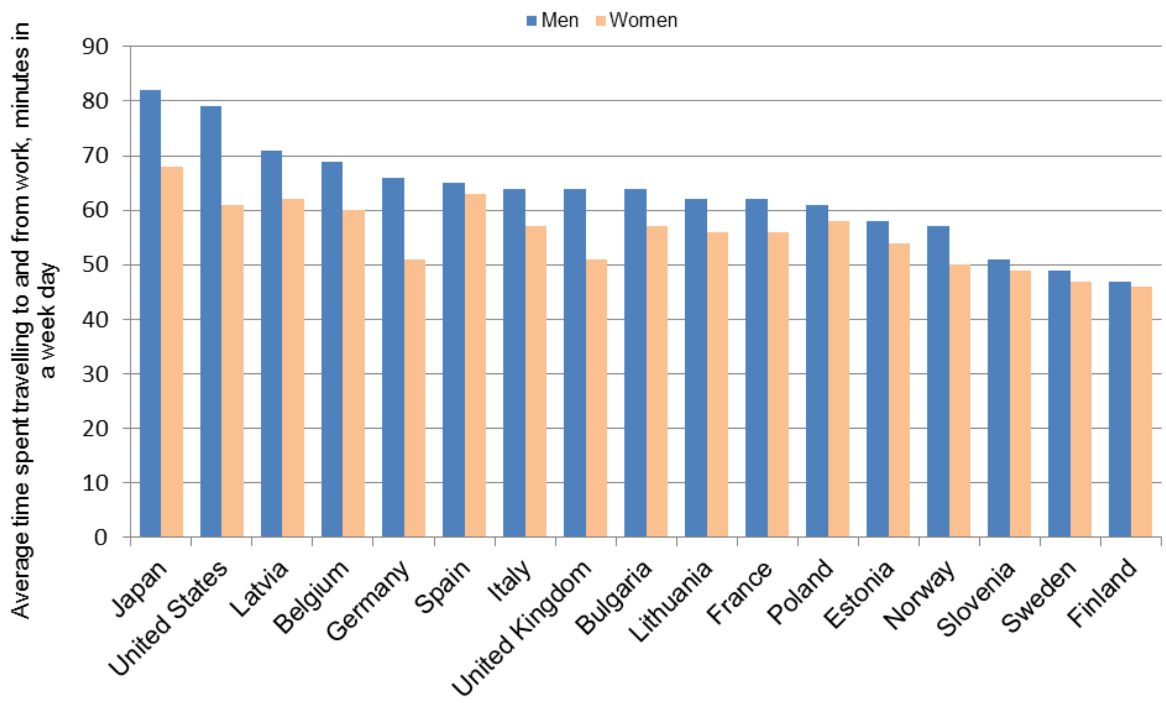


Figure 2-2: Average time spent travelling to and from work. Time in minutes in a week day, commuting respondents (Data source: OECD Family Database, http://www.oecd.org/els/soc/oecdfamilydatabase.htm, retrieved Apr 2013)

Deeper insights into the commuting behaviour of residents of all of the 366 U.S. metropolitan statistical areas (metro areas) are provided by the 2009 American Community Survey (ACS)[9]. According to these data, the mean travel time to work for the U.S. was 25.1 minutes. This is a slight increase compared to the situation 30 years ago (1980) when the mean travel time for workers was just under 22 minutes. It then increased between 1980 and 2000 to about 25 minutes, where it remained in 2009.

A closer look at the temporal distribution of average travel times (Figure 2-3) shows that approximately one third of the respondents spends 15 minutes or less, one third between 16 and 29 minutes and one third 30 minutes or more for travel to work. Travel times tend to be lower for smaller metro areas, the 10 metro areas with the shortest average commute times have populations of fewer than 300,000 people. Among the 10 metro areas with the longest travel times, several are among the U.S. most populous. For example, the New York-Northern New Jersey-Long Island NY-NJ-PA Metro Area had the longest average travel time at 34.6 minutes, followed by the Washington-Arlington-Alexandria, DC-VA-MD-WV Metro Area, with an average travel time of 33.4 minutes.

[9] http://www.census.gov/acs/www/

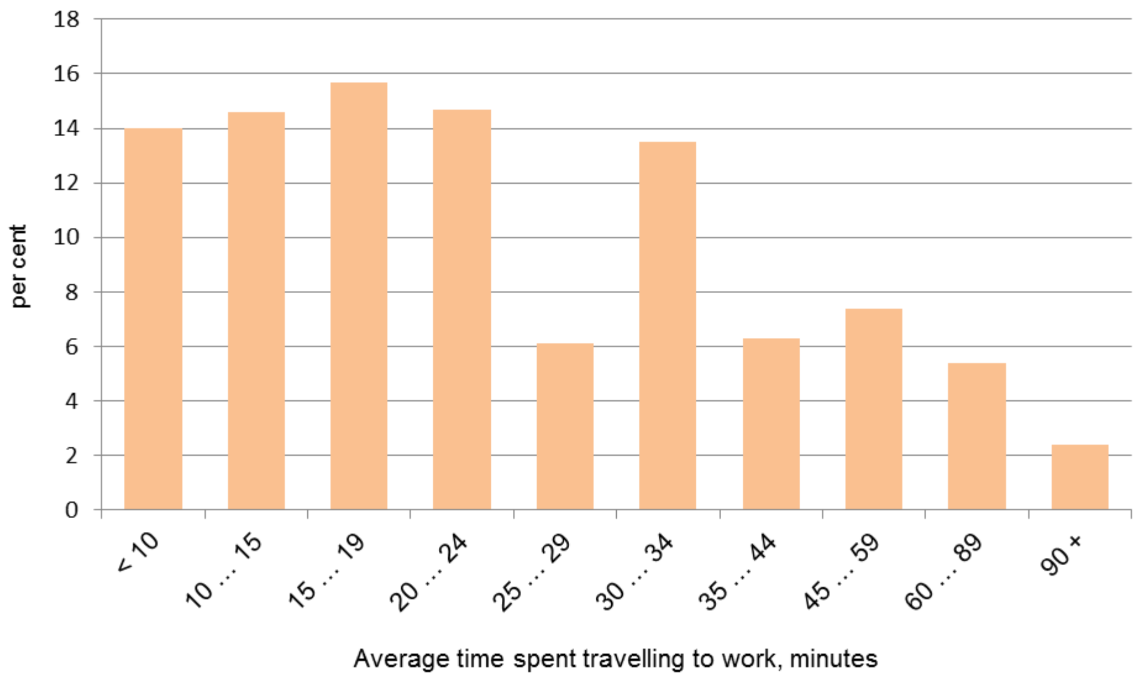


Figure 2-3: Average travel times to work, temporal distribution among residents of U.S. metro areas (Data source: American Community Survey 2009)

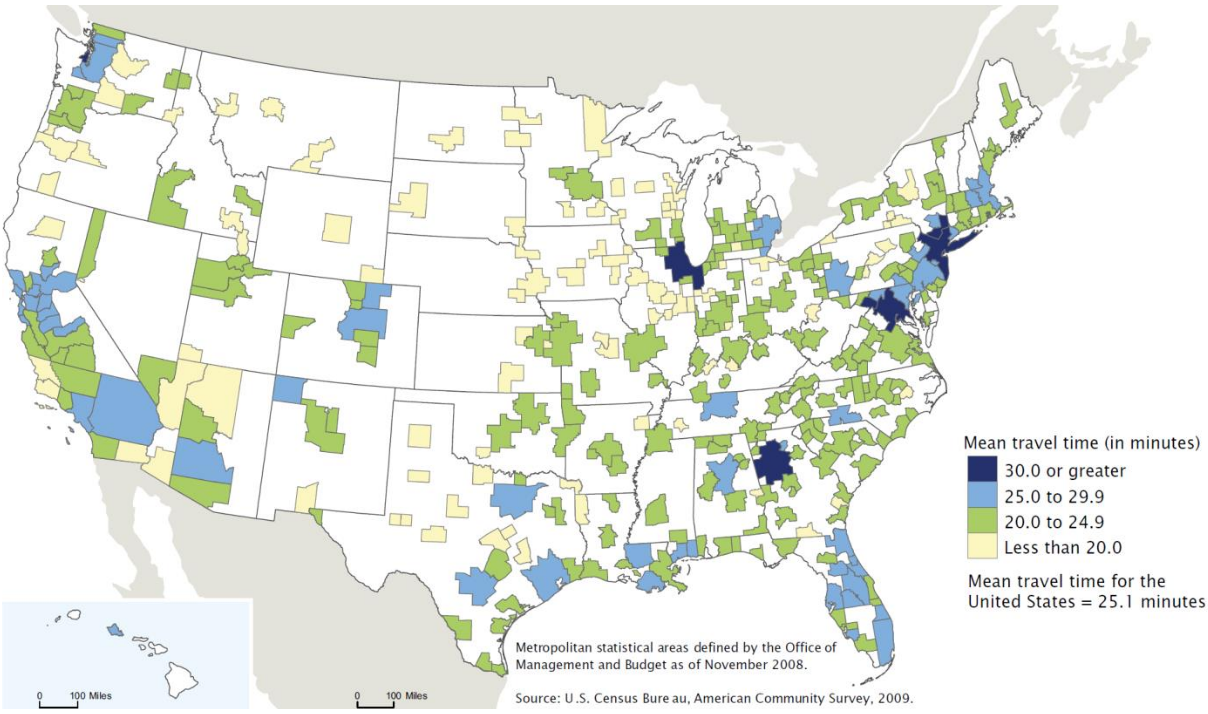


Figure 2-4: Average travel times for workers in U.S. metro areas (mean travel time to work). (Source: American Community Survey 2009)

It should again be noted, that these data are only statistical averages. For illustrative purposes, figure 2-5 presents a colour-coded map of the Bay Area (San Francisco) where average travel times are depicted at the spatial resolution of U.S. zip code areas. It shows that within a certain metro region, the average commute times might differ considerably, depending on a set of factors already mentioned in chapter 2.2. It also proves that average commute times only in very rare cases exceed the 30 minutes level. We therefore argue that for the U.S. situation and for the purpose of the development and assessment of broader PAV/PATS implementation scenarios, a “30 minutes one way commute time” paradigm would represent an acceptable heuristic.

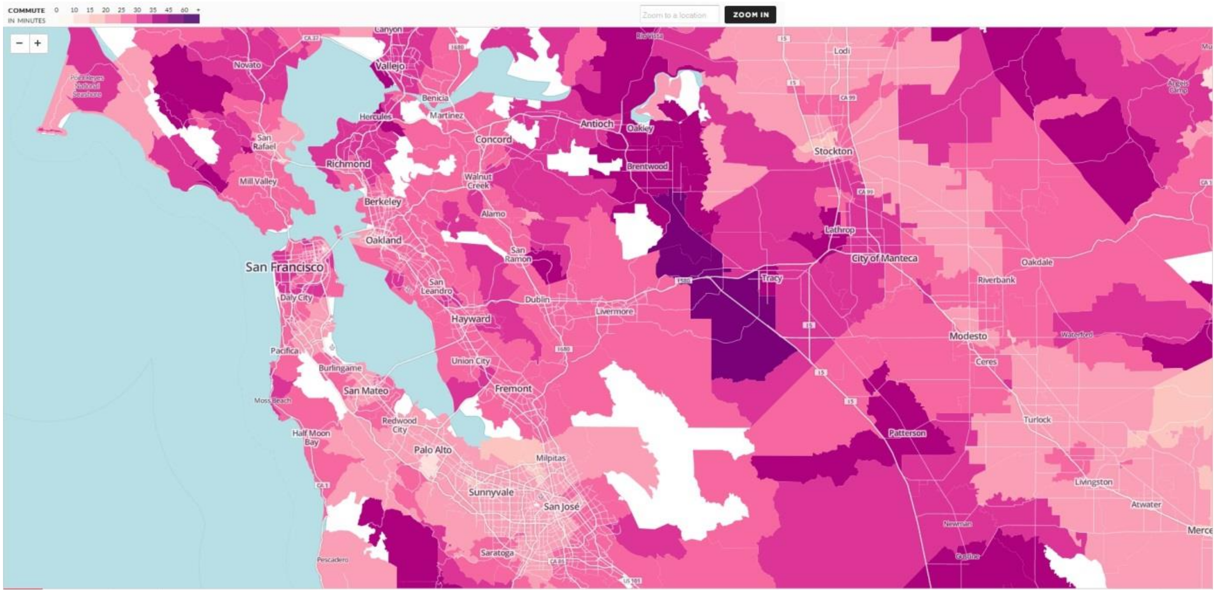


Figure 2-5: Average commute times in the Bay Area (San Francisco) at the spatial resolution of U.S. zip code areas (project.wnyc.org/commute-times-us/embed.html)

Unfortunately, similar comprehensive and comparable statistics are currently not available for the European Union as a whole. Time survey data and commuter data for metro regions are collected by various EU, national and local authorities. These activities are only loosely coordinated. The survey methods are slightly different between member states and regions. In addition, due to the complexity and cost of data collection, but also because of a certain temporal inertia of changes in spatial structures and socio-demographics, and hence also in general travel patterns, surveys in specific regions are usually performed only every five to ten years. Some of these datasets are publicly available, others – especially when financed by transportation operators or local planning authorities – are only published in excerpts.

For a strict EU-wide analysis of the potential impacts of PAV/PATS implementation scenarios under the assumptions of the myCopter vision statement, all metro regions within the Union would have to be considered. In the terminology of EU regional statistics, metropolitan regions are so-called NUTS[10]-3 regions or groupings of NUTS-3 regions representing all urban agglomerations of more than 250 000 inhabitants. Currently, there are over 250 metro regions within the Union (Their regional distribution is shown in figure 2-6). An individual analysis of commute times and MCB within all of these metro areas would constitute a new project and is certainly not possible within the organizational and financial constraints of the myCopter project. We therefore decided to base further discussions within this paper on available data for selected metro regions in Germany.

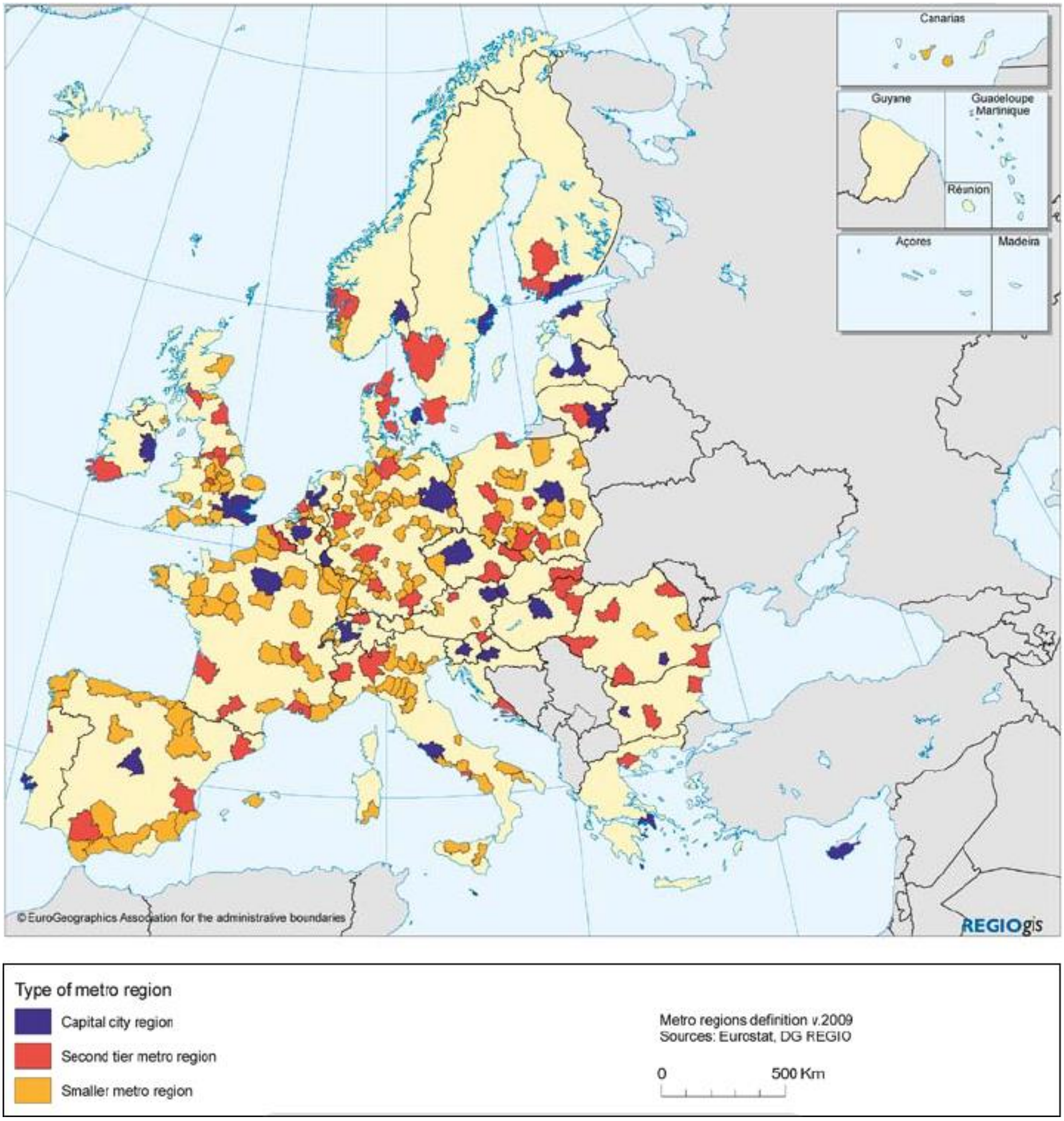
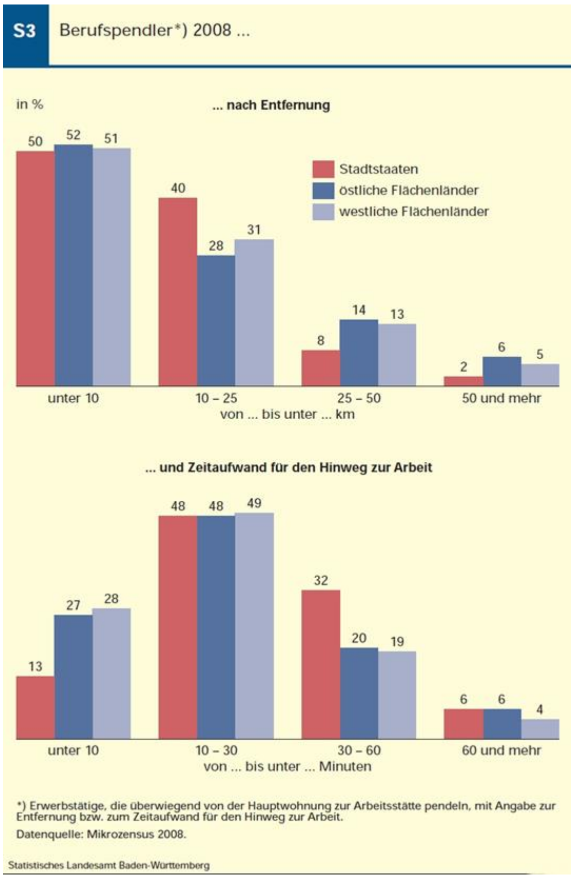


Figure 2-6: Metro regions within the European Union.

[10] An Abbreviation for 'Nomenclature of Units for Territorial Statistics' or 'Nomenclature des unités territoriales statistiques'. NUTS is a geocode standard for statistical purposes, developed and regulated by the European Union.

Figure 2-7 is taken from a publication (Winkelmann 2010) that presents an in-depth analysis of commuting behaviour in Germany 2008. It depicts distances (in km, upper picture) and commute times (in minutes, lower picture) of workers in different German federal states: city-states (red), East German states (dark blue) and West German states (light blue). What can be seen from these graphs is that:

- There are only small differences between East and West German federal states. Differences are obvious between city states (which are, in this case, the cities of Berlin, Bremen and Hamburg) and the (larger) territorial states.
- In general, only about 5% of workers travel to work longer than 60 minutes and 50 km (which is comparable to the U.S. situation, see above).
- More than two thirds of workers travel less than 30 minutes and 25 km to work.
- Half of the workers travel less than 10 km to work.
- Travel times are slightly longer and travel distances are slightly shorter in city states.



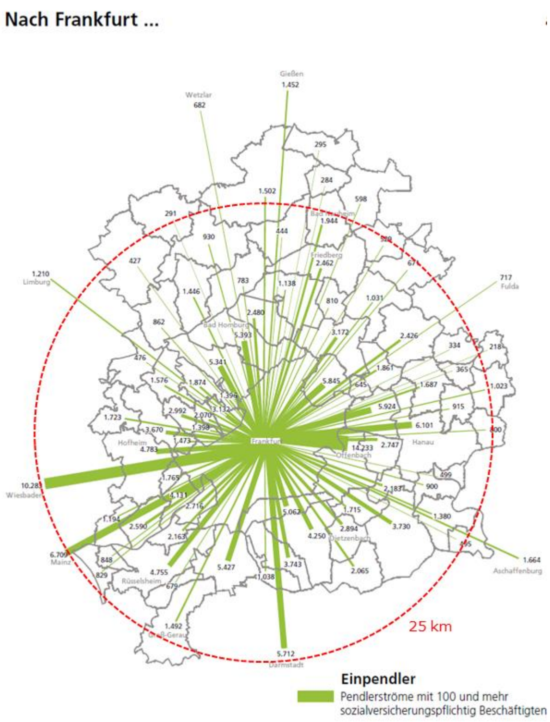


Figure 2-7: Commuting to work in Germany 2008 (taken from Winkelmann 2010)

Figure 2-8: Commuting into the city of Frankfurt 2010. Daily commuters by county.

These data are supported by an in-depth analysis for the metro region of Frankfurt which is based on statistical information gathered in 2010 (Regionalverband 2011). They show that the majority of people that are commuting into the city of Frankfurt live within a radius of 25 km around the city centre (Figure 2-8) and hence confirm the general observations presented in figure 2-7. They also provide an explanation for the longer travel times despite the shorter travel distances in metro areas: The share of public transport users in metro areas is substantially higher than in more rural areas. The average travel times by public transport are (assuming the same origin-destination-relation) usually longer than by car (Figure 2-9), and the difference increases as the distance to the city centre grows. For communities at the outer fringe of the Frankfurt region, the time differences may well exceed 30 minutes and indicate a clear travel time advantage for car users, although the data for car travel exclude congestion and search for parking space.

This observation may also have consequences for the impact assessment of PAV/PATS implementation scenarios: The substantial travel time reduction that is envisaged by PAV use might be even more attractive for commuters that currently use public transportation than commuters that currently travel by car and hence substantially influence the modal shift processes caused by the (hypothetical) implementation of PAV. Since empirical data on PAV implementation are missing, these consequences remain speculative but appear to be highly plausible.

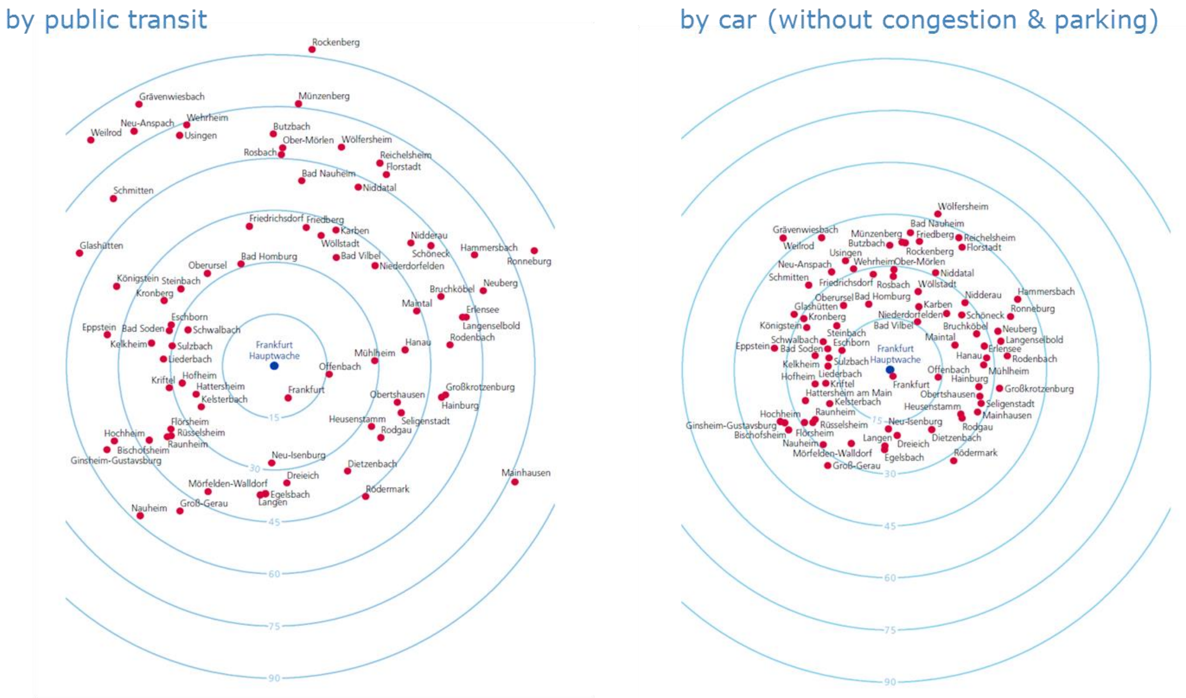


Figure 2-9: Isochrones of travel times into the city of Frankfurt by public transport (left) and by car. Please note that the times for car travel do not include delays due to congestion and search for parking space. (Regionalverband 2011, modified)

2.4 Travel time delays by congestion

Currently, there is no generally accepted way to measure congestion and its impacts. Typical definitions of congestions are based on indicators like travel times, speed, volume, level of service (LOS) and traffic signal cycle failure (meaning that one has to wait through more than one cycle to clear the queue) (Bertini 2005). Available analyses are mainly case studies of varying quality and methodology performed in regions that are scattered across Europe. The COMPETE study commissioned by DG TREN indicated that congestion in Europe is mainly a problem of urban access links with the exception of the very densely populated Randstad region (Netherlands) and the Ruhr area (Germany). It also noticed that, as concerns the monitoring of traffic quality in urban areas over time, the US and Canada are far ahead of many European countries or regions (Schade et al 2006).

Against this background, we attempted to approach the problem of choosing an indicator that is helpful for the impact assessment of PAV implementation by relating it to a user perspective. From this perspective, congestion impacts are mainly perceived as extensions of travel times, as delays. At the same time, travel times are an important decision criterion in mode choice (see Ch. 2.2). We therefore tried to find data that describe congestion in various cities or metro regions in terms of travel time delays.

We found that TomTom International, a company that provides traffic navigation and management products and services, captures real-world travel time information from its customers (FCD[11]) and publishes them in aggregated and anonymized form. We used a subset of these data, collected in the second quarter of 2012 in European and North American cities, for a first attempt to better understand the congestion situation and the role that PAV might play to reduce its effects.

Figure 2-10 shows the key result of this analysis and presents a graph that depicts average congestion level (measured as travel time delay compared to free flow conditions and normalizing it to (hypothetical) 30 minutes travel times under free flow conditions) on the x-axis and peak hour congestion level on the y-axis[12] for the most congested 25 North American and European cities, respectively.

[11] Floating car data / floating cellular data

[12] To illustrate this way of presenting the data: In the city of Marseille (upper right), a car trip that would take 30 minutes under free flow (undisturbed) conditions, was on average ca. 12,5 minutes longer due to congestion. During the peak hour, the trip was 25 minutes longer and hence took a total time of 55 minutes.

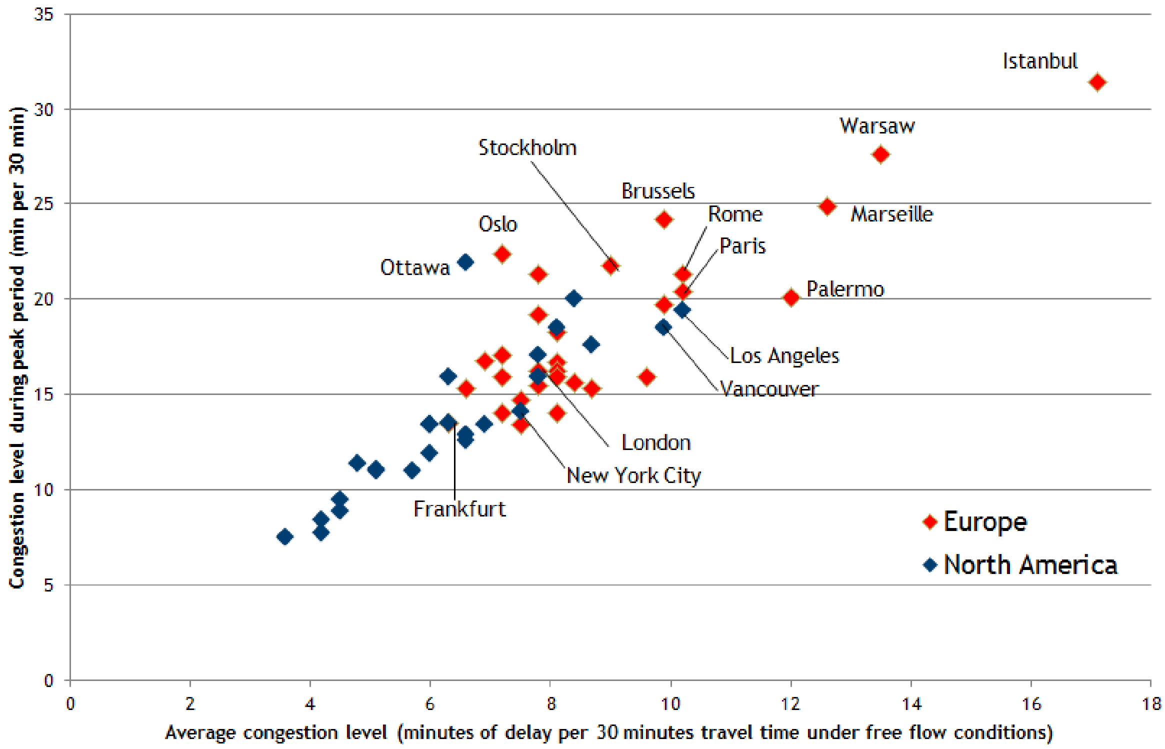


Figure 2-10: Comparison of average and peak hour congestion levels in major European and North American cities (analysis based on floating car data for Q2/2012)

The graph indicates that about 30 European and North American cities show average travel time delays > 25% and peak hour travel time delays > 50 % (compared to free flow conditions) because of congestion. The problem is more prominent for European than for North American cities. One explanation is that (as a general trend) most North American cities have younger, more extensive, more “car-friendly” structures that most European cities.

The peak hour congestion patterns also differ by city and region. While the congestion level is higher during the evening than during the morning peak in all North American cities included in the analysis, the picture is somewhat mixed for European cities: For roughly half of them, the morning peak is more problematic than the evening peak (Figure 2-11).

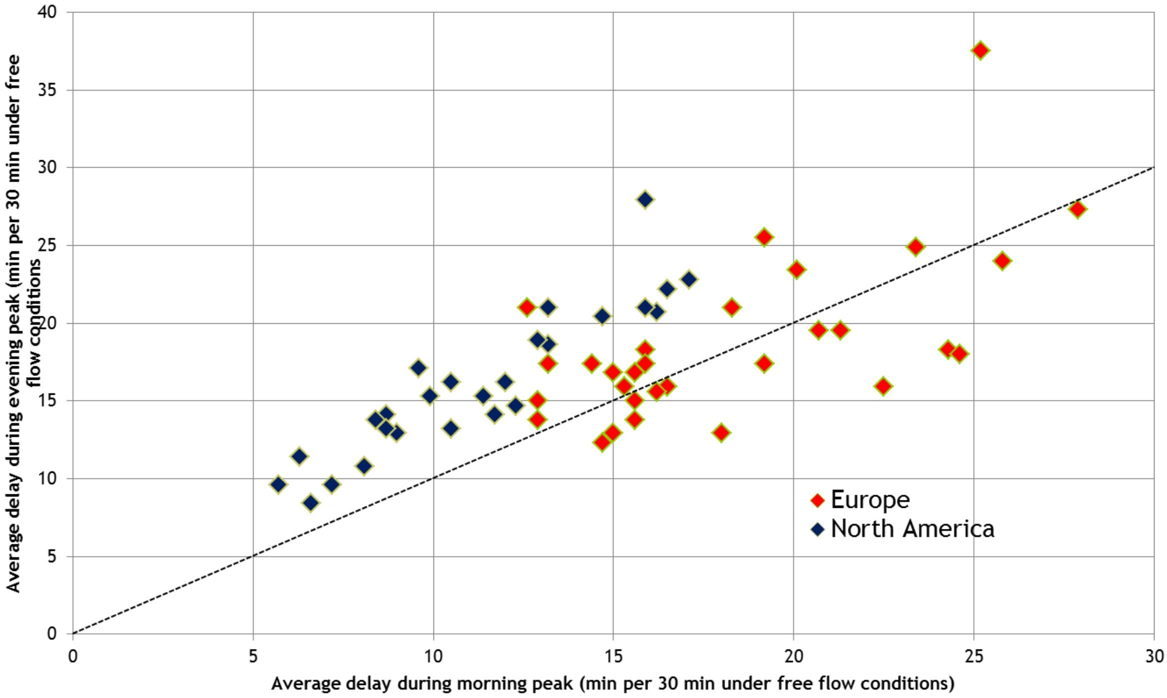


Figure 2-11: Comparison of congestion levels in major European and North American cities during morning and evening peak (analysis based on floating car data for Q2/2012)

2.5 Summary and first conclusions

Although all cities / metro regions are different (because of variations e.g. in their spatial structure, economy, socio-demographics) and site-specific studies are both too complex and too detailed for the needs of the myCopter project, some good estimates and heuristics ('rules of thumbs') could be identified or developed that will inform and support future work:

- The average commuting time (both for North America and Europe) is approximately 30 min one way
- Floating car data (for the most congested 25 North American and European cities, resp.) indicate that ca. 30 cities show travel time delays > 50 % during peak hours
- In most cities, the evening peak is more problematic (higher congestion levels) than the morning peak
- Older cities show a more complex spatial structure than younger, average speeds are lower
- Most North American cities have younger, more car friendly structures. The average speeds are higher, commuter distances longer and congestion levels lower than in European cities.
- With very few exceptions (NYC, SFO, WAS, BOS, CHI), the share of public transportation in commuting in North American metro areas is below 10%. (European cities: ca. 25 – 40 %)

Based on these findings, data for European and North American cities were gathered and analysed in order to assess the number of PAVs (and the related infrastructure needs) required to substitute a share of car commuter traffic by PAV that is sufficient to significantly reduce urban congestion and contribute to the project's overall goal.

These data, supported by more detailed data from various German cities, allow for some (preliminary) conclusions on PATS requirements with regard to PAV design (range, speed, …) as well as well as plausible mission scenarios and infrastructure requirements:

- In order to have measurable impact on traffic congestion in metro areas, PATS would have to substitute a substantial share of car traffic during peak hour(s). Experts consulted by ITAS estimated that a net substitution of 10 % of recent car traffic could have this effect, assuming that this reduction in travel times does not induce new traffic or shifts from other transportation modes (like public transportation or cycling)
- The vast majority (ca. 90 %) of commuting trips to work is shorter than 25 km and does not take longer than 30 minutes.
- Peak hour delays in most European cities are no longer than 15 min, in very rare case up to 30 min (based on the assumption of 30 min travel time to work under free flow conditions)
- Key factors for modal choice are availability, cost, reliability and door-to-door travel times.
- Door-to-door travel times for PATS will heavily depend both on the PAV concept (pre- and post-trip routines, level of autonomy) and PATS infrastructures, especially within cities.
- Weather data indicate that availability / reliability may be further limiting factors.

Assuming a number of approx. 300.000 people that commute every day into a major city, modal shares typical for European cities and a net substitution rate of 10 % of car traffic by PAV, an "automated" ATM for such a prototypical city would have to handle between 2.500 and 10.000 approaches per hour. Between 40 and 160 independent landing sites for PAV would be needed (assuming turnover times of 30 seconds and 30 seconds separation). Further assuming a conventional business model ("individual ownership") and limited autonomy (no ability of fully automated flying) of PAV, this scenario indicates a required storage capacity for 7.000 to 20.000 PAV within the city.

3 Development of narrative scenarios for User Group Discussions

In an earlier project phase, a so-called “commuter scenario” has been developed that serves as an internal benchmark for the enabling technologies developed in myCopter as well as a key design feature for PAV application and integration scenarios to be used in Tasks 7.3 and 7.4

Within Task 7.3, group interviews with potential users are planned that are aiming at providing deeper insights into their expectations towards PAVs; contributing to the preparation of tools for simulations of product usage and generating additional input to be considered in the development of technical design options for PAV on the basis of the results of the focus groups. For these focus groups, narrative scenarios are needed as an input for group discussions.

Scenario development and planning is a well-established method in various scientific and societal contexts, including science and technology policy and technology assessment. Scenario processes can serve various purposes, including helping to direct attention to driving forces, possible avenues of evolution and the span of contingencies that may be confronted in future developments, providing scientists, policymakers and planners with ‘compass points’ with which to orient thinking about the innumerable possible futures; or building a common vision and generating consensus and direction among a group of participants (Sloccum 2003). Various approaches for the development and presentation of scenarios are common, each of which has its specific advantages and disadvantages in different contexts

One way of presenting scenarios is in the form of narratives. Narrative scenarios can be described as a form of storytelling, as very short stories written in colloquial language that put a future situation or technology vision into an everyday context. The narrative approach allows the scenario designer to provide broader, contextualized views of the future. By using stories to illustrate abstract (technical) descriptions, it is possible to be user driven rather than technology driven (Rasmussen 2005). Narrative scenarios have a participatory element. They allow for the discussion of the probable – and sometimes unexpected or unimagined – social, economic, cultural, political, environmental or technological consequences with experts and non-experts and may provide a link between general ideas and visions on the one hand and specification of technical system requirements on the other hand.

Based on results of

- a continuous collection of comments from the public regarding news coverage of the myCopter (and related) projects,
- combining, structuring and visualization of this public discussion from online forums with a special Software for argument mapping (see previous reporting), and
- a one-day “explorative workshop” with 11 students from KIT in May 2012 on “new dimensions of urban traffic“,

two narrative scenarios have been developed based on the “commuter scenario” and using two different core designs of PAV functionalities (fully autonomous” and “augmented flight”). They are presented in the boxes below. Highlighted in red are colloquial “translations” of PAV functionalities that are developed within the myCopter consortium or considered to be descriptions of additional elements of a consistent user scenario.

It is 8 in the morning. Jim Wamugi is late. He is looking for this homeTab, a tablet computer-like device that he uses to manage and control communication, entertainment and household appliances at his recently acquired home, some 20 miles away from downtown Sogal. There it is. While opening the ezPAV app, he grabs another cup of coffee. 'Good morning sir, what can I do for you?" buzzes the machine. "I need a lift to the office in about five minutes.", Jim growls. "No problem, sir. The next myCopt will be at your door in six minutes."

He enters the myCopt and confirms the destination at the HMI. "We will arrive at the FreeDesign PAVpad at 8.25. Do you want to have e-New York Times projected on the big screen? And continue listening to Robbie Williams' last album? …" Jim smiles. The guy must be in his sixties now, but he is still recording music for twentysomethings.

The myCopt gently lifts off, gains speed and gets into a thick stream of other PAV in a virtual highway in the sky towards the Central Business District. A pretty soft ride at 100 mph today, Jim thinks.

Close to the FreeDesign office building, the myCopt leaves the swarm and descends to the landing pad on the roof. Jim disembarks, and the PAV silently disappears. In the entrance hall he meets his new boss who has arrived a minute before him. "Did you watch the game yesterday evening?", she asked with a grin …

Box 3-1: Narrative scenario for the "fully autonomous" PAV functionality

"Frank, did you plug-in the copt yesterday evening?" "Of course, honey." Mary Tsu leaves her family home and heads toward to the garage right next to it. If he wouldn't have forgotten it from time to time, she wouldn't have asked… She presses a button on the remote, the garage door opens and the myCopt slides out. Mary walks around it, checking for visible damages. Then she boards the PAV and calls automated flight control. "Mary Tsu, Registration HS15456MC, Destination SingBang CBD." "Flight control. Your dedicated parking lot is PL1328. You are scheduled to arrive at the SingMed landing facilty at 8.37. Good to go in three minutes."

Mary lifts off. Apart from the altitude control stick, flying the PAV feels like driving the car she used to have 15 years ago. OK, projections of permitted flight paths on the windscreen weren't common back then… After the heavy rainfalls in the last week, the flooding around the river was still enormous. She decided to have a closer look and flew another loop, almost hitting a goose that was crossing her path. After that, she returned to the virtual highway in the sky and switched the PAV to automatic.

Close to SingMed, flight control called. "Due to your flight route changes, you have lost your landing slot. You are now rescheduled to land at 8.44. We will put you in position 8 in the arrival cue." "Dammit", she thought.

After landing, she manoeuvres her PAV to lot PL1328 and secures it. "OMG, one of the most remote places in this huge facility. A 10 minutes walk to my office…"

Box 3-2: Narrative scenario for the "augmented flight" PAV functionality

The scenarios have been introduced to the myCopter consortium members at the midterm meeting and were discussed extensively. They will be further refined in the course of the project and used as a key input for the focus group discussions with non-experts to be held in autumn of this year.

4 Literature

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