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[1] Dissemination level using one of the following codes: **PU** = Public, **PP** = Restricted to other programme participants (including the Commission Services), **RE** = Restricted to a group specified by the consortium (including the Commission Services), **CO** = Confidential, only for members of the consortium (including the Commission Services)

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Executive Summary

Work package 7 (WP7) of myCopter is responsible for exploring the socio-technological environment of Personal Aerial Vehicles (PAVs). Its aim is to look into the infrastructural environment for PAVs and to study the potential impact on society and the social expectations towards PAVs. Currently, the demands and preferences of society in relation to PAVs are unclear. WP7 will try to close this research gap by performing a technology assessment at an early stage of technology development, and to contribute to a reflexive pioneering work in the area of individual transportation of the future.

This Screening Report is the first deliverable from WP7 and aims at giving an overview of topics which have to be addressed when imaging the realization of a Personal Aerial Transportation System (PATS) for commuter traffic in urban environments in Europe. By this it describes a first Reference PAV of the myCopter project in its context of use and by this the concept of a PAV for which the enabling technologies developed in myCopter should be sufficient.

After an introduction about the history of development of the project itself, other concepts, projects and visions dealing with personal air transportation are introduced in chapter 1. Chapter 2 describes the internal discussions between the project partners regarding a common vision of the PAV mission, the requirements the vehicle shall possess and about expected user types. The next chapter forms the main section of the report and looks into the key issues surrounding a future implementation of a personal air transportation system. It deals with the topics of safety, legal aspects, technical & operational challenges, environmental and socio-economic issues and the aspect of system integration. Chapter 4 has a look on the opportunities which are hoped for to occur like positive effects on journey time and the road traffic situation. Chapter 5 discusses, from different perspective, the innovation of PAVs as a new element in the transport system.

The final section (chapter 6) gives an outlook about the future work of WP7 and the upcoming activities in it.

Unit Conversion

Multiply	by	to obtain
knots	1.852	km/h
km/h	0.54	knots
mph (miles per hour)	1.61	km/h
km/h	0.62	mph
feet (ft)	0.305	m
m	3.28	ft

Note: Throughout the report the metric unit system is used

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Objective of the Screening Report

The purpose of this document is to present the findings of the first year 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 the insight 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 are regarding PAVs. 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. In order to get light into these issues a first step of the work package was to undergo a scoping phase, and to map the socio-economic environment of this new transport form. The aim was to identify the challenges and issues surrounding an actual realisation of a PATS, and its integration into the existing transportation system in Europe. Based on the opinion that the realisation of a PATS needs more than technical issues to be solved the WP7 has its focus on the socio-economic environment of PAVs. It applies the methodology of technology assessment in an early stage of technology development and wants to contribute to a reflexive pioneering work in the field of individual future transportation, and help to avoid technological lock-ins.[3]

[3] myCopter Proposal, (2010)

1 Chapter: Why to Look Into the Topic of Personal Air Vehicles? - Introduction

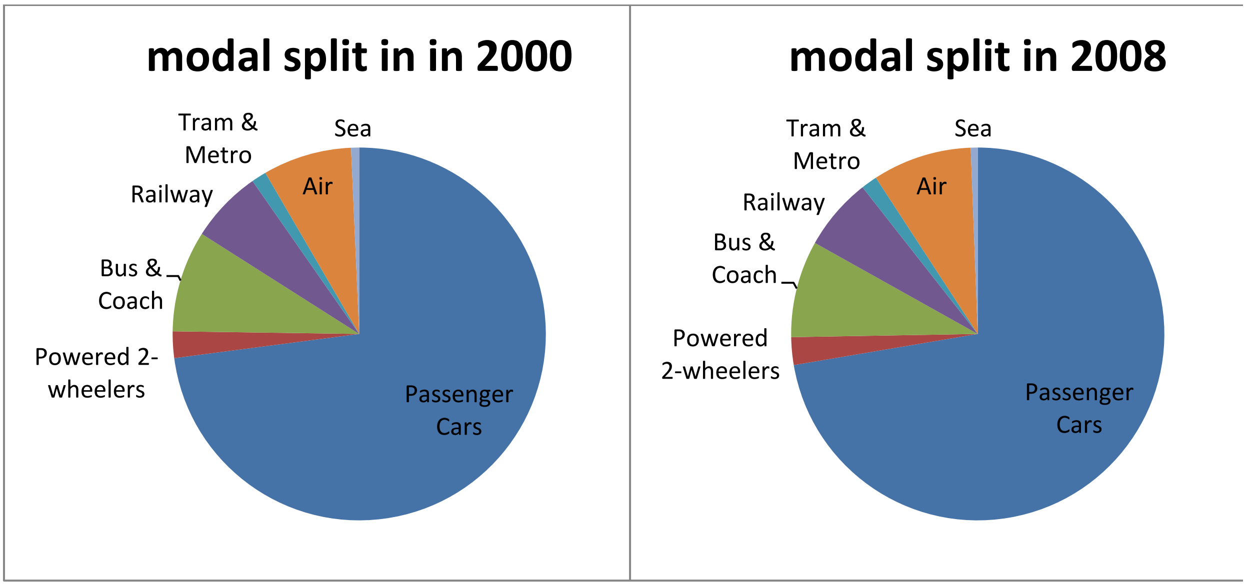
"As the automobile improved quality of life and standards of living in the 20th century, PAVs are envisioned to do likewise in the 21st century."[4]

Many see personal air vehicles (PAVs) as a new form of transportation, enabled through further technical development, that have the potential to play an important role in the personal transportation of the 21st century.

However, the current situation in Europe looks different. Today, people use aircrafts mainly for longer journeys at high speed with a trained pilot in the cockpit. Generally, aircrafts account only for a small amount of the total passenger kilometers in the EU27 (see Figure 1.1) and this trend was stable for the last decade. Even at greater distances aircrafts cover only a very small proportion of the total pkm.[5] s

In the US the mode share between a personal vehicle and an airplane is in favour of the car up to a travel distance of 750 miles (one-way trip length). Only for trips longer than 750 miles the airplane is used more often than the car.[6]

Figure 1.1: Modal split in % for the EU 27 passenger transport.[7] Note: the numbers for Air and Sea are only domestic and intra EU-27 transport



One major problem of the commercial air transportation system via airplanes is that in the case of this form of transportation the origin and destination is bound to specific locations (airports), and that further modes of transport are generally required to get to the airport and to reach the final destination. Additionally, especially for shorter journeys, the time lost by the

[4] Moore, (2005), p.642

[5] Hahn, (2006)

[6] US Department of Transportation, (2001)

[7] European Union, (2010), p. 128

whole airport procedure (luggage management, security checks, etc.) is not balanced by the higher cruising speed. Travelling by car, though, is used for a broader range of distances, at a lower speed level, and offers individual door to door transportation, as direct as the road network allows, for anyone holding a driving licence. However, there are problems regarding the current dominant individual car mobility, discussed in terms of increasing inefficiency of the system (reduced average travel speeds in urban areas, traffic jams, increased travel time and the associated higher fuel consumption and GHG emissions)[8].

One main reason for the inefficiency of the current road transportation system is the fact that most people drive alone in their cars, and, therefore, the car occupancy rates are generally low in Europe[9]. In Western Europe the figures stabilise around a level of 1.5 persons per car. In the Eastern European countries the occupancy rates are slightly higher (around 1.8) but with a decreasing tendency, reflecting the growth rates of car ownership there.[10]

Occupancy rates for the travel purpose of commuting are generally lower. For Europe older data from the IEA 1997 name an occupancy rate of 1.1 to 1.2 for commuting to and from work.[11] Newer data from Germany[12] respectively Great Britain[13] for 2008 confirm this range with an occupancy of 1.2, respectively 1.1, for the purpose of commuting.

The personal air vehicle envisioned in the myCopter project (for details see chapter 2.1) lies in between the commercial air transportation system and the passenger car sector. The aim is to offer a transport solution that has shorter travel times than a car. This could be reached through higher average travel speeds and / or more direct routes compared to the routes taken by car. In contrast to cars, today, most air vehicles are tied to special areas for take-off and landing which normally are closer to the user's home than the local airport but, nevertheless, are probably further away than the parking space. The ability of dual mode PAV concepts to operate in two modes (air and ground vehicle function) gives the option to bridge this distance (home to take-off area, landing area to destination) without the need of changing the vehicle. A single mode PAV designed for flying only would probably require alternative forms of transportation for the user though. In the context of myCopter, the tasks fulfilled by commercial airliner transport services are **not** the ones the project wants to address; the focus is, first of all, on people travelling relatively short distances between their homes and working places

In Germany the average commuting distance in 2002 was 15.6 km with two thirds of all trips shorter than this average and only 5% longer than 50 km[14]. For the UK the average

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[8] Olson and Nolan, (2008); European Commission, (2011d)

[9] ratio between the passenger -kilometres and the supplied vehicle -kilometers-kilometer (European Environment Agency 2010)]

[10] European Environment Agency, (2010)

[11] International Energy Agency, (1997)

[12] Bundesministerium für Verkehr et al., (2010)

[13] N.N., (2009b)

[14] Kloas and Kuhfeld, (2003)

commuting distance is very similar with 8.7 miles or around 13.8 km for 2007.[15] Looking at the mode choice for commuting trips, the statistics (see Figure 1.3) show a clear preference for using the car in the UK which is the dominating mode of transport for all commuting trips longer than 3.2 km or 2 miles. In the UK (data from the National Travel and Labour Force Survey 2005) 69% of the commuting trips were done by car; for business trips the percentage is even higher with a figure of 80%.[16]

Figure 1.2: Travel routes for PAV, car and airline trips[17]

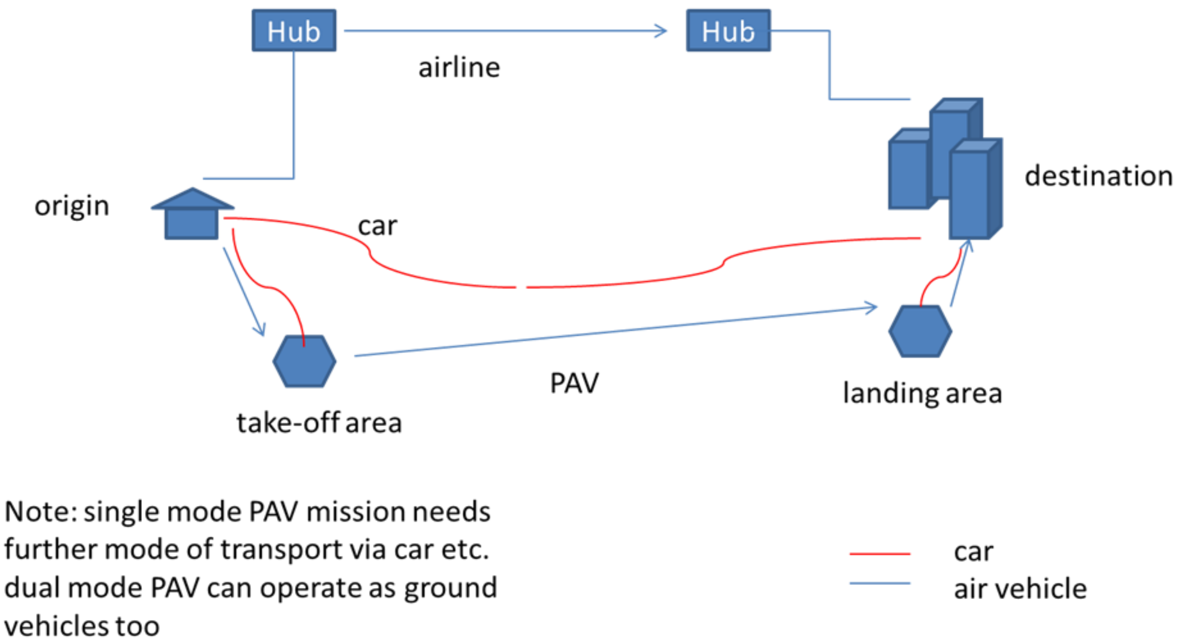
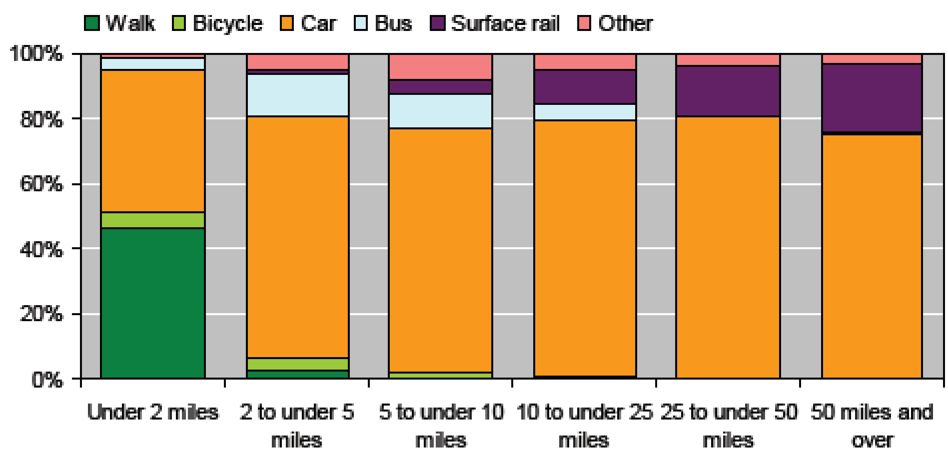


Figure 1.3: Mode of travel for commuting trips by trip length[18]



[15] RAC Foundation, (2007)

[16] Department for Transport UK, (2007)

[17] graph in the style of Lewe et al., (2002)

[18] Department for Transport UK, (2007)

Having its main emphasis on providing new transport solutions for people commuting to and from work, myCopter has its focus on these shorter distances of up to 50 km which are currently mainly bridged by using the car.

What is a PAV?

In most projects regarding personal air transportation, PAVs are described as a transport option that allows individual or personal mobility. The personal aspect is reflected by a low (lower as in commercial aircrafts) number of seats in the vehicle which allows for more specific and individual flight paths.

Aerospace engineer Mark Moore from NASA defines PAVs as self-operated aircrafts which are affordable and usable for a large portion of the population[19] and meet the personal transportation needs of customers.[20] Personal ownership and maintenance are not seen as necessary; in contrast, fractional ownership is suggested as a scheme to reduce costs and to improve utilisation.[21]

DeLaurentis et al., (2002) describe PAVs as: „vehicles of the future (30 years) that may operate synergistically with ground and other air infrastructure to dramatically improve individual mobility within the larger transportation environment". This definition highlights the embedment of the PAV into the larger transport system and stresses the future orientation.

Other aspects which are frequently mentioned in the literature are the user friendliness or easy to use qualities of PAVs[22] which facilitate a quick and cheap training and licence obtainment.

PAVs generally can be categorised into different groups based on the distances required for take-off and landing. These groups are[23]:

acronym	name	definition
VTOL	Vertical Take-off and Landing	< 100 ft
SSTOL	Super Short Take-off and Landing	< 500 ft
STOL	Short Take-off and Landing	< 1000 ft
CTOL	Conventional Take-off and Landing	< 2000 ft

A further division can be made based on the ability of the vehicle to operate in one or two modes (air and street). Dual mode air vehicles are able to operate on the ground as well, while single mode air vehicles are not able to do so. Therefore, another mode of transport (private car, taxi, public transport…) is necessary to transport the user to and from the take-off/landing area.

[19] Moore, (2005)

[20] Moore, (2006)

[21] Moore, (2006)

[22] RhinCorps Ltd.Co., (2005)

[23] DeLaurentis et al., (2002)

1.1 The project myCopter

The project "myCopter "Enabling Technologies for Personal Air Transport Systems" is funded as part of the aeronautics and air transport part of the 7th framework programme of the European Union under contract AAT.20106.3-3. One of the main reasons for the undertaking formulated in the project proposal[24] is the situation of today's ground-based road infrastructure with its congestion problems, especially under the aspect of the ongoing[25] and the future expected traffic growth for the EU27[26], both in passenger and freight transport. Responding to these challenges, the aim of the project is to pave the way for Personal Aerial Vehicles to be used by average people for travelling between homes and working places in an urban environment without relying on today's complex pilot training. The training requirements should not be more time consuming and complex than today's drivers licence obtainment.

To enable PAVs to become a reality, a so called Personal Air Transport System (PATS), consisting of PAVs and their supporting infrastructure would need to be developed, together with required training procedures and a facilitating legal framework.

The PAVs would have the advantage of being able to leave the often congested ground network and to use the third dimension at a low level (outside controlled airspace) for the individual passenger transport. As they should fly outside controlled airspace the PAVs would not conflict with current commercial air traffic but could be integrated into the next generation of controlled airspace. PAVs should not depend on conventional air traffic control (ATC) from the ground and should be able to fly fully or partially autonomously.

As the title indicates, myCopter will be dealing mainly with the development of technologies which need to exist in the first place to allow for such a system of PAVs to be in place.

Main goals within the project are:

- **Human aircraft interaction, including training issues:** The design of the interaction between the human and the PAV is of utmost importance. The human perception is considered first, so to allow for fast and efficient training. Different levels of autonomy that come with the respective operation training are foreseen.

- **Automation of aerial systems in cluttered environments:** The PAVs should be autonomous to a very high degree. This includes navigation in the urban environment, avoidance of obstacles and other uncontrolled air traffic, and the localisation of landing spots. The challenge will be to find a solution which makes allowance for safety and gives the user the ability to feel in control and override the system in case of an emergency. Additionally, flying in groups to minimise the noise and the visual impact is investigated.

- **Exploring the socio-technological environment:** traffic plays a major, often negative, role in today's society. A new transport system with hundreds of small flying objects

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[24] see myCopter Proposal, (2010)

[25] for the period 1995 - -2008 the EU 27 annual transport growth rates were 1.6% for passenger transport (pkm) and 2.3% per freight transport (tkm) European Union, (2010)

[26] Ecorys Research and Consulting, (2007)

would have a large impact on society and the public expectations from such a system should not be ignored. It is looked for a dialogue with regulators, airspace users, and the air transport business. Furthermore, the integration of the PATS into the existent transport system in the air and on the ground as well as into the settlement structure is necessary.

For details on the international consortium and a description of the work packages please see the strategy section on the project website “http://www.mycopter.eu/”.

1.1.1 History of the Project

As a reaction to a perceived lack of innovation in the air transport sector, in 2006, the European Commission funded a project called “Out of the Box” to “identify potential new concepts and technologies for future air transportation”[27]. The aim was to gain direct recommendations for research activities which could then be integrated into the second call of the 7th Framework Programme.

The project asked for ideas which would be “more innovative, radical and farsighted” and encouraged the submission of ideas which had specific technology challenges, a forward looking character rather than immediate application potential, and the potential to offer significant benefits to the air transport system.[28] One hundred ideas have been generated and down selected in an evaluation process to a limited number of six. One of these six most promising ideas was that of a Personal Air Transportation System (PATS).

The Out of the Box team was convinced that the actual design of a PAV is not the challenge anymore and that other studies focusing on the design of the air vehicle alone are not sufficient and promising.[29] Instead, they the challenging issues for a PATS from their point of view are in the areas of “operating systems, systems engineering, regulation, and control”.[30] Therefore the focus should be on the system aspects and should answer questions such as where PAVs can take-off and land, what their environmental impact is, what is about certification, maintenance, training, infrastructure requirements and ownership models.[31]

The project myCopter is one of the FP7 projects that were established as a reaction to this Out of the Box study and will deal with these system aspects and issues of a future PATS. One other project related to the PATS idea in FP7 is the PPlane Project[32] that will be presented in chapter 1.4.3.7.

In the following chapter (1.2) we are looking at previous visions and attempts to develop personal air vehicles, and some historical efforts of designing and developing PAVs will be described. Chapter (1.3.) continues with an overview of selected PAV concepts worked on today and leads over to a presentation of PAV related research at the American and the European level chapter (1.4).

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[27] Truman and de Graaff, (2007), p.7

[28] Truman and de Graaff, (2007), p. 13

[29] Truman and de Graaff, (2007)

[30] Truman and de Graaff, (2007), p.27

[31] Truman and de Graaff, (2007), p.27

[32] European Commission, (2011b)

1.2 Previous Efforts: The Old Dream of a Flying Car

The media give us an idea about how future life with advanced technologies could also shape our way of travelling. In 2008, the Discovery Channel showed a series called "NextWorld" with an episode on "Future Life on Earth" in which it was assumed that people would fly to work, "piloting environmentally friendly personal vehicles between cities Another episode was designated to "Future Flight" and predicted "a future in which just about every one of us would have a personal airplane".[33] But these expectations are not only shown in today's movies like the "Fifth Element" (director: Luc Besson) where a multilevel above street flying car concept is shown. In contrast, such concepts are around since the beginning of the 20th century[34] and they have found their way into television through cartoon series like the Jetsons in the early 70s but also through magazines and newspapers (see Figure 1.4 & Figure 1.5). Adverts in the early 60s pictured the situation of Mr. and Mrs. America having not only one to several cars in their garage but also an airplane and perhaps even a small helicopter.[35]

[33] Discovery Channel, (2008)

[34] (Hall, (2001)

[35] N.N., (2005)

Figure 1.4: Cover of a German technical magazine copy from 1956

Source :N.N., (1956)

Figure 1.5: Picture from 1945 of a helicopter in the backyard

Source: American Historical Association, (1945)

Interestingly, a book of the American Historical Association from 1945 about the potential of helicopters and personal airplanes sees the helicopter as a mode of transportation complementing the car. While the helicopter is thought to be a good solution for longer inter-regional trips it is not seen as an answer to transportation in urban areas.

"You can use your car in crowded congested urban areas and your helicopter for all other travel." [36]

[36] American Historical Association, (1945)

Figure 1.6: The Convaircar by Henry Dreyfuss in 1947. Due to a fatal crash of the prototype the project was closed shortly after the first test flight.

Source: Szondy, (N.N.)

Figure 1.7: The Taylor Aerocar with foldable wings and a detachable tail unit

Source:Vance, (2010)

Figure 1.8: The Aerobile by Waldo Waterman. A high-wing monoplane with detachable wings and three wheels.

Source: Neil, (2007)

Beside the mentioned expectations of the society that personal airplanes would become affordable and easy to use by many, the last century generated also many attempts to fulfil this dream by building actual flying cars. Some of the more famous ones were the “Aerobile” developed by Waldo Waterman that had three seats and removable wings so that driving on the ground on normal streets was possible (see Figure 1.8). The first test flight was in 1937 and, although it was even certified by the CAA in 1957, it never turned into mass production.[37]

Another example for an early flying car attempt is the Convaircar. In contrast to other prototypes which tried to add a ground driving ability to an air vehicle, the Convaircar was actually a car (specially designed for low weight) with a plane attached to its roof (see Figure 1.6).[38] The idea was that people could rent the “flying device” at the local airports and attach it to their own cars. The project was stopped after a fatal crash due to a pilot error.[39]

One last famous example to be mentioned here is the Aerocar by Moulton Taylor, an aeronautical engineer and pilot, who built his first Aerocar in 1949 (see Figure 1.7). The Aerocar was a two-passenger construction with wings that could be folded back against a detachable tail section. This whole tail -wing unit could then be put into a trailer and towed behind the car on the ground.[40] The conversion was meant to take only five minutes time. Even though the Aerocar was also certified by the CAA, in 1956, only five of them were built.

1.3 Flying Cars and PAV Concepts Today

In this subchapter some newer concepts are presented and compared. Key questions are what the vehicles can offer, how far the development process has proceeded in 2011, and what the expected target groups and use cases are, according to the developers. Another aspect paid attention to, is the regulatory framework in which the PAVs are expected to operate. This is in particular important, because even if technical solutions for the „door to door“ travelling exist, the realisation of a high number of PAVs operating in an urban environment strongly depends on the legal framework. Besides, many other issues such as acceptance by society, noise disturbance, environmental issues, etc., the design of the legal framework also co-determine how high the access barriers for the users will be.

An overview of different PAV concepts worked on today, their specifications, development stage, prices, and target groups aimed for follows below (see Table 1.1.).

[37] Borzykowski, (2010)

[38] Borzykowski, (2010)

[39] Pilot, (2003)

[40] Vance, (2010)

Table 1.1: Overview of some PAV concepts worked on today worldwidely in the order of decreasing achievement of completion

Name	Configuration: seats |VTOL or STOL |driving on ground ability	Technology type	Certification	Development stage	Target group & price
Calidus - AutoGyro[41]	2 tandem configuration SSTOL: 80-120 taxi-mode around 15 km/h possible	Gyrocopter with closed canopy	UL (Germany)	Fully developed since 2009	Mainly recreational flying Price: €60,000 to 70,000
Maverick [42]	2 - 4 SSTOL: 91.4 m yes	Powered-parachute aircraft with road driving ability (even off road). Lift generated by a parachute, thrust by a propeller	S-LSA, licenced as kit-car for road use in the US	Fully developed, in sale since summer 2011	Commercial target group: search & rescue, fire spotting, supply and healthcare, access to remote areas (e.g. for farmers) non-commercial target group: Indigenous people in remote areas like the Amazon Price: ~ €58,000
KISS 209 [43]	1 + 1	Helicopter with gas turbine engine;	UL-Helicopter (Italy)	Fully developed, in sale in Italy	Price: ~ €140,000

[41] AutoGyro, (2011b)

[42] LSA, (2011); Gaubatz, (2011)

[43] Skamljic, (2011)

(= Keep it stupidly simple)	VTOL no	special feature: retractable landing gear and assisted pre-check due to "e-brain"			
ICON A5 [44]	2 side-by-side STOL: ~228 m no	Amphibious design, folding wings (manually or automatically) seaplane, retractable landing gear	S-LSA	First prototype flight 2008, expected delivery 2013	Sport, fun & recreation Price: ~ €96,000
Martin Jetpack[45]	VTOL 1 no	A jetpack consisting of a gasoline engine propelling two ducted fans	UL vehicle class [46]	Prototype stage but first sales are expected to start in 2012	Focus on recreational customer but also on military applications (for this a UAV jetpack version is developed also) price for the non-military version: USD100,000
Transition (by Terrafugia)[47]	2 side-by-side STOL: 518 m over 15 m obstacles yes	Dual mode road able Light Sport Aircraft	Special Light Sport Aircraft (S-LSA) cleared for road use by the US National Highway Traffic Safety Administration in June	Proof of concept vehicle completed 2009; first delivery scheduled for 2012	Focus on pilots Price: ~ €192,000

[44]Icon Aircraft, (N.N.); Gaubatz, (2011)Gaubatz, (2011)

[45] N.N., (2011b)

[46] defined as a vehicle for one person max., used for recreation or sport purposes only, with not more than 254 pounds empty weight and a fuel capacity of not more than 5 U.S. gallons as well as restricted power-off stall- and full power in flight speed (Regulation, (1982))

[47] Terrafugia, (2010); NHTSA, (2011)

			2011		
carplane [48]	1+1 (in separate cabins) SSTOL: 85 m yes	Dual mode vehicle with twin shaped hulls and swing wings stored between the hulls in road mode; road mode electric; air mode uses combustion engine	Aimed for LSA	2015	Recreation, business travel and emergency service Price: ~ €200,000 at the beginning[49]
skywalker [50]	2 side-by-side VTOL no	Semi-enclosed counter rotating, dual shaft propeller design	Probably as an Experimental Light Sport Aircraft (E-LSA)	Early: computer design and model stage	Commuter & recreation Price: €95,000 to 110,000

[48] German Center for Research and Innovation, (2011)

[49] dpa, (2011, German Center for Research and Innovation, (2011)

[50] Mirror Image Aerospace, (2009)

Figure 1.9: The skywalker VTOL aircraft by Mirror Image Aerospace

Source: Mirror Image Aerospace, (2009)

Figure 1.10: The Calidus from AutoGyro

Source: AutoGyro, (2011a)

Whereas, some of the future designs see their target groups in special operations like policing, rescuing, emergency and military applications (e.g. Maverick, UAV version Martin Jetpack), others specifically address the commuter (e.g. skywalker see Figure 1.9) and promise door-to-door mobility

> *"Whether it`s finding a new route to work on your morning commute… Or picking up some groceries for an afternoon snack on your yachtthe Skywalker will provide a whole new perspective in your daily transportation!"*[51] *Mirror Image Aerospace, (2009)*

Other concepts like the ICON A5[52] go for the wealthy recreational customer who wants to have fun and adventure and the ability to access also remote spots for weekend escapes.

One main difference between the presented concepts is the distances they need to cover to get airborne. Some vehicles have the ability of vertical take-off, and, although all vehicles need a certain space cleared from obstacles for their take-off, these vehicles have less space restrictions than the SSTOL and the STOL concepts.

In contrast to the skywalker, ICON A5, KISS 209 and Martin Jetpack, the Terrafugia Transition, the Maverick, and also the Carplane concept have an additional ability of driving on the ground; they are dual mode PAVs. Because of this, they have the possibility to cope with bad weather situations in the air by just using the streets instead. Bad weather which prevents flight realisation is seen as one major problem for recreational pilots.[53] The Calidus (see Figure 1.10) lies a bit in between a single- and a dual mode vehicle; it is able to manoeuvre on the ground at low speeds but it is not thought to be driven on streets.

[51] Mirror Image Aerospace, (2009)

[52] Icon Aircraft)

[53] Wax, (2010)

Figure 1.11: The "Maverick Sport" in car- and air mode (with open parachute)

Source: Maverick, (2010)

The Maverick (see Figure 1.11) is a bit different from the other concepts in term of its target group which are, first of all, people in remote often low developed areas with no proper street network. Therefore, the vehicle is designed as a kind of off-road vehicle with the ability to take off the ground and to fly where it is not possible to continue travelling on the ground. It comes for a quite low price and was only the second vehicle ever to get a legal declaration for the street and the air in the US.[54]

As you can already see in the table column "certification", a variety of different certification categories exists to which the different concepts are assigned to. At the lower end is the Ultra Light category which the Martin Jetpack is aiming for; other concepts are assigned to the Special Light Sport or Experimental Light Sport Aircraft category. The different certification classes differ regarding the weight (maximum take off mass) the vehicles are allowed to have and on other performance parameters such as speed, seating capacity, type of engine, etc. (details on the different certification categories for aircrafts can be found in chapter 3 Table 3.3). But not only has the vehicle itself other abilities and dimensions. The certification category also has implications on the question of how much pilot training is required and where (airspace segment) and when (only daylight, weather conditions) it is allowed to fly the vehicle. Additionally, it is to be taken into account that the aircraft certification categories and the pilot licences differ at the national level in Europe.

To sum up, it should be noted that the presented PAV examples are in quite different development stages with some of them already being sold, others existing as prototypes or being early computer models. In general, concepts which need a significant runway length such as the Terrafugia concept with over 500 m are not considered to be suitable for the commuter user scenario of myCopter. Other concepts such as the KISS 209 helicopter with its VTOL ability, which already offers a kind of assisted pre-check of the vehicle, comes closer to the easy handling envisioned in myCopter. Nevertheless, it should be noted that right now none of the already produced PAVs from Table 1.1 are so automated that it would be possible for a user with an average car driver training level to handle these vehicles. Further issues are the high purchase and maintenance costs in contrast to average cars as well as open questions regarding the supporting infrastructure on the ground, the air traffic management, and the legal background for such a personal air transportation system. These

[54] Ward, (2010)

issues will be discussed more in detail in the later chapters, see for example chapter 3.4.1 about the costs, chapter 3.3.3-3.3.5 and 3.3.2 for infrastructure and ATM issues or chapter 3.2. for legal aspects.

1.4 PAV Related Research

The following subchapter summarises some related research activities at the US- (chapter 1.4.1) and the EU level (chapter 1.4.3) regarding personal air transportation in a broader sense[55]. In general, there are two big players who have done extensive research on personal air transportation systems and personal air vehicles. These are the National Aeronautics and Space Administration (NASA) in the US and the European Union in the form of their Framework Programmes for Research and Technological Development. For clarity reasons, for every initiative and project the main research areas are assigned to and indicated behind the caption.

1.4.1 US Level (NASA) [Vehicle and Infrastructure]

NASAs research in the field of personalised air travel is conducted through the Small Aircraft Transportation System (SATS) programme[56]. The research regarding the Personal Air Vehicles is done separately in the Personal Air Vehicle Exploration Programme called PAVE.

The SATS programme is guided by a long-term vision of small, advanced fixed-wing aircrafts (4 to 10 passengers) which are used for personal air transportation between small airports as a matter of routine and in high numbers.[57] The five-year programme has focused on:[58]

- More extensive use of airports lacking instrument landing systems and other navigation systems as well as increased safety of operation at these airports
- Lower landing requirements at minimally equipped landing facilities
- Improved safety and mission reliability for single-piloted aircrafts

One argument for the programme was the free capacity of hundreds of small airports in the US which could be used to transport people in and away from rural areas and isolated communities. A review of the project by a committee of experts assembled by the US Transportation Research Board questioned the ability of the SATS to satisfy the travel demand or even of its likeliness to emerge at all. The committee did not share the vision and questioned the affordability of such advanced aircrafts for a broader range of public. They saw a limited potential of meeting the geographical travel demands (high demands in the metropolitan areas, whereas, SATS focuses on the non-metropolitan areas), obstacles regarding the suitability of the existent small airports in terms of noise, regulatory and emissions issues, of handling the infrastructure investment challenges, as well as of receiving acceptance.[59].

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[55] not only small PAVs of up to 4 passengers but also mid-sized jets of up to 20 passengers are addressed in some of the presented projects in this chapter

[56] Moore, (2006)

[57] Transportation Research Board, (2002)

[58] Transportation Research Board, (2002)

[59] Transportation Research Board, (2002)

1.4.2 NASA Personal Air Vehicle Exploration Programme [Vehicle]

While the SATS programme has some research questions in common with the myCopter project (improved safety, less requirements for ground facilities), it is dealing with bigger air vehicles with no VTOL ability. The smaller PAVs are covered in the PAVE project. Generally, NASA sees here several steps to be taken on the way to a true VTOL PAV (see Figure 1.12). Their “transition path” starts with the current commercial airliners system and goes over to air-taxi services, which are already in place but normally flown by 1-2 pilots which makes them hardly economically feasible for the average commuter. In a next step they expect a so called “Gridlock Commuter” (see Figure 1.14) and, with it, finally, personal air vehicles with VTOL ability to be in place. Interestingly, NASA envisions for its Gridlock Commuter vehicle a compromise between a true dual mode PAV and a single mode type of. In order to not to have to fulfil all regulations and safety standards for the street modus they aim for a simplification with only driving in, what they call, a “taxi-mode” on side-streets for a limited distance.[60] The Gridlock Commuter shall have a STOL capability of around 250 feet (~ 76 m) and would, therefore, still need some sort of runway.

For the rural segment of the PAVE project the design of a Next Generation General Aviation Aircraft is envisioned, which should be as comfortable, safe, and affordable as a car and provide on-demand travel solutions for people in rural areas. One example for this New Generation GA aircrafts is the TailFan (see Figure 1.13). It is a ducted fan aircraft for low noise emissions with foldable wings and a CTOL ability of around 2,500 ft.[61]

For the TailFan NASA addresses the topic of navigation with a so called “horselike” approach.[62] The horse metaphor is used to describe the abilities of the vehicle itself (in terms of intelligence, situation awareness, autonomy…) and the relationship between the vehicle and the operator.[63] The metaphor is commonly used to stress the behaviour and abilities that are desired for automated future vehicles. For example like a “horse” the vehicle shall avoid other objects and know how to find its way home. For TailFan this means the building of a navigation system “smart enough to know where to fly but allowing human aviators enough control to intervene in case of an emergency”.[64] Therefore, the TailFan concept is a mixture between flying completely without a user’s input and conventional piloting.

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[60] NASA, (N.N.)

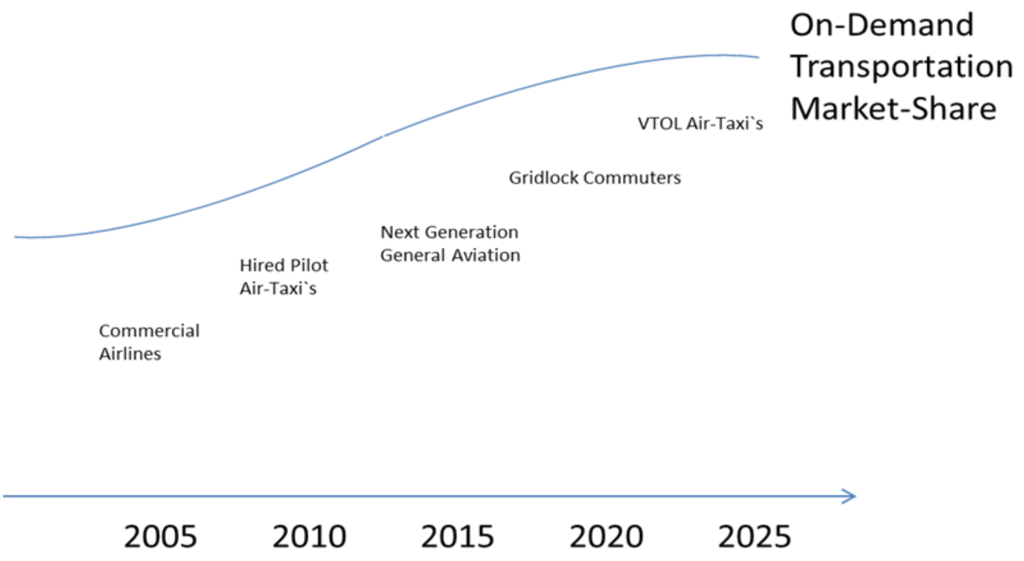
[61] Pilot, (2003)

[62] Malik, (2004)

[63] Schutte et al., (2007)

[64] Hahn, (2006)

Figure 1.12: Part of a NASA diagram about the development of new mobility choices



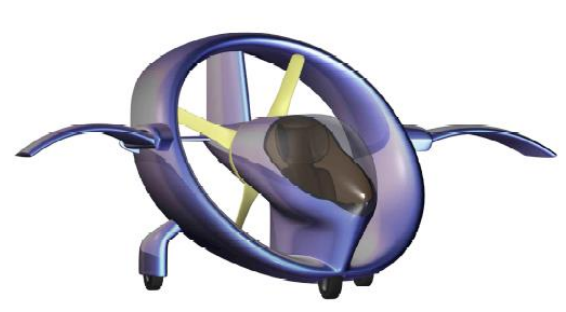
Source: replica from a graph by Moore, (2006)

Generally, NASA sees PAVs as a solution for trip distances from around 50 to 500 miles (or 80 to 800 km).[65]. Accordingly, their vehicles are meant to cover a broader distance range and greater distances than it is envisioned for the myCopter mission with distances of 0 to 50 km (see chapter 2 for details).

Figure 1.13: Picture of a "TailFan" vehicle with folding wings and tail, concept by NASA

Source: Malik, (2004)

Figure 1.14: The Gridlock Commuter vehicle concept by NASA with a spiralduct arrangement and foldable wings



Source: NASA, (N.N.)

1.4.2.1 Next Generation Air Transportation System [ATM & Infrastructure]

One major undertaking which will have a significant impact on the national air transportation system of the United States is the NextGen programme. This long term programme aims at transforming the national air transportation system of the United States, mainly the aging

[65] Moore, (2006)

ground-based air traffic control system, into a satellite-based system to tackle the future demands of the American air traffic.[66] The system changes shall reduce congestions and improve the passenger satisfaction.

The programme consists of five main elements:

- The full implementation of ADS-B across the national airspace to assist air traffic controllers and pilots with accurate information for separation in the air and on the ground
- The System Wide Information Management, SWIM, a standardised single infrastructure and information management system that provides high quality and in-time data to all users and applications. The aim is to reduce the number of different interface types and systems, to avoid data redundancy, and to assist the sharing of multi-user information
- Next Generation Data Communications means the conversion from the old voice communication system used by air traffic controllers and pilots to a data communication system where pieces of information are exchanged via data link
- The Next Generation Network Enabled Weather, a new national weather information system based on global weather observations and sensors which is updated in real time. The goal is to allow for better decision making for the air transportation sector and to reduce weather attributed weather delays
- The NAS voice switch is the replacement for many different currently used voice switching systems by one single air / ground to ground / ground voice communication system

1.4.3 EU Level

In the following part, research projects at the European level that address the topic of personal air transportation are introduced.

1.4.3.1 Single European Sky and SESAR [ATM]

Single European Sky is a response of the European Commission to coping with the ongoing and expected growth in air travel.[67] The finding that the airspace could not be organised following national borders but traffic flows instead led to a call for common rules and procedures at the European level and the “Single European Sky” initiative was created to meet this need in 1999.[68]

While the SES is mainly acting in the area of legislation, the supporting Single European Sky ATM Research (SESAR) programme is responsible for the technologies and procedures needed to modernise and optimise the future European ATM.[69] SESAR is an initiative by the European Commission that started in 2004 and that has the aim to restructure the air traffic management system in Europe.[70] It should be noted that SESAR is not a single project but

[66] Federal Aviation Administration, (2007b)

[67] Eurocontrol, (2010)

[68] Eurocontrol, (2010)

[69] Eurocontrol, (2010)

[70] SESAR Joint Undertaking, (2010a)

consists of more than 300 projects involving all the players such as the airliner and the aviation industry. The undertaking consists of three main phases:[71]

- A Definition Phase (2004-2008) led by Eurocontrol that has delivered a master plan for the development and deployment of the next generation ATM system
- A subsequent Development Phase (2008-2013) responsible for the future technological systems, components, and operational procedures
- And, lately, a Deployment Phase (2014-2020) in which the new air traffic management infrastructure shall be produced and implemented at large scale

At the core of SESAR is the new concept of operations, the so called four-dimensional (4D) trajectory also known as "business trajectory".[72]

It works on the principle that the airspace user, the air navigation service provider, and the airport operator agree on a common trajectory for the flight which is defined according to its three spatial dimensions and time. By this, trajectory constraints of the airspace and of the airport capacities are included. Once the trajectory is accepted, it becomes the reference for the airspace user who has to follow it; and also the service provider who shall facilitate the user in doing so. Real time information sharing between all stakeholders is foreseen for all phases of the flight including ground operations.[73] An individual project called 4D Contract Guidance and Control Project is dedicated to clarify questions around the 4D business trajectory and to path the way for its implementation.[74]

Although SESAR will have a major influence on the European airspace architecture, the operational procedures and technical components in the air and on the ground focus clearly on the commercial aviation sector and on flights in controlled airspace. It remains to be seen how many of the new procedures and technologies will be adopted by the general aviation sector for flights in unmanaged airspace.

1.4.3.2 FLYSAFE [Cockpit Display, Safety, Information Management]

FLYSAFE was a major project with more than 35 partners from 14 countries and alone 29 million euro of EC funding and part of the 6th Framework Programme.[75] Its aim was to define and test tools and systems which would contribute to flight safety. In particular the threat of collision with other aircraft, collision with terrain or obstacles, and adverse atmospheric conditions, as major threats responsible for accidents in aviation, were studied.

The two main outcomes of the project are an Integrated Surveillance System (NG ISS) and a Weather Information Management System (WIMS).

The aim of WIMS is to improve the accuracy of weather warnings provided for aircrafts in flight by making warnings more specific in terms of airspace and time periods by up-linking of

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[71] SESAR Joint Undertaking, (2010a)

[72] SESAR Joint Undertaking, (2010b)

[73] SESAR Joint Undertaking, (2010b)

[74] N.N., (2011a)

[75] N.N., (2009a)

dedicated products to individual aircrafts. A second key for improving weather hazard warnings is the development of specialised tools for generating weather forecasts by using on-board weather sensors for the short term range forecast.[76]

The Next Generation Integrated Surveillance System (NG ISS) is a tool to collect and manage all the information about potential flight hazards (regarding terrain, traffic, and atmosphere) on-board for the pilots. The system is responsible for a coherent display presentation of all these pieces of information and supports the crew by aircraft management, in this way.[77]

Just like SESAR, FLYSAFE primarily addresses the commercial air transport sector, but states on its homepage that it will also look at the adaption potential of project results to other fields like business jets and helicopters.[78]

1.4.3.3 European Personal Air Transportation System (EPTAS) Project

The EPATS is a project funded by the European Commission under the Sixth Framework Programme which focuses on a new air transport system with small, smart aircrafts able to operate under all-weather condition. It is mainly intended to serve destinations with an underdeveloped transport network where other fast modes of transportation are not viable due to a low flow of passengers.[79] The system shall fill a niche between today's surface- and the hub and spoke air transportation system[80] (see Figure 1.15**Error! Not a valid bookmark self-reference.**) and offer a new, fast transportation mode for long distance trips at affordable costs.

The project is looking at technologies required for this kind of system, at its market potential up to the year 2020, and at the potential impacts on ATM and airport infrastructure in Europe, as well as on environmental, safety and security issues.[81]

In contrast to myCopter, EPTAS addresses only long distance passenger trips with travel distances starting from 100 km up to 1,000 km[82] and can be described as an air taxi service for small communities which are otherwise poorly connected. The project wants to use smaller airports which still have free capacities at present.[83] The aircrafts under consideration have no VTOL capability, are operated by one pilot, and have a seating capacity from 3 to 19

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[76] FLYSAFE, (2005-2009)

[77] FLYSAFE, (2005-2009)

[78] FLYSAFE, (2005-2009)

[79] Baron et al., (2010)

[80]Laplace et al., (2008)

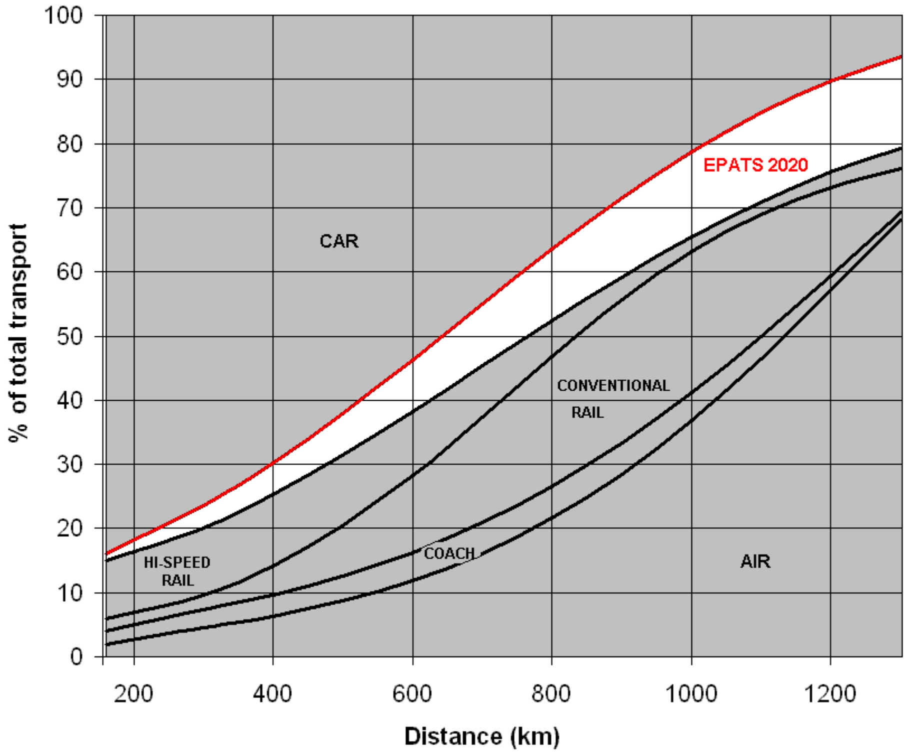
[81] Baron, (2007)

[82] Laplace et al., (2008)

[83] van Schaik et al., (2007)

passengers[84], which is far beyond the seating capacity of the myCopter project. Nevertheless, the project also aims for all weather operability which raises similar questions in terms of sensor technology and air traffic management.

Figure 1.15: EPATS vision for the modal split of interregional trips in Europe for 2020



Source: Baron and Piwek, (2008), p.60

Some smaller projects addressing more specific areas of research such as all weather operations, cockpit design, automation, legislation, etc., at the European level will now be presented and related to the research issues of myCopter.

1.4.3.4 ALICIA[85] [Cockpit Architecture, Procedures, Regulations, ATM]

The first project to be presented is ALICIA (= All Conditions Operations and Innovative Cockpit Infrastructure) which started in 2009 and is an FP7 Framework Programme project. To improve time efficiency, this project aims at developing a new cockpit architecture which permits operability of an aircraft in almost any degraded weather conditions, allowing aircrafts to fly closer together at a lower risk and to reduce air transport delays. This new flight decks shall provide a better standardisation among different aircraft types, shall allow a better use of new products, and shall reduce time to market.[86]

The project differentiates between mission requirements of fixed wing and rotary wing aircrafts, looks into ATM interaction, and also examines operations in unmanaged airspace

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[84] Baron et al., (2010)

[85] Vial et al., (2010)

[86] Vial et al., (2010)

from a technological and regulatory perspective. This last topic is highly relevant for myCopter because operations in unmanaged airspace are often not covered in much detail in other bigger projects / programmes, such as SESAR which have other foci.

1.4.3.5 sFly [Navigation & Automation]

The project sFly (2009-2011) is an FP7 project and is looking at very small and light helicopters (< 500 g) which can operate autonomously in city-like environments (inside and outside).[87] These helicopters can be used for search and rescue tasks, environmental monitoring, security surveillance tasks, inspections, etc.[88]. As GPS has problems in very dense environments and is shadowed by buildings, etc., it is not a viable solution for the helicopters in sFly. The project is therefore looking into complete vision-based and fully autonomous navigation and also includes work on coordinated swarm flying of these vehicles in dense environments.[89]

Although, the helicopters dealt with in sFly are much smaller and unmanned, the environment in which they operate (close to buildings or even in buildings) and the high level of automation aimed for are comparable. sFly is led by the Autonomous Systems Lab of the Swiss Federal Institute of Technology Zurich which is also involved in myCopter and here responsible for the work package about control and navigation of a single PAV.

1.4.3.6 SAFAR [Avionics Architecture; Navigation]

The Small Aircraft Future Avionics Architecture is a FP7 three year project that has started in 2008.[90] Like myCopter SAFAR also addresses the individual transport sector and calls for a broader range of options next to the road traffic and a broader range of products besides the road traffic.[91]

In contrast to other projects like FLYSAFE, SAFAR is looking at the whole avionics architecture for small aircrafts that shall provide point-to-point on demand traffic. The goals are to improve the handling qualities and the safety of the aircrafts and, at the same time, to make the aircrafts less cost intensive. SAFAR tackles the Low Capacity Air Transport Sector with aircrafts belonging to the CS-23 category for commuter aeroplanes with up to 20 seats and a MTOW of around 8600 kg.[92] The project aims at reducing the pilot workload significantly by providing continuous flight envelope protection and by improving the handling characteristics of the aircraft. The project aims at different modes of automation (manual control, control via flight guidance and control via flight management). In the long term, automatic 4-D flight vectoring via on-board ATM/FM is aimed for, and, as a pre-step, 4-D flight vectoring provided by ATC via ADS-B is foreseen.[93]

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[87] N.N., (2010)

[88] N.N., (2010, Cristofaro and Martinelli, (2011)

[89] N.N., (2010)

[90] European Commission, (2011c)

[91] European Commission, (2011b)

[92] EASA, (2003)

[93] N.N., (2011d)

In all projects introduced until then the size of the vehicles envisioned is very different from myCopter, with the vehicles being either much smaller (sFly) or much bigger as in the FLYSAFE, EPTAS, or SAFAR project. The issues of different level of automation, the visualisation of these different modes, and the goal of a reduced pilot workload are similar tasks to be studied though in SAFAR.

1.4.3.7 PPLane

The PPlane project is another FP7 project addressing directly the Out of the Box idea of a personal air transportation system. The project started in October 2009 and has a duration of 30 months. Unlike myCopter, PPlane is looking at aircrafts from 4 of up to 8 passengers[94], and investigates several potential PATS concepts with different levels of automation and of required pilot training.[95]. As the project website states, a selection process shall follow to find out about the most promising air transportation systems and to elaborate them further by also including technological and societal aspects. In a last phase, scenarios for verification and recommendations are intended. The focus points of the project seem to be safety and security aspects, automation and control, human factors, and environment, but they also state to be looking into economic and social factors as well as into regulation issues.[96]

As part of this selection process, a Delphi Survey was conducted which collected the views of more than 150 experts (mainly from the field of aeronautics) regarding customer preferences in the field of future personal air transportation.[97]

1.4.3.8 INNOVATIVE FUTURE AIR TRANSPORT SYSTEM [ATM, Automation, Navigation]

The Innovative Future Air Transport System (IFATS) was a FP 6 project with the objective to take the automation of the air traffic system as far as possible, following the assumption that human errors are a main cause of accidents in aviation.[98] The aim of the project was to define a “technically viable concept of a highly automated Air Transport System”[99] by adding as much automation to the aircraft and to the ground control as possible, leading to a situation where aircrafts would operate autonomously and fly pre-programmed flight plans monitored by an automatic control which is again supervised by ground operators.[100]

The tasks of current pilots and controllers were strongly modified in this project with the aim to lower the risk of human errors and terrorist threats.[101]The two tasks of piloting and managing aircrafts have been merged in IFATS into a single one which is performed on the

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[94] Warwick, (2010)

[95] Anon., (2009)

[96] Anon., (2009)

[97] Roudstein, (2010)

[98] Le Tallec and Joulia, (2005)

[99] Le Tallec and Joulia, (2005), p.1

[100] Transport Research Knowledge Centre, (2009)

[101] Transport Research Knowledge Centre, (2009)

ground. Next to the definition of a highly autonomous ATS concept the following goals were pursued in the project:[102]

- Determination of minimum requirements and functionalities of the onboard system to ensure safe operation in the case of communication loss with the ground control system
- Performance of a safety analysis of the IFATS concepts and provision of guidelines regarding certification issues
- Identification of issues (technical and cultural ones) which need to be solved in order to build such an air transport system
- Identification of an adequate level of automation for this future system
- Analysis of how the transformation from the present to the future system could look like

Although the project is, first of all, looking at the commercial aviation sector and, therefore, dealing with other aircraft sizes, the question of what level of automation is needed to get an acceptable level of safety for such a future air transport system is also one of myCopter's key problems. Also the concept of removing the pilots from the aircraft and to place human beings only on ground stations where they have the task of managing all aircrafts in flight via secured data links is an interesting option for myCopter in the case of which also a very high level of automation is considered. Additionally, different system architectures for the management of PAVs in the lower airspace are imaginable.

1.4.3.9 CREATE [Innovation]

The project "Creating innovative air transport technologies for Europe is a successor activity of the Out of the Box project to which myCopter is related. Similar to Out of the Box, the Create project is concerned with innovation in aviation. The project is looking at the process to find new ideas and develop them further up to the step where these ideas find their way into actual research.[103] Within the project a creative workshop was conducted to generate innovative ideas. It is interesting that quite a few of these ideas relate to the vision of and to the issues which are addressed in myCopter (see Figure 1.16 and Figure 1.1.7). One idea was the use of advanced VTOL/STOL airliners starting and landing from VTOL/STOL airports located near city centres. Others relate to the noise issue by suggesting hovering airports to avoid ground noise or the surrounding of VTOL airports with a funnel shaped high walled structure which acts as a sound screen and separates nearby residents from the noise.[104] Also a special skin made up of photo-electric cells for aircrafts was discussed which would make the aircrafts "invisible", and this is an issue which is also touched upon in myCopter where flying of PAVs in groups is discussed among other things in order to minimise their impact on urban areas in terms of noise and clear skies. Different ideas regarding small and personal aircrafts were discussed both for efficient low and slow travel. The same ideas were also discussed for high speed personal aircrafts with a propeller system aiming at a silent take-off and a switch, later on, to another engine for the cruise. As it is also the conception of myCopter, the Final Report of Create states that, in the past, little

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[102] Transport Research Knowledge Centre, (2009)

[103] Muller et al., (2010)

[104] Muller et al., (2010)

consideration was given to other challenges surrounding personal air transportation such as ATC, flying competences, auto-controls and collision avoidance.[105]

Figure 1.16: Artist`s impression of a VTOL aircraft in an urban environment used for door-to-door transportation; produced in the context of the Create project

Source: Muller et al., (2010), p.64

Figure 1.17: Artist`s impression of a future flying car providing personal transportation in the air and on the ground; produced in the context of the Create project

Source: Muller et al., (2010) p. 81

[105] Muller et al., (2010)

2 Chapter: What is the PATS Vision of myCopter? – Scenarios, Reference PAV and User Types

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 which 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.

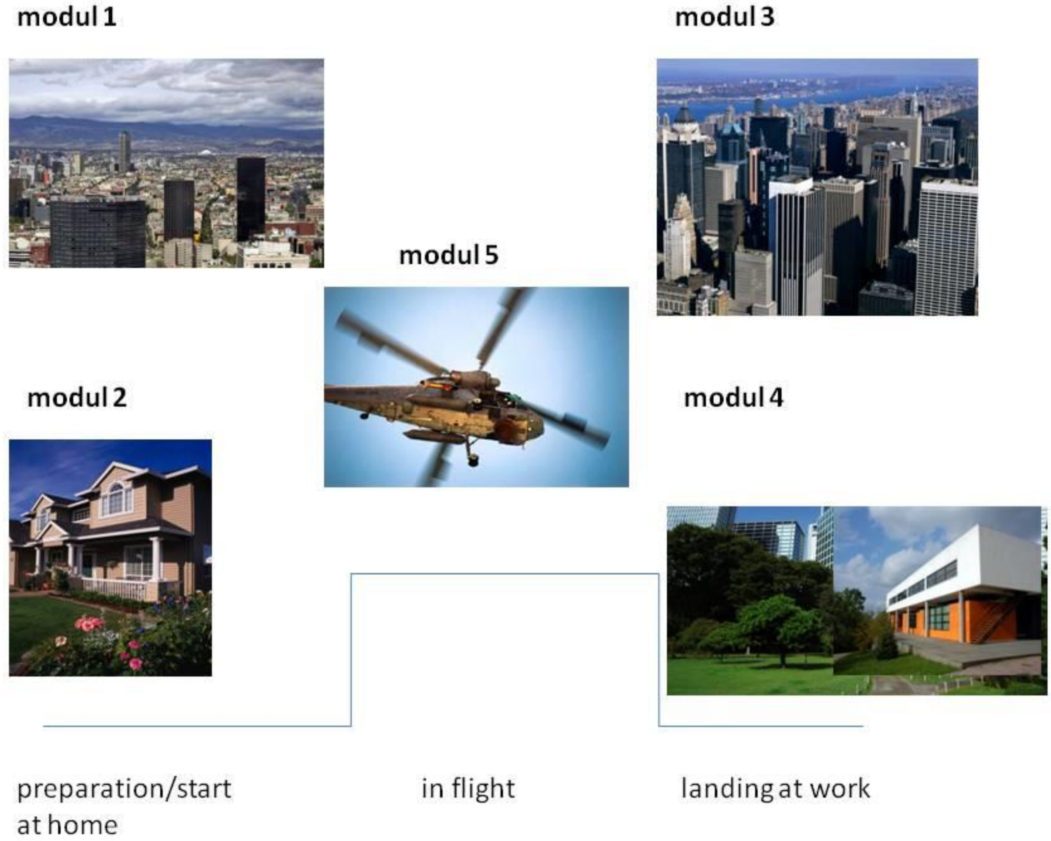
This means that, regarding the design of a PATS, internal dependencies of “performance requirements” of the PAV exist and further on a dependency of the PAV requirements on the system and the desired mission, which the single vehicle shall allow for are given.

In order to position the project in the area of ongoing and past research in the field of personal air transportation and to establish a common discussion basis for the project, the idea of a personal air vehicle has to be defined further. This allows 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.

To do this WP7 has started with the development of a reference case for the vehicle. For this purpose potential application examples, in the following called “travel scenarios”, were developed. 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 vehicle system. 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		Destination
dense		dense
sparse		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.



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, the joining of other PAVs to form swarms. Alternatively, the user could be in the loop and could control the PAV, however, 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 out the user 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 a well-equipped landing site 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, formal things 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.

2.1 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.

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 discussed by all project partners during an internal workshop in May 2010. For the further work in the project a “Reference PAV” was envisioned and abilities of this PAV were discussed. Below you find a table with the specification characteristic and requirements of the Reference PAV which the consortium agreed on.

Table 2.1: Initial PAV specifications of the “Reference PAV” in myCopter as defined at the internal workshop (May 2010)

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	
maneuverability on ground	yes, but only for short distances, not on the street
ability to come autonomously to the user	included in the “full level of automation”
VTOL /SVTOL	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, not into clouds, probably
av. cruising altitude	< 500 m above ground level
total range	100 km
cruising speed	150 - 200 km/h
max. speed [km/h]	
climb rate at MTOW [m/s]	
level of automation	different levels (including “full”)

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.[106]

With regard 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 readable. 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 2.1 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.

[106] European Union, (2008)

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. Therefore, the consortium has set the 90 % usability benchmark, a figure which, probably, is 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 if new findings will occur. 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.

For the WP7 and this screening report, though, the Reference PAV and the travel scenarios will be the background for considerations during the scoping process.

2.2 User Types

In the performance requirements section as well as in the travel scenarios, assumptions about the user who is envisioned to fly with this kind of PAV are shining through. As the aim of myCopter is to make a PAV functional for a broader public, the skills required to use them should be minimal and comparable to the effort necessary to obtain a drivers licence, today. That a system thought to be used by the general public cannot be designed for the same training level as the one today's private pilots have, is supported by the fact that only a very low fraction of the population (below 1 %, see chapter 1 for details) accepts the time and monetary effort to obtain and maintain a private pilot licence. Therefore, the approach of myCopter is to lower the amount of knowledge and of training required for using the PAV to a minimum and to design the handling characteristics of the vehicle more intuitively.

The level of authority of the PAV in myCopter is thought to be variable and shared between the user and the machine itself.[107] Also the level of autonomy could be quite different with one extreme being the situation that the "machine" does everything autonomously and only informs the user about what is going on or a system with a reduced level of autonomy where some tasks still have to be performed by the user.

Although both options are thinkable, myCopter clearly goes into the direction of a system where a lot of the authority is handed over to the machine and the level of autonomy is quite high. Nevertheless, there will be some training left to be taught to new users on how to handle the PAV (see workpackage 2 of this project for details about training requirements).The type of user envisioned (ordinary person with no flying skills up to a user type holding the private pilot licence) also bears consequences for the design of the Human

[107] Jump et al., (2011)

Machine Interface with the purpose of controlling the PAV (see work package 3 of myCopter for details).

This screening report takes both approaches (full autonomy vs. “reduced level of autonomy”) into consideration but, with many PAVs operating in a densely populated environment, sees the full autonomy as the ultimate goal for the commuter context mission of myCopter. This scenario with a full autonomous PAV could also be described as an Unmanned Aerial Vehicle (UAV) with human payload.

3 Chapter: How Could a PATS Become Reality? - A look into the Key Issues for Implementation

Whenever the idea of personal air vehicles or flying cars is presented and discussed, many questions regarding not only the technical feasibility of such vehicles but especially concerns about safety (collision avoidance, controlled flight into terrain, terrorist threats, etc.) are expressed. Further questions arise on how a design of Air Traffic Management for them could look like and on where the aircrafts would be allowed to fly and at what times. Other major challenges seem to be the topics of certification and regulation and the question of how to integrate the PAVs into the existing ground transportation but also into the existing air transportation system.[108] In the field of environmental issues the uncertainty about energy consumption and emissions is noticeable; especially the issue of noise disturbance seems to be a key one that comes up whenever people are confronted with the idea of PAVs flying around in higher counts in a city environment.

In contrast to other projects dealing with the design and actual construction of PAVs myCopter takes a different starting point and focuses on these related issues believing that they need to be addressed in order to see a future implementation of a Personal Air Transport System.

The goal of this report is, first of all, to detect the most important issues which surround a successful and easy implementation of PAVs. Therefore, this chapter gives an overview of the issues that were identified and tries to picture their relevance and "problem potential". Because of the number of issues found and the early stage of the project not all of them will be described in detail at this stage. A focus was set on weather safety and on noise. A deeper assessment, especially of the operational and technical challenges, will be part of Task 7.2. of this work package.

3.1 Safety

One major issue that is often dominating the discussions and comes first is the safety issue. It is fed by numerous news referring to helicopter accidents or gyrocopter crashes worldwide and their frightening pictures.[109] In contrast to other modes of ground transportation where an engine failure or fuel shortage often leads to minor incidents this is rarely true for aviation. The fact that air vehicles cannot just stop on the next emergency lane if a technical problem occurs, as there are hundreds or thousands of meters between them and the ground, makes safety a very sensitive topic. This is also confirmed by the results of the PPlane Delphi Study were asked to assess the importance (from 1 least important to 5 most important) of potential attributes of a future PATS 128 from 141 responses assigned "safety during flight" with the highest importance value of 5.[110]

The safety issue is complex and has many faces; there can be internal and external safety hazards. With internal safety hazards the PAV itself (mechanical failures, e.g.) and its control

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[108] Muller et al., (2010)

[109] see some examples: Gyrocopter crash in New Zealand Fairfax, (2011); 16 people killed in North Sea helicopter crash N.N., (2011c)

[110] Roudstein, (2010)

system (including on board sensor systems, etc.) are addressed, whereas, the control unit could be a human with its associated human errors (tiredness, non-attention, misinterpretation etc.) or a technical system. External hazards relate to weather conditions, collisions with other objects in the air (bird strikes, air vehicles) or with ground objects.

3.1.1 Weather

Although aircrafts flying under IFR have a clearly lower dependency on weather conditions, they still are affected by snow events, freezing rain or other hazards, and airport closures. Delays in connection with unfavourable weather do even occur in the commercial IFR sector. For smaller air and rotorcrafts with a lower level of instrument equipment even greater restrictions in terms of weather can be expected. This subchapter aims at investigating how tricky it might be to realise the high requirements on the “usability over the year” of 90% for our Reference PAV.

This requirement of 90% seems to be at the lower end of what could be accepted and competitive against a car. Asked for the “acceptable flight cancellation ratio” of flights due to traffic or weather reasons the PPlane Survey got a “desired cancellation ratio” of 1 in 298 flights and a higher “tolerable cancellation ratio” of 1 in 50 in average which would translate to a usability over the year of 99,7% respectively 98%.[111]

As a first step, potentially limiting weather phenomena and the amplitude at which they must occur to prevent a safe PAV flight were collected. Although the propulsion system for the Reference PAV is not fixed, the fact that it will have VTOL abilities and be a quite light weight vehicle gives some clues about where to look for orientation regarding reasonable “no-fly criteria” (e.g. current rotorcraft directives).

Weather phenomena which are addressed in such directives are, for example, surface winds (including gusts) or turbulences and “no-fly” limits for small piston engine rotorcrafts like the Robinson R22 and R44 can be found in the Special Airworthiness Information by the FAA.[112]

Another criteria which is seen as critical for a safe flight performance is the absence of de-icing conditions, respectively, the forming of ice on the vehicle outside (airframe icing) or build-up of ice in the induction system that has to be considered.[113]

Currently, many aircrafts are not approved for flight in known icing (FIKI) conditions according to the FAA.[114] This means that pilots should not fly in areas where visible moisture (fog, rain or clouds) exists and the temperature is below 5°C.

To expand operability a number of de-icing and anti-icing devices are on the market that are also beneficial in a number of other conditions such as sand, dust, salt, snow, and heavy rain conditions and also helpful against brownout and Foreign Object Damage (FOD).[115] As icing is not only a topic on cold and wet days but might also occur on warmer days with a high

[111] Roudstein, (2010)

[112] FAA, (1995)

[113] QBE Aviation, (2011)

[114] FAA Aviation Safety, (2010)

[115] Pall Corporation, (2010)

humidity[116] it is seen as an import issue to be addressed regarding the Reference PAV in order to attain a good usability over the year performance.

The icing issue seems to be quite difficult to cope with; even aircrafts with an approval to fly into known icing conditions are not advised by the FAA to really do this.[117]

For the Reference PAV, the discussion resulted in the decision that the PAV should be able to fly in icing conditions although the explanations above have illustrated that this ability is not easily obtained.

The consortia also agreed that a flight in a thunderstorm was completely unacceptable due to unfavourable conditions such as turbulences, the potential of lightning strikes, hail stones, etc. and that the flight path of the PAV should be re-routed in such an event or be delayed.

3.1.1.1 Weather Analysis

To get a first impression about how tricky it might be to get a similar level of “reliability” or usability for the PAV as of the one of a car, a weather analysis for a transect was conducted in Germany (distance 30 km; location: near Frankfurt). The aim was to see on how many days of a given year a flight from A to B in this region would have been possible at certain times of the day.

If the PAV is to be used for trips to and from work, only a certain flexibility in terms of time can be accepted and the commuters are likely to request this form of transport in the morning and afternoon or in the evening hours. To get an impression of the availability of use of a PAV, weather data from the German meteorological service (Deutscher Wetterdienst) were used to check days (split up in morning and afternoon blocks) for their weather suitability following pre-defined “no-fly” criteria. The German meteorological service provides special weather forecasts for VFR and IFR pilots at different flight levels which are actualised several times per day. For the following weather analysis input data from the GAFOR (General Aviation Forecast) were used.

The GAFOR generally breaks the weather situation down into categories following a stepwise division of the visual flight possibilities based on the horizontal visibility on the ground in km and on the cloud base height in ft (for details see Table 3.1). The data are structured in five main flight visibility categories (C – Charlie = clear, O – Oscar = open, D – Delta = difficult, M – Mike = marginal, X – X-Ray = closed) and are updated four times during winter months and five times during summer months, which allows for a detailed temporal analysis.

The GAFOR data are sometimes corrected or amended during the day. Normally, this is done if the weather situation becomes worse than predicted. In order to determine the maximum number of days with bad weather situations, the version with the worst flight visibility category was consistently used for the analysis.

[116] QBE Aviation, (2011)

[117] Federal Aviation Administration, (2008)

Frankfurt on the Main was chosen as study area, an area that is situated in the GAFOR district 45.[118] This area was selected corresponding to the travel scenario of myCopter with people flying into an inner city area for work, in this case Frankfurt on the Main.

<table>
<tr><th></th><th>< 1.5 km</th><th>1.5-5 km</th><th>5-8 km</th><th>8-10 km</th><th>> 10 km</th></tr>
<tr><td>> 5000 ft</td><td rowspan="4">X</td><td rowspan="2">M6</td><td rowspan="2">D3</td><td rowspan="2">O</td><td>C</td></tr>
<tr><td>2000 – 5000 ft</td><td>O</td></tr>
<tr><td>1000 – 2000 ft</td><td>M7</td><td>D4</td><td colspan="2">D1</td></tr>
<tr><td>500 – 1000 ft</td><td>M8</td><td>M5</td><td colspan="2">M2</td></tr>
<tr><td>< 500 ft</td><td colspan="5">X</td></tr>
</table>

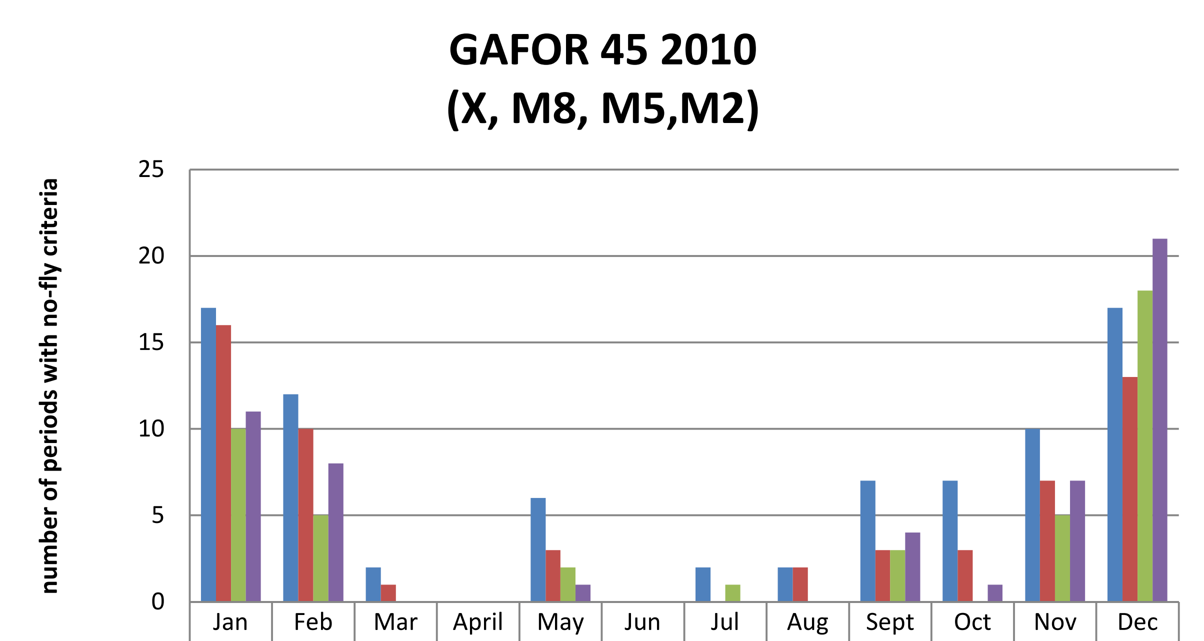
Table 3.1: Overview of the Flight visibility categories of the German GAFOR based on the criteria of visibility on the ground in km (first row) and cloud base height in ft over reference height in ft (first column)

Source: Deutscher Wetterdienst - Abteilung Flugmeteorologie, (2008)

For a first analysis, the situation of a PAV able to cope with quite difficult weather conditions was envisioned, and the four flight visibility categories X, M8, M5 and M2 (see Table 3.1) were used as no-fly criteria for the analysis. These four categories represent bad weather situations with a cloud base lower limit of 1000 ft or less and / or a very low ground visibility of 1.5 km or less for parts of the X-Ray category. The result (see Figure 3.1) shows that especially the winter months (November – February) have a high number of days with time periods belonging to the four no-fly categories.

[118] Germany in total is divided in 68 subparts for the GAFOR Deutscher Wetterdienst - Abteilung Flugmeteorologie, (2008)

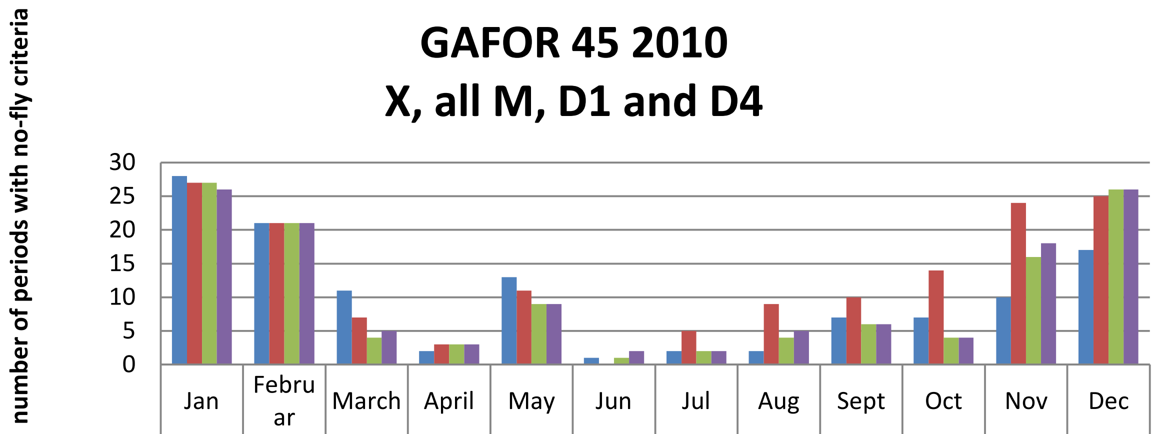
Figure 3.1: Number of time periods with a GAFOR flight visibility category of X-Ray, M8, M5 or M2 for the year 2010 and four time periods for the GAFOR subpart 45 ("Rhine-Main area and Wetterau")



	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
6-8 Uhr	17	12	2	0	6	0	2	2	7	7	10	17
8-10 Uhr	16	10	1	0	3	0	0	2	3	3	7	13
17-19	10	5	0	0	2	0	1	0	3	0	5	18
19-21 Uhr	11	8	0	0	1	0	0	0	4	1	7	21

In a second analysis only the "good" flight visibility categories (C, O and D3) were used as acceptable situations for the PAV flight realisation and all other categories (X, all M, D1 and D4) were used as no-fly criteria to cover the range of decreasing requirements for the vehicle and potential user abilities. This second analysis also gives an impression of the occurrence of days with a higher flight comfort level (assuming that good weather means less turbulences, etc.) The results for this second analysis with more flight visibility categories used as "no-fly" criteria shows the following result:

Figure 3.2: Number of time periods with a GAFOR flight visibility category of X-Ray, M8, M7, M6, M5, M2, D1 or D4 for the year 2010 and four time periods for the GAFOR subpart 45 (“Rhine-Main area and Wetterau”)

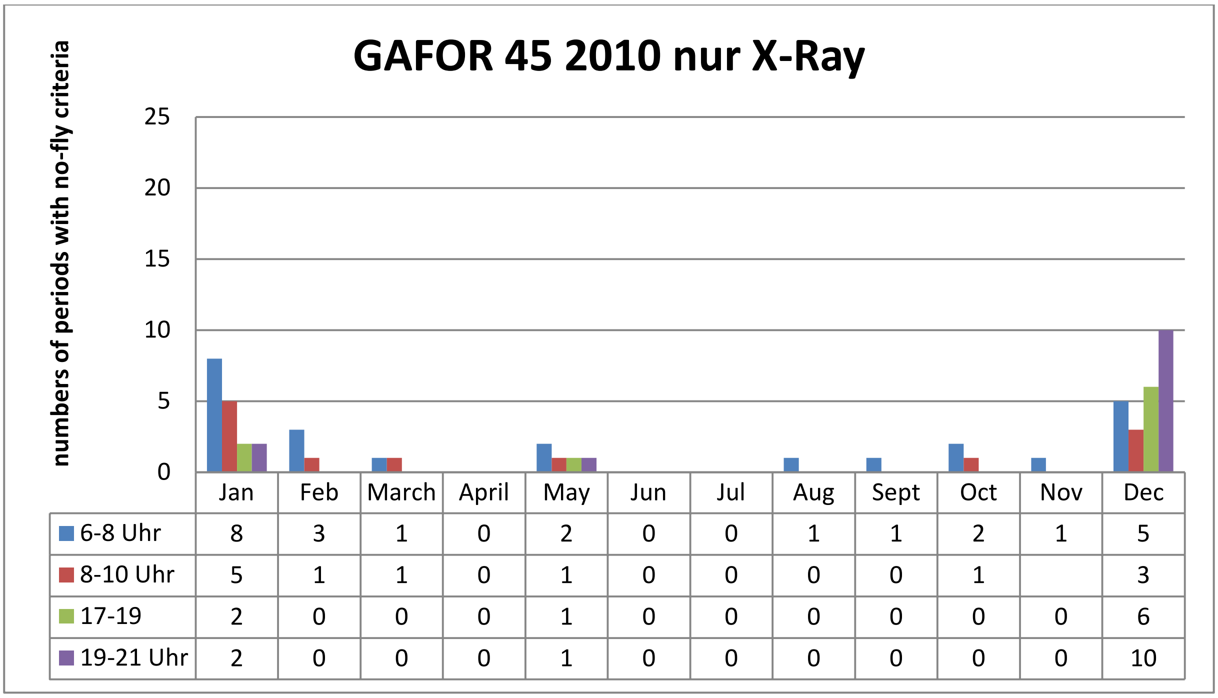


	Jan	Februar	March	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
6-8 Uhr	28	21	11	2	13	1	2	2	7	7	10	17
8-10 Uhr	27	21	7	3	11	0	5	9	10	14	24	25
17-19	27	21	4	3	9	1	2	4	6	4	16	26
19-21 Uhr	26	21	5	3	9	2	2	5	6	4	18	26

As you can see, for this analysis (see Figure 3.2.) the numbers of no-fly periods increases sharply, and the winter months are nearly completely blocked for PAV flights under these assumptions.

One last analysis, taking into consideration only the X-Ray category as no fly-criteria, was also done to identify the lowermost limit for the year 2010 when flights would have been possible (under the assumption of only X-Ray as exclusion criteria). Although the results now look quite promising, it should be noted that, right now, the X-Ray category is used for weather situations in which flights following visual flight rules are not possible. Even if the Reference PAV shall have the ability of flying in a visually degraded environment, the flying into clouds is not seen as desirable and, therefore, it is debatable if, in the end, flights in M8, M5, and M2 conditions will be manageable in a safe manner by the Reference PAV. This will also depend on the actual design, especially on the propulsion type and on the sensor equipment of the Reference PAV as well as on the distribution of flight tasks between the human being and the system.

Figure 3.3: Number of time periods with a GAFOR flight visibility category of X-Ray for the year 2010 and four time periods for the GAFOR subpart 45 (“Rhine -Main area and Wetterau”)



To return to the original aim of the weather analysis, the usability comparison of the PAV versus a private car; the three analyses lead to the following result on the usability over the year:

Table 3.2: Percentage of time periods belonging to the “no-fly” criteria of the three different weather analyses for the year 2010 and GAFOR subpart 45

	6-8	8-10	17-19	19-21
only X-Ray	6.58	3.29	2.47	3.56
X, M8, M5, M2	22.47	15.89	12.05	14.52
X, all M, D1 and D4	33.15	42.74	33.70	34.79

As one can see in Table 3.2, the aim of a 90 % usability over the year for the PAV is only reached in the X-Ray category for all four time blocks, and nearly achieved by the X, M8, M5, and M2 group for the 17 - 19 o`clock period with 100 – 12 % = 88 % usability.

For a placement of these findings one has to know that the year 2010 was a very cold year for Germany with lots of snow and frost and less sunshine until the middle of March. Some weather stations had time records for snow depths and it was the coldest winter of the last 13 years.[119] Compared to other GAFOR areas in Germany the GAFOR 45 subpart provides quite good conditions for visual flights and is rated to be in the front third by an expert from the German meteorological service, who was consulted for a rating about this subpart in

[119] Streicher, (2011)

comparison the other GAFOR areas in Germany[120] A better rating is prevented for the Rhine-Main area and Wetterau due to a high number of fog days in this area.[121]

Although this analysis was only looking at one certain area in one year, it illustrates that the dependency on weather conditions is quite high, and that the topic of how to expand the operability of the PAV into challenging weather conditions will have to be considered further.

3.1.2 Further Safety Issues

Next to the influence of weather conditions on flight safety, a number of technical and human induced errors can lead to accidents or unsafe situations in aviation. The annually issued statistics of the European Aviation Safety Agency (EASA) give an impression on the numbers of accidents and fatalities occurring in its Member States (see Figure 3.4)

Figure 3.4: Overview of accident numbers and fatalities in different aircraft categories of aircrafts registered by the EASA Member States (EU27 plus Iceland, Liechtenstein, Norway and Switzerland) with a MTOM below 2250 kg.

Aircraft category	Period	Number of all accidents	Fatal accidents	Fatalities on board	Ground fatalities
Balloon	2006–2009 (average)	22	0	0	0
	2010 (total)	14	0	0	0
Aeroplane	2006–2009 (average)	533	65	122	1
	2010 (total)	449	53	95	1
Glider	2006–2009 (average)	188	18	21	0
	2010 (total)	165	17	21	0
Gyroplane	2006–2009 (average)	10	3	3	0
	2010 (total)	9	0	0	0
Helicopter	2006–2009 (average)	84	10	21	2
	2010 (total)	70	10	28	0
Microlight	2006–2009 (average)	209	33	21	2
	2010 (total)	207	34	28	0
Other	2006–2009 (average)	73	13	15	1
	2010 (total)	85	10	11	0
Motorgliders	2006–2009 (average)	61	11	15	0
	2010 (total)	82	9	11	0
Average	**2006–2009**	**1180**	**153**	**217**	**5**
Total	**2010**	**1047**	**129**	**189**	**1**
Difference (%)		**–11.3%**	**–15.5%**	**–13.0%**	**–80.0%**

Source: EASA, (2010a), p.3

As myCopter comes from a PAV with VTOL abilities, the helicopter aircraft category seems to be most related. More significance than pure accident numbers (which would need to be compared to fleet sizes for a better placement) are the reasons for accidents to occur. Here the EASA uses so called “accident categories” as a tool to cluster and classify the reasons leading to accidents. These categories have the aim to provide a common taxonomy and

[120] Streicher, (2011)

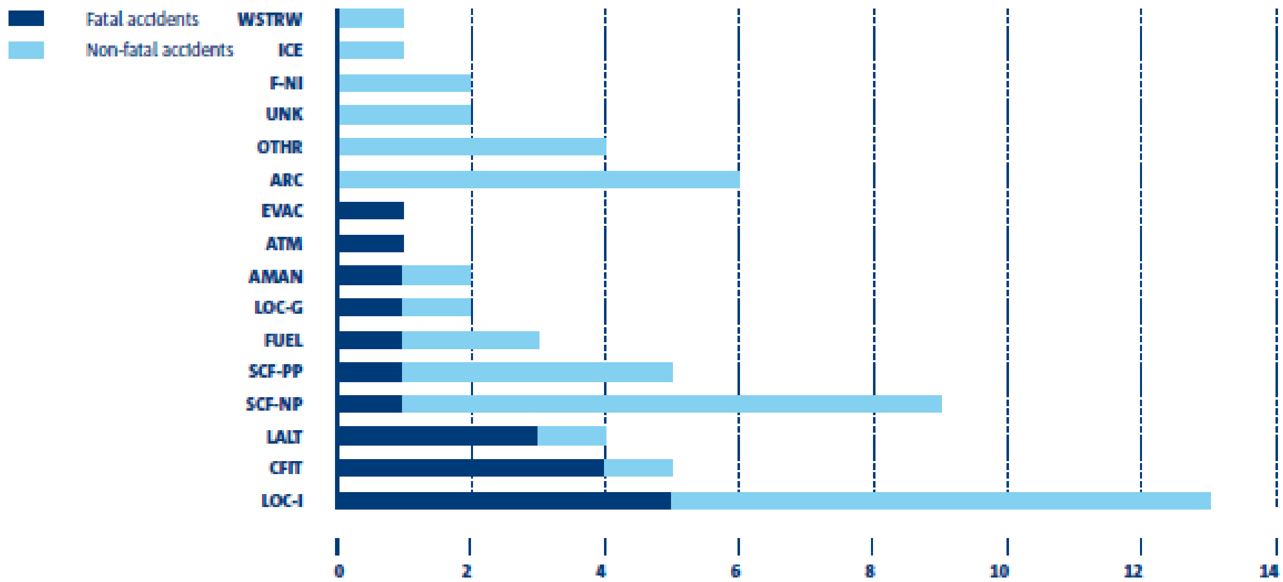
[121] Streicher, (2011)

definitions used for the reporting of aviation accidents and shall help to focus on accident prevention.[122]

The following Figure 3.5 shows that the “Loss of control in flight” (LOC-I) and the “Controlled flight into terrain” (CFIT) categories were the two most frequently ascribed categories regarding fatal accidents of helicopters operating in the field of General Aviation for the years 2001 to 2010 in the EASA Member States. Accidents under the “Controlled flight into terrain” category are often caused by bad weather conditions such as reduced visibility due to fog, by night time operations or by flying in hilly or mountainous terrain.[123]

The Figure 3.5 also shows that “Loss of control in flight” and system, component failure or malfunction of other parts than the powerplant unit are two important issues regarding non-fatal GA helicopter accidents in this space of time.

Figure 3.5: Overview of accident categories in the field of General Aviation for helicopters registered by EASA Member States with a MTOW above 2250 kg in the years 2001 - -2010 **Acronyms[124]: WSTRW = Windshear or thunderstorm; ICE = Icing; F-NI Fire / /smoke (non-impact); UNK = Unkown or undetermined; OTHR = Other; ARC = Abnormal runway contact; EVAC = Evacuation; ATM = Air Traffic Management; AMAN = Abrupt manoeuvre; LOC-G = Loss of control – Ground; FUEL = Fuel related; SCF-PP = System /component failure or malfunction (powerplant); SCF-NP = System / /component failure or malfunction (non-powerplant); LALT = Low altitude operation; CFIT = Controlled flight into or toward terrain; LOC-I = Loss of control – In-flight.**



Source: EASA, (2010a), p. 31

A deeper investigation of accidents and safety risks in the field of helicopter operations was conducted by the European Helicopter Safety Team (EHEST) which is part of ESSI

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[122] Stephens and Menzel, (2004)

[123] EASA, (2010a)

[124] for more detailed information about the accident categories see Stephens and Menzel, (2004)

(European Strategic Safety Initiative) a ten year programme of the EASA, European national aviation authorities, manufacturers, operators, research organisations, and the GA community, with the aim to improve aviation safety at the European level.[125] The EHEST has analysed over 300 European helicopter accidents (140 accidents belonging to GA operations) in the years 2000 to 2005, using two different coding taxonomies, the Standard Problem Statements (SPS) and the Human Factors Analysis and Classification System (HFACS), and have deduced from this analyses suggestions for future safety enhancement.[126] The SPS taxonomy consists of 14 main areas such as “Pilot judgement”; “Mission risk”; or “Data issues” which are further narrowed down two levels to get the Standard Problem Statement. The HFACS has its focus on human errors and is split into four levels: “organisational influences”, “supervision”, “preconditions for unsafe acts”, and ”unsafe acts of operators” (this can be the flight crew, the air traffic controllers, the maintainers, etc.).[127] The two taxonomies complement each other with the SPS coding, the more technical issues and the HFACS focuses on the human factor.

The results from EHEST do also show that most accidents occurred during “En-route” followed by “Manoeuvring” and “Approach and Landing” phases of flight.

Figure 3.6: Percentage of accidents in the EHEST Analysis 2000 - -2005 European Helicopter Accidents Dataset in which the level 1 Standard Problem Statement was identified at least once

Source: van Hijum and Masson, (2010), p. 21

Note: the category “Data Issues” is used for accidents where due to a lack of information about the accident itself no full understanding about the factors leading to the accidents could be obtained

The SPS categories that have mostly occurred in the dataset were “Pilot Judgment & Actions” and “Safety Culture / Management” (see A deeper investigation of accidents and safety risks in the field of helicopter operations was conducted by the European Helicopter Safety Team (EHEST) which is part of ESSI (European Strategic Safety Initiative) a ten year

[125] van Hijum and Masson, (2010)

[126] van Hijum and Masson, (2010)

[127] van Hijum and Masson, (2010)

programme of the EASA, European national aviation authorities, manufacturers, operators, research organisations, and the GA community, with the aim to improve aviation safety at the European level. The EHEST has analysed over 300 European helicopter accidents (140 accidents belonging to GA operations) in the years 2000 to 2005, using two different coding taxonomies, the Standard Problem Statements (SPS) and the Human Factors Analysis and Classification System (HFACS), and have deduced from this analyses suggestions for future safety enhancement. The SPS taxonomy consists of 14 main areas such as “Pilot judgement”; “Mission risk”; or “Data issues” which are further narrowed down two levels to get the Standard Problem Statement. The HFACS has its focus on human errors and is split into four levels: “organisational influences”, “supervision”, “preconditions for unsafe acts”, and ”unsafe acts of operators” (this can be the flight crew, the air traffic controllers, the maintainers, etc.). The two taxonomies complement each other with the SPS coding, the more technical issues and the HFACS focuses on the human factor.

The results from EHEST do also show that most accidents occurred during “En-route” followed by “Manoeuvring” and “Approach and Landing” phases of flight.

Figure 3.6) The first category with over 70% of the counts is used to describe factors that relate to “pilot decision making, unsafe flight profile, landing procedures, procedure implementation, crew resource management, and human factors, such as diverted attention and perceptual judgment errors.”[128] The second category “Safety Culture / Management” is used for issues regarding the flight training, disregarding of known risks, self-induced pressure, or pilot experience.[129]

As a limitation of these findings by EASA and EHEST you have to take in mind that the air vehicles looked into there have partly a higher mean take-off mass than the PAVs considered for myCopter, and that they have a helicopter design, whereas the arrangement and number of rotors of the PAV is not determined yet. Nevertheless, they give an overview of the variety of safety issues relating to helicopter operations and with the accident categories, the SPS and the HFACS taxonomy, they offer tools for their classification and common communication.

One further issue, which could be especially relevant for very light PAVs, is the issue of overloading or unbalanced loading. Helicopters are very sensitive to weight and balance issues.[130] If the vehicle is overloaded (exceeding the allowed payload limit) or does exceed the allowed centre of gravity this can lead to tilt, changes in its control behaviour, and performance during hovering, take-off, climb, autorotation, and landing.[131] The problem of unbalanced loading is addressed by the KISS 209M helicopter (see chapter 1.3) with a system that can pump hydraulic oil in other parts of the helicopter in order to compensate for pilot weight on one seat.[132]

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[128] van Hijum and Masson, (2010), p. 21

[129] van Hijum and Masson, (2010

[130] Federal Aviation Administration, (2007a)

[131] Federal Aviation Administration, (2007a)

[132] Skamljic, (2011)

If assuming a more autonomous system with no option for user input which could lead to a critical situation, the human errors are eliminated. But enough potential safety hazards remain in a fully autonomous system, too.

In the context of myCopter, at least two quite different systems architectures and combinations in between can be imagined. One of them is a system where all decisions and sufficient data to conduct a safe flight are located on board the PAV, another system could rely strongly on input (weather and location data, air traffic management) by external sources and depend strictly on a reliable data link to these pieces of information.information. With further progress of the project the degree of autonomy and the design of the system architecture will become more precise and will allow a more detailed analysis of safety issues.

3.2 Legal Aspects

One aspect which is seen as a major hurdle both for developers of PAVs and for persons who want to fly them is the issue of getting certification for the vehicle and the licence required to fly the vehicle in a given country and environment. A related issue is the question at what times people are allowed to fly PAVs and which parts of the airspace are open to them. A last aspect to be mentioned here is the topic of responsibility and insurance.

As it was stressed before and becomes more and more apparent, most of these questions and issues are related to each other, and changing one assumption about the PAV abilities, level of autonomy or system architecture, creates changes in many of the other fields.

For example, if the level of autonomy is not very pronounced and the final decision in critical situations is taken by the user, conventional insurance schemes might work. If we assume, however, a full autonomous system with a human being on board playing the role of pure “cargo” then the situation looks very different and will probably constitute an unsolved problem for the insurance industry.

3.2.1 Certification of the Vehicle PAV

The timescale of myCopter is rather long-term and PAVs are not assumed to be seen flying around in European cities in the next few years but rather in a few decades. Therefore, the certification categories and procedures existing today might have changed and new ones, like the European Light Aircraft process[133] (with the aim to simplify and lighter the regulatory regime for aircrafts and related products) might be in place. Nevertheless, the existing rules give a feeling in which legal framework PAVs will be integrated and, firstly, PAVs will surely have to cope with these existing categories. This is also illustrated by companies like Terrafugia who have specified their goals in terms of street and air certification for their vehicle and also report on the difficulties they experience to fit into the existing system.[134]

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[133] EASA, (2011c)

[134] see for example: Coxworth, (2010)

In Europe the organisation responsible for the certification and oversight of civil aviation products by their members (27 nations see full list in EASA, (2010c)) is the EASA (European Aviation Safety Agency). This agency was officially opened in 2003 and took over the airworthiness functions of the former JAA.[135] Table 3.3 gives an overview of aircraft certification categories for light aircrafts and helicopters covered by EASA or FAA, with a seating configuration comparable to the one of myCopter PAV.

[135] EASA, (2010d)

Table 3.3 Overview of different certification categories and their conditions of application in Europe (EASA) and the US (FAA)

	EASA	EASA	EASA	FAA
Name	Light Sport Aeroplanes[136]	Very Light Aeroplanes[137]	Very Light Rotorcraft[138]	Light Sport Aircraft Category (no helicopter)
Acronym	CS-LSA (Certification Specifications- LSA)	CS-VLA	CS- VLR	LSA
Only day-VFR	yes	yes	yes	-
Max. certified take-off mass in kg	600 kg for aeroplanes 650 kg for aeroplanes operated on water	750 kg	600 kg	600 kg
Max. stalling speed in landing configuration	83 km/h	83 km/h	-	83 km/h
Max. seating capacity	2	2	2	2
Engine	single, non-turbine engine with propeller	single engine (spark or compression-ignition)	no turbine and/or rocket engines	single
Cabin	non-pressurised	-	-	non-pressurised

[136] EASA, (2011a)

[137] EASA, (2009a)

[138] EASA, (2008a)

There are some “products” (aircrafts), though, which do not fall under the responsibility of the EASA and these exceptions are listed in the Annex II of their Basic Regulation[139] from 2008. These exceptions are, for example, historical aircrafts, ultra-lights, or amateur-built vehicles, and they are handled by the national authorities.[140] Exceptions which could become relevant in the myCopter context are:

- “aircraft specifically designed or modified for research, experimental or scientific purposes, and likely to be produced in very limited numbers;
- aircraft of which at least 51 % is built by an amateur, or a non-profit making association of amateurs, for their own purposes and without any commercial objective;
- aeroplanes, helicopters and powered parachutes having no more than two seats, a maximum take-off mass (MTOM), as recorded by the Member States, of no more than:
    - 300 kg for a land plane / helicopter, single-seater; or
    - 450 kg for a land plane / helicopter, two-seater; or
    - 330 kg for an amphibian or floatplane / helicopter single-seater; or
    - 495 kg for an amphibian or floatplane / helicopter two-seater, provided that, where operating both as a floatplane / helicopter and as a land plane / helicopter; it falls below both MTOM limits, as appropriate;
    - 472.5 kg for a land plane, two-seater equipped with an airframe mounted total recovery parachute system;
    - 315 kg for a land plane single-seater equipped with an airframe mounted total recovery parachute system;
- aeroplanes, having the stall speed or the minimum steady flight speed in landing configuration not exceeding 35 knots calibrated air speed (CAS);
- single and two-seater gyroplanes with a maximum take off mass not exceeding 560kg
- unmanned aircraft with an operating mass of no more than 150 kg;
- any other aircraft which has a maximum empty mass, including fuel, of no more than 70 kg” [141]

This means that gyrocopters of up to 560 kg and helicopters of up to 450 kg. and also very light UAVs would have to comply with national law. All these exceptions show that in the field of ultra light air vehicles Europe has no harmonised legislation so far. This exceptions show also that the case of a heavier UAV (with human cargo) would fall under the responsibility of the EASA and the development of certification standards for civil Unmanned Aircraft Systems (UAS) has already started and led to a “Policy Statement Airworthiness Certification of Unmanned Aircraft Systems (UAS) by the EASA in 2009.[142] Although it is stated as being an “interim solution” the policy describes the certification procedure for UAVs over 150 kg in Europe, does not contain operational legislation though.[143] The regulation covers in addition to the UAV vehicle itself also the control station and other remote equipment responsible for the command and control link there it is called UAS and not UAV.

[139] European Union, (2008)

[140] EASA, (2010b)

[141] European Union, (2008), p.32-33

[142] EASA, (2009b)

[143] EASA, (2009b)

The pilot licences needed to fly these different aircraft categories mentioned above are obtained from the national aviation authorities. In the US this authority is the FAA, for the UK it is the CAA, and for Germany it is the LBA. In Europe, most countries use the Joint Aviation Rules for Flight Crew Licensing (JAR-FCL) as a basis for their own certification rules.

3.2.2 Qualification of the User

Another hurdle for a higher market penetration of PAVs in Europe are the high requirements regarding the qualifications of the pilots, which is understandable when considering the abilities needed to pilot current air vehicles and to manage all the navigation and separation tasks. The requirements are not only high in terms of knowledge and training, but it is also very expensive and time consuming to take and to keep a pilot licence.

Therefore, it is no surprise that, compared to the figures for driver licences, the figures for private pilot licences (PPL) are much lower. In 2008, around 23,000 PPLs of one sort or another were held in the UK[144] If you compare these figures with the driving licences existent in the UK (nearly 37 million), you will note that the percentage of people holding a PPL represents only 0.04% of the population compared to 60% holding a drivers licence. Other figures from Germany draw a similar picture with around 53 million driving licences stated in 2004[145] (64 % of population at that time[146]) but with only around 36.000 PPLs[147] which corresponds to 0.04 % of the population.

The aim of myCopter is to minimise the training requirements for the user by both improving the handling characteristics of the vehicle, especially the HMI, and by “transferring” pilot tasks to the system itself automation).At present, the researchers of the myCopter project have two rather different types of user scenarios in mind. One is a scenario with the PAV being fully autonomous where a human enters the PAV, tells the system where he wants to go, and no further user input is required throughout the flight. For this scenario no real pilot training would be necessary and it is unclear what legal authorisation could become effective here. In this scenario the end-user would receive rather an introduction of the PAV from the seller on how to communicate with the system and how to get desired information displayed or limitations of the system explained. Tasks like maintenance and refuelling or recharging of the PAV would remain with the user and could be either performed by the user himelf or assigned to service providers of take-off and landing areas, for example.

In contrast to the situation with a full autonomous system with an aeronautical unskilled user, the other scenario includes that the human user does have control in certain situations and that there are situations were “pilot input” is obligatory because the system is not able or not certified to perform the task. For this scenario a more or less conventional pilot training and licence procedure seems to be realistic. And the requirements and costs for this pilot training, depending on the automation level of the PAV, could lie in between the quite extensive

[144] Civil Aviation Authority, (2008)

[145] Kalinowska et al., (2007)

[146] Statistisches Bundesamt Deutschland, (2010)

[147] Strecker, (2008)

education level existent today for a PPL, or be less complex and costly such as today's requirement for ultra-light vehicles which is, presently the Sport Pilot Licence for Germany or the National Private Pilot`s Licence for micro-lights (NPPL(M)), for example.[148]

In the US the FAA allows one-seater ultra-light vehicles to be flown without any pilot licence, if they conform with a few requirements: do not fly faster than 55 kt (around 100 km/h), are still able to fly at a speed of 25 kt (ca. 46 km/h), have no more than around 19 l fuel on board, and no not exceed a 254 pounds (around 115 kg) empty weight limit.[149]

To get a feeling for the demands on training existent today, the following table shortly lists the training requirements (time effort and costs) of different licences and of their limitations.

[148] British Microlight Aircraft Association, (2011)

[149] FAA, (1982)

Table 3.4: Training requirements and their operational limits of different national licences and the future EASA PPL expected to be introduced in 2012

	LAPL (EASA) helicopters[150]	PPL (EASA)[151]	SPL (Germany) [152]	NPPL(M) UK [153]
Minimum total flight time under construction	40 h	45 h[154]	25 h	25 hours
Theory lesson	amount of time not specified	amount of time not specified	EASA, (2010b) 60h[155]	not obligatory can be done in self study, written exam must be passed
Medical requirements	LAPL medical certificate	class II medical certificate[156]	medical certificate class II	self-certification signed by doctor
Minimum age	17	17	16	17[157]
Validity	12 months with requirements	not known	5 years provided that certain requirements are met	not known

[150] EASA, (2010b)

[151] with different ratings for A = aeroplanes, H = helicopters, PL = powered lift, As = airships; Safety Regulation Group, (2011)

[152] ASAD, (2009-2011)

[153] British Microlight Aircraft Association, (N.N.)

[154] EASA, (2011b)

[155] EASA, (2010b)

[156] EASA, (2008b), see the same publication for a detailed section about the acceptable means of compliance for the class II medical certificate

[157] McCafferty, (2003-2008)

Costs	not known	not known	around €5,500	around 3500- 5200 Euro[158] others name up to 7000[159]
Operational limits	not known	not known	visual flights only at the following times: 30 min.. before sunrise until 30 min. after sunset 1 to 2-seater only MTWO of 472.5 kg	no passenger to be carried no flight with cloud base less than 1000 feet above ground or less than 10km visibility. only UK registered aircrafts and only in the airspace of the UK

[158] British Microlight Aircraft Association, (N.N.)

[159] McCafferty, (2003-2008)

As you can see from the Table 3.4, different training requirements and associated privileges exist. The present situation of quite different national pilot licences in Europe shall be harmonised by a new European Light Aircraft Pilot Licence (LAPL) expected for spring 2012 for the non-ultra-light sector.[160] For ultra-light vehicles the picture remains patchy and is, currently, still handled individually with different regulations for pilot qualifications existing on the national level. In contrast to the more complex European certificates, the ultra-light licences have lower requirements in terms of minimum flight training hours, frequency of repetition of medical certificates and validity.

As the MTOW limit of 450 kg is set for the Reference PAV in myCopter, it would come under the Annex II air vehicle section and, therefore, under national legislation. To fulfil the mission of myCopter also heavier vehicles could become relevant if, for example, the technical equipment would add more weight as thought, though. It is also possible that in the future the EASA will harmonise the ultra-light vehicle category and add it to their sphere of control.

3.2.3 Airspace Regulation or Where to Fly

Somehow related to the legal and safety issue is the topic of the used airspace in which the PAVs are envisioned to operate. The proposal states that at the beginning, the PAVs are expected to operate outside the controlled airspace but that they should be integrated into a future generation of controlled airspace. Based on the airspace classification scheme of the International Civil Aviation Organization (ICAO) that is explained in their Annex 11 “Air Traffic Services”, the EASA concepts published for the airspace classes in Europe are presented in Table 3.5.

The different airspace classes A to G describe the services that are provided by the air traffic control and are characterised by a decreasing level of control executed by the ATC and by different limits for air speed, flight heights, etc. The airspace classes A to E are known as controlled airspace which means that the ATC has the authority to control the air traffic in this space. In contrast, uncontrolled airspace can have ATC service or information provision but this cannot be guaranteed because of work load, etc., which is referred to with the term “as far as practical” in Table 3.5. This means that the separation task in the uncontrolled airspace is within the responsibility of the pilot.

The understanding of myCopter is that PAVs would operate in these uncontrolled airspaces (F and G) where no ATC clearance has to be obtained and a lot of smaller and mostly slower vehicles such as balloons, sailplanes, gliders, trikes, etc., operate. For a safe operation in this airspace, standards exist for minimum clearance to avoid noise disturbance and to provide a safety margin in the case of an emergency landing. For Germany, these rules can be found in the air traffic order (“Luftverkehr-Ordnung) § 6.[161] This order determines the so called lowest safety altitude (LSALT) which is only to be undercut for starts and landings. Above cities and other dense settlements, industry, crowds of people, and danger zones the LSALT is 300 m above the highest obstacles in a radius of 600 m. In all other cases such as

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[160] Deutscher AERO Club e.V., (2011)

[161] Bundesministerium der Justiz, (2010a)

in ground or water environment without the mentioned constraints the LSALT is 150 m. For cross-country flights after VFR with motor-powered air vehicles a higher LSALT of 600 m is in force. In the UK the situation is very similar with a 500 feet rule (around 150 m) above persons, vessels, or vehicles and another rule of 1,000 feet above obstacles for flights above congested areas (cities or settlements) within a horizontal radius of 600 m of the aircraft.[162]

It could be argued that these safety heights could be arranged lower for a PAV with a VTOL ability that needs far less space for landing than other air vehicles and, therefore, has a greater choice regarding landing spots, even in a densely populated area. Today, these safety altitudes are already undercut by the military, the police and by emergency services. The issue of noise disturbance would remain though.

When remembering the average cruising altitude of below 500 m ASL assumed for the Reference PAV, it looks as if the zone between 300 to 500 m would be the airspace for PAV flights under current assumptions and legal framework.

[162] Secretary of State for Transport, (2005)

Table 3.5: Air Traffic Service Airspace Classes proposed by the EASA. Overview of provided services and flight requirements

Class	Type of flight	Separation provided	Service provided	Speed limitation*	Radio communication capability requirement	Continuous two-way air-ground voice requirement	Subject to an ATC clearance
A	IFR only	all aircraft	air traffic control service	not applicable	yes	yes	yes
B	IFR	all aircraft	ATC	not applicable	yes	yes	yes
	VFR	all aircraft	ATC	not applicable	yes	yes	yes
C	IFR	IFR from IFR IFR from VFR	ATC	not applicable	yes	yes	yes
	VFR	VFR from IFR	1) ATC service for separation from IFR; 2)VFR/VFR traffic information (and traffic avoidance advice on request)	around 460 km/h IAS (indicated air speed) below 3,050 m AMSL	yes	yes	yes
D	IFR	IFR from IFR	ATC service, traffic information about VFR flights (and traffic avoidance advice on request)	around 460 km/h IAS below 3,050 m AMSL	yes	yes	yes
	VFR	Nil	IFR/VFR and VFR/VFR traffic information (and traffic avoidance advice on request)	around 460 km/h IAS below 3,050 m AMSL	yes	yes	yes
E	IFR	IFR from IFR	ATC service and, as far as practical, traffic information about VFR flights	around 460 km/h IAS below 3,050 m AMSL	yes	yes	yes
	VFR	Nil	traffic information as far as practical	around 460 km/h IAS below 3,050 m AMSL	no**	no**	no

F	IFR	IFR from IFR as far as practical	air traffic advisory service; flight information service	around 460 km/h IAS below 3,050 m AMSL	yes***	no***	no
	VFR	Nil	flight information service	around 46 0km/h IAS below 3,050 m AMSL	no**	no**	no
G	IFR	Nil	flight information service	around 460 km/h IAS below 3,050 m AMSL	yes**	no**	no
	VFR	Nil	flight information service	around 460 km/h IAS below 3,050 m AMSL	no**	no**	no
* When the height of the transition altitude is lower than 3,050 m AMSL (above mean sea level), FL100 should be used in lieu of 10,000 ft							
** Pilots shall maintain continuous air-ground voice communication watch and shall establish two-way communication, as necessary, on the appropriate communication channel in RMZ (Radio Mandatory Zone)							
***Air-ground voice communication mandatory for flights participating in the advisory service. Pilots shall maintain continuous air-ground voice communication watch and shall establish two-way communication, as necessary, on the appropriate communication channel in RMZ.							

Source: EASA, (2011d)

3.2.4 Insurance

Highly automated PAVs will, probably, be a new case for the insurance industry. For dual mode PAVs like Terrafugia the question of which insurance will be applicable to them is already raised, an extended car or aircraft insurance or a completely new insurance category.

Coming back to the Reference PAV with its high level of automation, the car insurance topic seems not relevant but the question of responsibility comes to the fore. Depending on the design of the PATS system and level of automation of the single PAVs there could be situations where the system on board has the control, the human being or a control unit on the ground. While the case of a user (with appropriate training background) having control will be similar to today's aviation insurance, the other two cases will probably not be covered by existing policies yet.

For these two cases it seems to be wise to look into the current situation in the UAV sector. The interest in UAV application in Europe varies, some nations do not have UAV experience at all, and others are pushing the development forward and want to see the current restraints regarding the civilian use removed.[163] Nevertheless, the process of developing a comprehensive UAV regulation system has started, as mentioned in chapter 3.2.1.

To establish a common European regulatory framework for UAVs, a special working group, WG-73, was established. It shall produce recommendations for Minimum Aviation System Performance Standards and Minimum Operational Performance Standards to be adopted by the EASA and EUROCONTROL.[164] A study by Frost & Sullivan about the current activities in the UAV sector for the EU expects the completion of these standards not before 2012 and a routinely operation of UAVs in controlled airspace not before 2015.[165]

The dominant issue behind the insurance topic is the question of responsibility. Who is responsible for decisions that robots and autonomous systems take and that lead to undesired results? Who is liable and who has to pay for the damage caused? It could be the manufacturer, the programmer, the seller, the user or the machine itself.[166] In the past the authority was clearly in the hands of humans even if machines and robots took over tasks. A red button to switch off the system was always available and the responsibility, therefore, lied clearly with the user. The Research Centre Robot-Law at the University of Wurzburg is investigating these questions associated with the use of robots and is involved in a project called "A legal Framework for Robotics in Europe".[167]

The unclear situation concerning reasonability and accountability hampers the application of already existing technologies. For example in the field of automatic car full brake applications,

[163] Frost & Sullivan, (2007)

[164] Frost & Sullivan, (2007)

[165] Frost & Sullivan, (2007)

[166] Strassmann, (2011)

[167] Hilgendorf, (2011)

the technology is there but manufacturers hesitate to sell the technology before the issue of accountability is solved.[168] First test cases about failed park assistance systems in the car sector went already to court in Germany, up to now the driver was still accountable, but experts expect this situation to change and a high court decision to be made.[169]

Prof. Dr. Eric Hilgendorf from the University of Wurzburg imagines that autonomous robots would become corporate bodies and would have to be equipped by funding coming from manufactures, sellers, users, etc. and be insured. Then, in case of damage the system itself could be made accountable.[170]

An internet article is thinking about the topic of insurance for flying cars and how complicated this might become if other vehicles approach, not only from the sides, the front and behind but also from above and below. It speculates that there could be different rates for people flying at different speeds, altitudes or distances and sees an option for an air road system with several lanes at different hights and with increasing speed limits upwardly.[171]

3.3 Technical & Operational Challenges

There is of course also a technical component and a challenge to be met in order to create a PAV, but the overall challenge to create a personal air vehicle itself seems mostly overcome with a number of PAVs already on the market, and small helicopters and, especially, gyrocopters existent all over the world. Nevertheless, a lot of challenges regarding their production in higher quantities, to a lower price, with a simple manageability and a high level of safety and automation remain. One key aspect is the relationship between the human user and the PAV or its internal system. The degree of autonomy of the system is very important for the overall design and management of the whole personal air transportation system and has also far reaching consequences on training requirements etc..

In this chapter the focus will be on questions regarding the level of automation and autonomy of the PAVs, the air traffic management and the surrounding infrastructure for them.

3.3.1 Automation & Autonomy

"There is a strong incentive for personal aircraft in the steady growth of road congestion and all are agreed that the small VTOL Aircraft is not much more complicated than the modern Automobile and can be mass produced at comparable prices given sufficient demand .The real difficulty is the requirement for a Complete Revolution in air traffic control. We cannot accept much longer the personal control of individual aircraft, it must convert to a fully automatic system.

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[168] Strassmann, (2011)

[169] Strassmann, (2011)

[170] Strassmann, (2011)

[171] Drivesteady, (2011)

The great deterrent in the past has been the expense and uncertain Reliability of electronic equipment. This situation is rapidly changing and the magnitude of the task of tracking [and controlling] thousands of vehicles should not dismay us……..”

Ronald Smelt,1970[172]

First of all it should be clarified, what is meant by the term automation and the similar term autonomy that describes a much more sophisticated concept. Whereas the term automation describes a system that does exactly what it is programmed to do and is not open for decisions while it is executing the pre-programmed actions An autonomous system is able to make decisions and then follow these decisions; it has something that can be described as “free will”.[173] Transferred to the field of aviation, automation can be compared to an autopilot who adheres to the route which is typed in.[174]

The level of automation is of crucial relevance for the socio-economical assessment since the user / driver / pilot is directly affected. Taking the overarching idea of the project seriously the myCopter PAV should be prepared for commuter travel. This can be assumed to be a more serious use case of the PAV technology for business purposes in contrast to a “just for fun usage” in which case you would simply avoid flying in unfavourable weather conditions, for example. In this scoping report we focussed first of all on these external frameworks for PAVs (like weather regulation, noise etc.) and developed concrete scenario of commuter usage since these parameters define first of all the reference PAV for which the myCopter project develops enabling technologies.

In the case of automation, research input from the other work packages regarding the feasibility of different levels of automation is needed, since this topic seems to be challenging as we can prove by the lack of automation in small aerial vehicles.

Without assuming an autonomous, system it is very difficult to envision anyone but a trained pilot flying these aerial vehicles, thus, the prevention of the envisaged expansion of aerial vehicles for personal use, so far. Key functions are take-off and landing, avoiding obstacles while flying at low altitude, and controlling the route with respect to other aerial traffic, as well as emergency control. Taking over these functions by autonomous technologies needs a bundle of sensors and actuators as well as control software that are robust in all weather conditions and include a certain level of redundancy for safety reasons.

Therefore, the right level of automation on the scale from no automation, semi-automation to full automation or autonomous control is intertwined with different decisions about the PAV design, for example:

- Concerning the pilot / driver / passenger these terms correlate with different skills and trainings necessary to use the PAV. While the first one refers to a full pilot licence, the second one refers to a much less complex and costly car drivings licence and the third one takes the human passenger “on board” without having any additional skills

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[172] In: Bushnell, (N.N.)

[173] Clough, (2002); Hill et al., (2007)

[174] Clough, (2002)

- Concerning the weight of the PAV, since the sensors, actuators, and the control systems add to the overall weight of the PAV as well as to the additional power supplies needed to run them
- Concerning the acceptance of the PAVs in everyday life and in emergency situations. The fully autonomous mode seems to be the only one thinkable in emergency situations such as thunder storms or heavy rain. Would pilots, drivers, and passengers accept full autonomous flying? How should the "taking over by the system" be organised?

The level of autonomy is, therefore, crosscutting to many other challenges described in this report. See for example the sections about qualifications of the user (chapter 3.2.2), insurance (chapter 3.2.4), ATM (chapter 3.3.2), parking & storing, (chapter 3.3.4) and more.

The discussion necessary in the next phase of WP7, the so called "Technology Issues", will start with the description of the assumed levels of autonomy to be implemented in the myCopter PAV for which a taxonomy describing the degree of authority handed over from the human to the system might be helpful (see Table 3.6). Another taxonomy described by Endsley (1997) differs further into four groups of functions or tasks: "monitoring", "generating", "selecting", and "implementing", which can be either done by the computer, the human or by both.[175]

Table 3.6: Modified levels (additional subdivision of levels 4 and 5) of the "Pilot Authority and Control of Tasks" (PACT) taxonomy

PACT Locus of Authority	Computer Autonomy	PACT Level	Level of HMI
Computer Monitored by pilot	Full	5b	Computer does everything autonomously
		5a	Computer chooses action, performs it & informs human
Computer backed up by pilot	Action unless revoked	4b	Computer chooses action & performs it unless human disapproves
		4a	Computer chooses action & performs it if human approves
Pilot backed up by computer	Advice, and if authorised, action	3	Computer suggests options and proposes one of them
Pilot assisted by computer	Advice	2	Computer suggests options to human
Pilot assisted by computer only when requested	Advice only if requested	1	Human asks computer to suggest options and human selects
Pilot	None	0	Whole task done by human except for actual operation

Source: Hill et al., (2007)

[175] see Timpe et al., (2002) for a detailed explanation

However, from a reflective perspective it is neither the pilot nor the fully autonomous mode which is most interesting. In the semi-autonomous mode conflicts might appear between the human user and the technical system. In which cases should the system be allowed to overrule? And this question is not only relevant for decisions concerning the flying of the PAV in a narrow sense. You could imagine that physiological computing takes the decision not to start at all since the user appears ill or drunk. The dealing with these kinds of conflicts might become a central issue of the assessment.

3.3.2 ATM

Air traffic management (ATM) is a term describing different services necessary to ensure a safe realisation of flights and of a controlled flow of traffic.[176] Air traffic control is one service included in ATM and describes the safe separation between aircrafts and between aircrafts and obstacles, while at the same time maintaining the traffic flow.[177]Besides, the already mentioned regulative framework for the PAVs itself and the people who want to fly them, a PATS will also need any kind of air traffic management (ATM).

The myCopter PAVs are not thought to rely on current ground based air traffic control and, initially, should operate outside of the controlled airspace.[178] This ensures a lot of freedom and creates new possibilities. This set-up also calls for new procedures and a mature management system to enable frequent PAV operations of a safe manner in a comparably low altitude in urban environment. This would also mean, though, that PAVs will be excluded from certain parts of today`s airspace.

Regarding the technical equipment for the future PAVs, the developments in SESAR could be a reference point. Although SESAR is dedicated to changes in the field of ATM in managed airspace and its direct influence on operations in unmanaged airspace seems to be minimal, even rotorcraft, operating primarily in the unmanaged airspace, will, probably, have to be suitably equipped to interact with managed airspace participants or to be able to do cross flights or to land at certain airports, for example.[179] If aircrafts should comply with this future managed airspace prepared by SESAR, they would need to align with the Reference Business Trajectory (RBT) system and to be able to follow these RBT. At present, this means a, probably, minimum equipment with ADS-B and GPS/GNSS (Global Navigation Satellite System) for all PAVs.

What seems imaginable for a future PATS is that the regulation of the “PAV airspace” will be intensified and expanded with increased traffic density. The example of Sao Paulo, a city with an intensive use of helicopters often referred to as the “world`s helicopter capital”, shows this evolvement of airspace regulations for helicopters. Until 2004, it had a more open structure

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[176] Commission of the European Communities, (1996a)

[177] Commission of the European Communities, (1996a)

[178] myCopter Proposal, (2010)

[179] Vial et al., (2010)

and pilots coordinated themselves, later on it was developed into a much more regulated system with designated special routes and corridors.[180]

While the previous considerations were thinking the system through its “internal eyes” and necessities for a smooth and safe operation, other requirements arise when considering the external protagonists, who can and often do exert pressure on the system.

This pressure is, for example, created by residents living close to helipads or frequent flight routes who complain about the noise disturbance (see chapter 3.4.3) or becomes manifests in public concerns regarding environmental or risk impact[181]. As a reaction to this pressure new regulations might arise or pilots might impose self-regulation on themselves to protect their business, as it is the case in Sao Paulo.[182]

The introduction of helicopter routes seems to be one common tool to structure and guide helicopter traffic in inner city areas. Due to safety reasons, single engine helicopters are often restricted to special routes (for example rivers) with less damage potential in case of an emergency. The Figure 3.7 shows the situation for the area of London. Other helicopter route systems are known from Sao Paulo or New York.[183] In New York these routes were introduced already in 1993 with the aim to reduce the sound levels around the airport area (see Figure 3.8).[184]

[180] Cwerner, (2009)

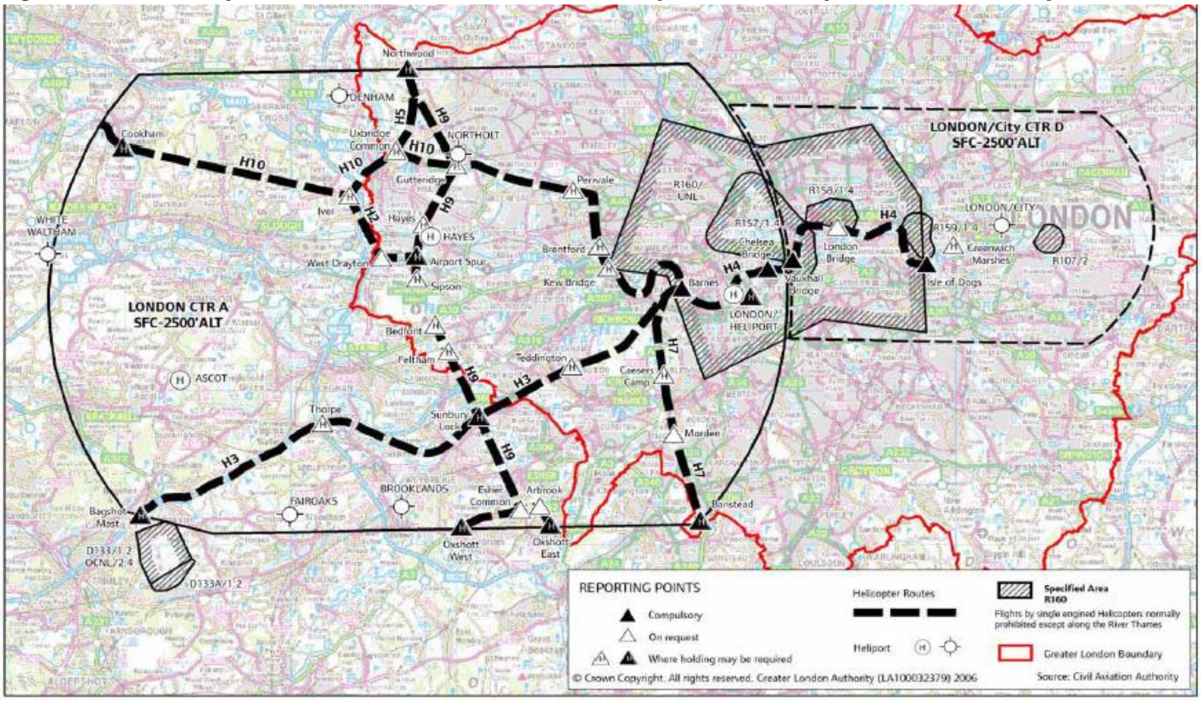
[181] Cwerner, (2006)

[182] Cwerner, (2009)

[183] Cwerner, (2006)

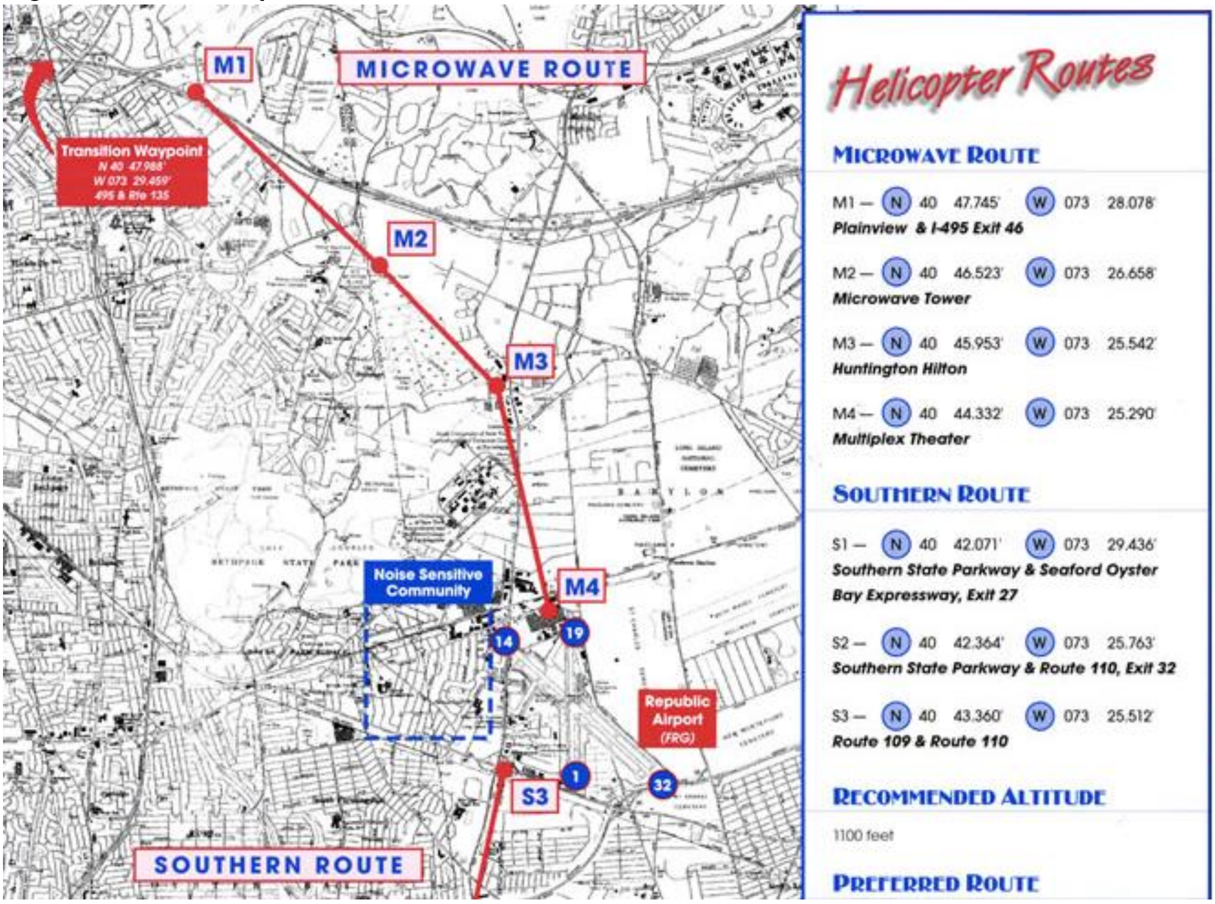
[184] New York State, (2008)

Figure 3.7: Helicopter Routes in the London CTR (control zone) and London/City CTR



Source: London Assembly, (2006), p. 16

Figure 3.8: Helicopter Noise Abatement Procedures and routes for New York



Source: New York State, (2008)

The general questions for myCopter regarding the air traffic management will be who is responsible for the safe separations of aircrafts in the air, for the supply of essential information concerning weather, safety and navigation. Furthermore it will have to be investigated how the delivery of these pieces of information and the execution of the separation task will be securely sustained.

In Sao Paulo the expanding helicopter travel density was addressed with the creation of “the world´s first dedicated air traffic control centre for civilian helicopters” which is located at Congonhas airport.[185] The accompanying new regulative rules have specified the number of helicopter procedures in the area and have strengthened the scheme of helicopter routes.[186] Through these measurements a dedicated team for the control of the urban helicopter air traffic in Sao Paulo was established. These measures provide a stable and reliable foundation for this form of transportation.

Another totally different approach which might be more in the sense of myCopter is the “Free Flight” (FF) concept. In this concept the separation task is done by the pilots and does not fall under the responsibility of the ATC, anymore.[187] The aircraft can choose the routes (“direct routing”) that seem to be optimal and the whole system of ATC is decentralised.

For FF, aircraft broadcast information about their altitudes, positions, IDs, velocities, and maybe even about route intentions to all other ones via ADS-B (or another technical system). These pieces of information can then be received and processed on board the aircraft’s by an on-board system and displayed on a “cockpit display of traffic information” (CDTI).[188]

The concept of Free Flight in a myCopter version could be designed in such a way that pieces of information about position, velocity and intended flight route would be exchanged by the PAVs among each other and processed by on-board systems which would be responsible for detecting potential separation conflicts and areas with overloaded traffic or helipads beyond capacity.

The design of an Air Traffic Management system will, certainly, be a major task of elaborating and testing for a future PATS. A study by Frost & Sullivan (2007) about current activities in the UAV market identifies several interconnected issues concerning a broader UAV application for Europe (see Figure 3.9). Next to the central aspect on how to tackle the sense & avoid issues, also, the integration of ATM is seen as a major concern.

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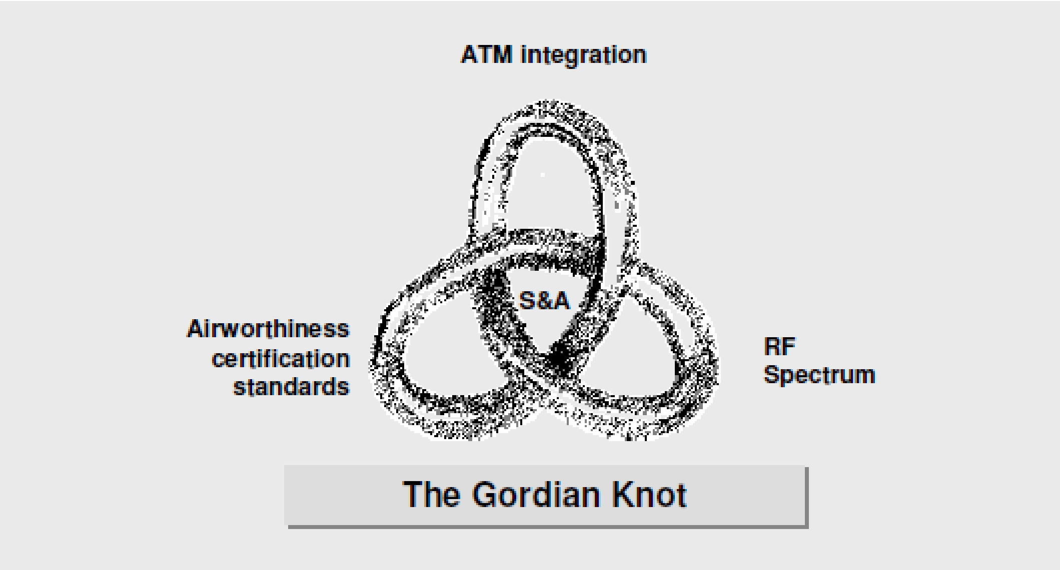
[185] Cwerner, (2006), p.205

[186] Cwerner, (2006)

[187] Hoekstra et al., (2002)

[188] Hoekstra et al., (2002)

Figure 3.9: The Gordian Knot: Interconnection of rules for airworthiness certification, ATM, and the allocation of RF (radio frequency) bandwidths for UAVs located around the central Sense and Avoid issue



Source: Frost & Sullivan, (2007), p.80

3.3.3 Take-Off and Landing Sites or Where to Land

One key for the fulfilment of the myCopter mission of bringing commuters from their homes to their working place will be the existence of take-off and landing sites for the PAVs. Another essential requirement for the Reference PAV would be that these sites would have to be close to the destinations so that the distances between these and the take-off/landing sites could be bridged by walking or public transport, for example. This would mean that a well distributed network of such sites would need to be in place and / or a connection with these sites and public transport facilities would have to be looked at. A further requirement would be that the times of operation would have to meet the users' needs for this form of transportation, at present, this would be morning and afternoon / early evening hours.

Generally, you have to distinct between heliports and helipads. Whereas, a helipad provides enough space for take-off and landing, heliports also offer infrastructure services and facilities such as maintenance, fuelling, or hangars.[189]

In the helicopter capital Sao Paolo several hundred helipads (mainly rooftop ones) exist. Also larger heliports, like the "Helicidade", are in use where hanger space is available; where people can get fuel and maintenance service, flying schools are integrated and even VIP meeting rooms exist.[190] While in Sao Paulo the helipads are mostly located at high-rise buildings of corporate headquarters, office buildings or 5-star hotels offering the direct arrival of customers and guest to these locations, they also sell slots for others who want to use the pads to arrive in this area or be lifted off from there.[191]

[189] Cwerner, (2009)

[190] Cwerner, (2006)

[191] Cwerner, (2006)

Figure 3.10: Picture of the Helicidade heliport in Sao Paulo with hangar facilities

Source: Helicopter Life, (2011)

In Germany, the Air Traffic Act allows air vehicles (including helicopters) only to be operated from authorised airfields, exceptions are emergency situations or landings operated by emergency services and ULs below a MTOW of 250 kg.[192] Also in other European countries such as Denmark, Holland or Poland ultra-lights are restricted to legal airfields, in other countries (France, Spain, Czech Republic) no airfield mandatory for ULs exist and they are allowed to start and land also from other suitable sites if the property owner allows it.[193]

It is difficult to assess how many helipads are currently existent in different European cities. On a voluntary basis, the homepage "helipad.org" lists some of them (mostly hospital helipads) mainly located in Germany, Switzerland, Austria, Luxembourg and Austria.

For our Travel Scenario (see chapter 2) the starting point could be somewhere around Frankfurt in a residential area and the destination could be the CBD of Frankfurt on the Main The "helipad.org" database lists only two helipads (used for hospitals) but further helipads could exist on some of the multi-storey buildings or future ones could be imagined on these buildings. For the less densely populated areas around Frankfurt probably no proper official helipads exist today but suitable areas and spots should exist (e.g., football grounds, parking areas, etc.) that could be assigned as take-off and landing sites. It also could be imagined to use some sites only temporarily in the morning and evening hours for the purpose of PAV landings and take-offs.

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[192] Bundesministerium der Justiz, (2010b);

[193] pilots24, (2002)

Already in 1910, the French architect and city planner Eugéne Hénard thought about potential rooftop landing zones for airplanes located on six-storey buildings of the future with underground hangars for airplanes that could be reached by elevators.[194] An overview of historic architecture visions and current examples concerning helipads is given in the book "Helidrome Architecture" by de Voogt, (2007).

This last example illustrates that the idea of intensive rooftop landings is not new and, partly, also associated questions of parking vehicles were already addressed.

3.3.4 Parking and Storing of the PAVs

While the parking and storing possibilities might be less critical in the sparsely populated areas where, nevertheless, the noise topic has to be considered (see chapter 3.4.3), this issue seems more complex in already congested inner city areas were also parking space for cars is limited and costly. [195] Strongly connected with the question of where to park the PAVs is the question if they can fly autonomously or not and the question if they fit into current automobile dominated and centred infrastructure of the present urban environment. The last question can be answered positively assuming that the dimensions of the Reference PAV will be in the range of a conventional car and, further, assuming a certain ground moving ability. For other PAVs with greater dimensions exceeding this "car infrastructure compatibility" the situation would be different.

The first question regarding the possibility of the PAV flying itself to a suitable parking spot should not be very different to the full autonomous level of flying described in the previous chapters and the UAV with human cargo concept. This could mean that the PAV would transport the user to its desired place and then fly autonomously to the next free PAV garage or parking spot.

On the parking spot an automated parking system such as they are already in place for cars since the 1950s could be used to store the PAVs in an automated and space saving manner.[196] These systems use lifts and carriers to move vehicles through the parking system; the user parks the vehicle at an entrance point and gets it returned upon request in only a few minutes.[197] The same could be imagined for PAVs with the difference that the PAV would check-in and -out by itself without a person on board.

Another option that is connected with the business models (see chapter 3.4.1) is the case that PAVs are not parked and unused most of the time, but shared in private user communities or renting concepts, for example, which would reduce the pressure on parking space.

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[194] de Voogt, (2007, Rodrigue, (2009)

[195] Rodrigue, (2009)

[196] skyparks, (N.N.))

[197] skyparks, (N.N.)

3.3.5 Support Infrastructure

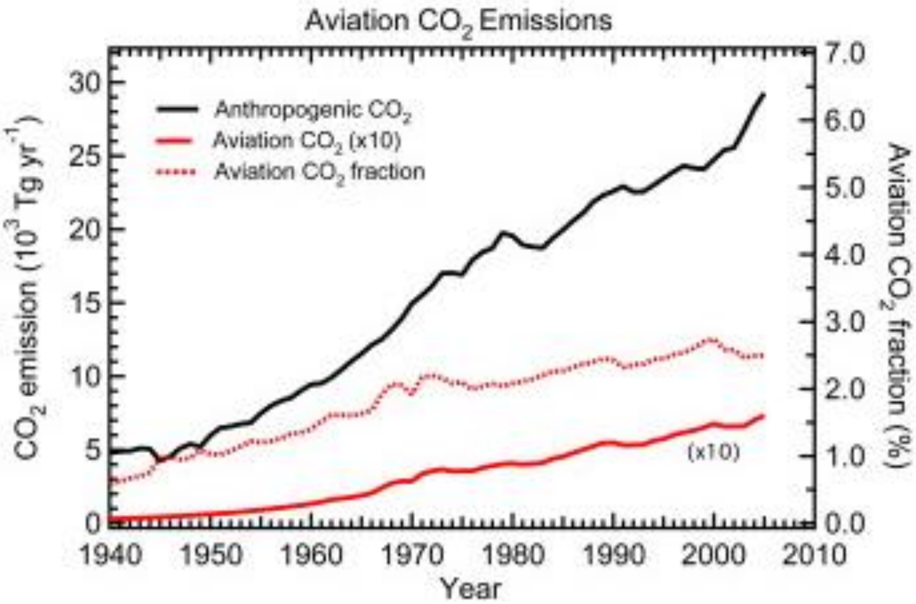
Besides the already mentioned physical infrastructure needed for take-off, landing and parking of the PAVs, also services like "user training" (similar to conventional piloting schools), places were maintenance, repairs, and refuelling or recharging of the vehicles can take place, are necessary. Today's helipads often do not provide fuel and helicopters have to travel to smaller airports or other places to be supplied with it. As the range of the myCopter Reference PAV is quite limited, a denser network of these frequently needed services like energy supply would probably need to be offered and could perhaps be integrated into the parking spots.

3.4 Socio-Economic and Ecological Challenges

In addition to the technical challenges that have to be overcome to construct safe and easy to handle PAVs, the socio-economic component and the ecological impact of the PAVs will have to be looked at. Some of the ecological aspects of PAVs such as noise and harmful substance emissions as well as their energy consumption will be key elements in the process of opinion making for the general public, NGOs, and politicians on this form of transportation.

Air traffic has increased considerably since the 1960s and contributes between 2 and 3 % to the total annual anthropogenic carbon dioxide emissions (see Figure 3.11).[198] The greenhouse gas emissions are of special concern because they are ascribed to have an enhanced global warming effect (factor 2-4) due to their place of formation at high altitudes. [199]

Figure 3.11: Growth in CO_2 emissions in teragram CO_2 per year for "all anthropogenic activities and from aviation fuel burn (left hand axis), and the fraction of total anthropogenic CO_2 emissions represented by aviation CO_2 emissions (%) (right hand axis). Note × 10 scaling of aviation CO_2 emissions."[200]



Source: Lee et al., (2009)

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[198] Wickrama et al., (1999)

[199] Wickrama et al., (1999)

[200] Lee et al., (2009), p.3522

This subchapter will focus especially on two of these ecological impacts, the noise issue, which is already a big topic for operators of airports and manufacturers, and the energy consumption topic. Other aspects such as the social acceptance and the expectations of society at large concerning PAVs will be investigated in Task 7.3 of this WP in the second and third year of the project.

3.4.1 Economics & Business Concept

Although it is difficult to picture an absolutely clear business concept for the PAV at the moment, certainly - similar to the automobile sector - different ownership and “utilisation” models are thinkable.

One would be a PAV-sharing model where companies would offer this new form of transportation and people could get a membership with either a certain amount of flight hours per month included (flat-rate model) or with pay for every individual trip. Such companies could be established ones expanding their portfolio like Peugeot does it with its “Mu by Peugeot” program and the goal to become a mobility provider.

Also private sharing models could be pictured where neighbours would partner with each other to buy and use PAVs together, or private PAVs are rented by individuals as it is already being organised by internet platforms like “take my car” (http://www.tamyca.de/) who organise car-sharing among private persons in Germany. Another option could be that companies would integrate PAVs into their normal company vehicle fleet and would offer them like staff cars to their employees.

To the general costs concerning PAVs no detailed investigation has been seen as meaningful, at present. What certainly can be stated is, that actual pilot training is more expensive than a car driving licence, especially, if one considers PPLs (the costs for a PPL(H) start from 25000€)[201] . On the other hand, ultra-light licences are comparably cheap, with costs of around €4000.[202] On top of this come costs for keeping the “pilot certification”, costs for maintenance, repairs of the PAV, fuel, and more.

Depending on the level of autonomy and automation the pilot training costs will decrease certainly but the high purchase prices for PAVs (see chapter 1.3) and running expenses remain unaffected.

3.4.2 Energy Consumption

One major topic contributing to the environmental input and to public acceptance or compliance with political goals in the field of greenhouse gas reductions will certainly be the question of how much energy the PAV will consume. To investigate this, a power requirement calculation for an example mission by the Reference PAV was undertaken by partners of the DLR Braunschweig. For the reference flight a distance of 30 km and a cruising altitude of 500 m above ground level with an average cruising speed of 175 km/h were assumed. Climbing and descending are expected to take place vertically at a speed of 5 m/s, respectively -5

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[201] HeliAviation, (2011)

[202] Nagel, (2011)

m/s.[203] A preliminary design study has led to the following parameters for the calculation regarding the Reference PAV (Table Table 3.7), only the MTWO was taken from the internal workshop results.

Table 3.7: Reference PAV parameters resulting from a preliminary design study

parameter	value	description
m	450	MTOW
n_r	4	number of main rotors
R	0.86 m	rotor radius
A	9.29 m^2	rotor disk area
n_b	3	number of blades
c	0.11 m	blade chord
σ	0.12	solidity
ΩR	200 m/s	rotor tip velocity
C_{d0}	0.009	profile drag coefficient
f_d	0.42 m^2	equivalent drag area
κ_W	0.95	wake contraction due to ducting

Source: Gursky, (2011)

Based on these parameters the power requirements in hover (P_{hover}) and for the cruising flight (P_{cruise}), consisting of induced, profile and additional parasite power, were calculated.[204] Furthermore, the power needed for vertical climb (P_{climb}) and descent (P_{des}) was calculated.

The total energy consumption for the reference flight (C_{ref}) was calculated according to the single power requirements for climb, cruise, and descent and the duration of the single flight periods:

$$C_{ref} = P_{climb}t_{climb} + P_{cruise}t_{cruise} + P_{des}t_{des}$$

The durations were calculated using the velocities and distances mentioned before (t_{cruise} = 617 s, t_{des} = 100 s and t_{climb} again 100s).

With P_{climb} = 66.54 kW, P_{cruise} = 55.60 kW and P_{des} = 51,35 kW the total energy consumption sums up to C_{ref} = 12.81 kWh for the reference flight.

To compare this with other energy densities provided by liquid fuels, you can generally say that the energy density of batteries is two orders of magnitude below the one of liquid fuels.[205] A Li-ion battery with a power output of 16 kWh, like the one used in the Opel Ampera,

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[203] Gursky, (2011)

[204] Gursky, (2011)

[205] Fischer et al., (2009)

currently, has a weight of around 200 kg.[206] This would mean that the provision of electric energy to meet the energy consumptions of the myCopter Reference PAV for a 30 km flight would be in this weight range. Although right now too heavy for the framed vehicle with a maximum take-off weight of only 450kg, these rough estimates shows that the development is on the right way and in the necessary order of magnitude, already.

3.4.3 Noise

Complaints from residents in the greater London area about helicopter noise:[207]

> *"It is literally impossible to listen to a TV, even at full volume, whilst a helicopter is passing by and impossible to have a telephone conversation unless all doors and windows are closed which, in Summer time, is unbearable. It is only when you live here day in, day out that you realise how damaging the Heliport noise is to one's enjoyment of living here." (Fulham resident)*
>
> *"The noise from the helicopters is so bad that our living room windows, which face the river, actually shake and rattle." (Battersea residents)*
>
> *"We do understand that living near the Heliport must involve a certain amount of inconvenience and noise disturbance but feel that it is now getting out of control and affecting our lives." (Battersea residents)*

Noise pollution is of major concern of citizens not only in the EU, but also in Japan and in the United States.[208] The European Commission stated in their Green Paper on Future Noise that environmental noise is one of the main environmental problems of Europe.[209] Older data from the EU estimate that around 20 % of the Union`s population (around 80 million people) are exposed to noise levels that are considered to be harmful in terms of health issues, leading to annoyance, sleep disruption, and more.[210] Although individual noise levels of cars, trucks, and aircrafts are decreasing, this success is offset by traffic growth on the ground and in the air.[211]

Unfortunately, the data records on noise exposure in the EU are poor.[212] Nevertheless, it is obvious that air traffic noise is one of the main sources of noise annoyance. This is confirmed by survey data from the Netherlands which the European Commission Working Group on Health and Socio-Economic Aspects mention in their position paper on night time noise. The survey (carried out in 1998 and 2003) asked people to what extent their sleep was disturbed

[206] Langbein, (2010)

[207] london.gov.uk, (2006, London Assembly, (2006)

[208] Schomer, (2001)

[209] Commission of the European Communities, (1996b)

[210] Commission of the European Communities, (1996)

[211] Commission of the European Communities, (1996)

[212] Commission of the European Communities, (1996)

by noise from different sources, and the result was that air traffic ranked third behind road traffic and neighbours' noise.[213]

As mentioned before, noise exposure is thought to have several negative effects on health and the overall well-being, such as sleep disturbance, indirect effects on mental illness, physiological and performance effects.[214] While the effects on health are not always easy to detect and often build up subtly over time, noise has also a more direct effect on people by disturbing them in their present activities, be it a conversation, watching tv, or trying to find relief from work stress at home. Noise can be loud and obtrusive or also very vague. What seems to be a common character of noise is that it is unwanted, uncontrolled and unpredictable.[215] Generally, noise could be defined as being the "negative evaluation of sounds that are judged to be disruptive and intrusive".[216] As this definition stresses the individual perception of human beings and offers no real comparableness, another approach is the quantification of this perception, to give the legislative bodies and other actors the possibility for comparable measurements.

This quantification is done by sound measurements and the basic concept for these noise measurements are described in the following box.

Excursus: noise measurement (summary of a corresponding chapter in the "Guidelines for Community Noise by the WHO)[217]

To measure noise, several attempts exist. Generally, they take into consideration the frequency content of the sounds, the overall sound pressure levels (measure of the vibrations of air), and the variation of these levels over time. As the spectrum of human hearing is very broad, the sound pressure levels are measured on a logarithmic scale in the unit of decibels. Most sounds are a mix of different frequencies (a frequency being the number of vibrations per second of the air measured in Hertz (Hz)), and the frequency range of the human hearing is generally considered to be between 20 – 20,000 Hz. As the hearing system is not equally sensitive to all frequencies, the environmental noise measurement applies different frequency weighting to compensate for this. A widely used weighting is the "A-weighting" where lower frequencies get less and mid- and higher frequencies get a higher weighting. Measurements using this filter are indicated by the added letter A behind the decibel unit.

For the measurement of more continuous sounds, such as road traffic, the energy average equivalent level of the A-weighted sound over a certain period of time LAeq,T is advised to be used by the WHO Guidelines for Community Noise. The LAeq,T is the sum of the total energy of a sound event over a certain time and stands for the level equivalent of that average sound energy.

[213] European Comission Working Group on Health and Socio-Economic Aspects, (2011)

[214] see further details in Berglund et al., (1999)

[215] Bronzaft, (N.N.)

[216] Bronzaft, (N.N.)

[217] Berglund et al., (1999)

For more isolated sound events the WHO advises the use of the maximum noise level (LAmax) or the A-weighted sound exposure level (SEL). Additionally, different LAeq, T for day, and night times are often used, whereas, the night-time LAeq,T is based on the assumption of an increased sensitivity to noise during night hours.

The noise emissions of myCopter – and its impacts – will be an important issue throughout the project. A first impression is that this issue is difficult to address both in terms of an overall accepted strategy for measuring or mapping noise emissions and in terms of an evaluation of the individual level of noise perception and annoyance.

For the latter issue two projects that could be helpful in this regard, are known, SEFA (Sound Engineering for Aircraft) and COSMA (Community Oriented Solutions to Minimize Aircraft Noise Annoyance), under the framework of the X-Noise network[218],. The SEFA project (2004 - 2007) was a first approach to reduce noise annoyance by lowering the noise level itself but also by changing the characteristics of aircraft noise signatures.[219]The COSMA project is continuing this work and has the aim to reduce the perceived noise annoyance by 50 % until 2020.[220]

For a better placement of some following statements about allowed noise levels, here some examples about sound emission levels of common sounds.

Table 3.8: Sound emission levels (A-weighted) of some common sounds

common noise source	sound level dB(A)
Rock Band	119
Chain Saw	110
Motorcycle at 25 feet	89
Lawn Mower	85
Garbage Disposal	80
Living Room Music	74
Vacuum Cleaner	70
Auto at 100 feet	63
Typical Conversation	60
Air Conditioner at 100 feet	58
Quit Urban Daytime	49
Rural Daytime Outdoors	40
Threshold of Hearing	0

Source: United States Air Force - Air Combat Command, (2001)

[218] X-Noise is a 6th Framework Program Project running from 2006-2010 dedicated to lower the exposure of communities to aircraft noise, Aubert, (2011)

[219] European Commission, (2011a)

[220] European Commission, (2011a)

It should be remembered that this decibel scale is logarithmic and that, therefore, it makes a great difference if one is exposed to 50 dB or 55 dB. Older date publications of 1999 from the WHO for the European Union report that more than 40 % of the population are exposed to noise levels from road traffic exceeding 55 dB(A) equivalent sound pressure level during daytime, and 20 % are even exposed to levels exceeding 65 dB(A).[221] During night-time, more than 30 % of the population is exposed to sound pressure levels exceeding 55 dB(A) which is expected to cause sleep disturbances.

But noise is not only a topic for affected residents living close to helipads, airports or flight routes. It is also a major issue for pilots who feel restrictions and are forced to noisy friendly flight profiles especially for take-off and landing. This conflict is sharpened by the aspect that helicopters (beside the helicopter flights for emergency and police services) are often perceived as a rich man`s toy, a transport option for only a very few people which effects a lot of people negatively, though, who never will have an advantage from their operation.[222]

The noise topic is highly debated internationally with a wide range of opposition from people living close to heliports or routes where helicopters frequently fly. The noise topic often also leads to stricter rules regarding helicopter operation as it has just happened in 2010 in France were a new order was published by the ministry of ecology, energy, and sustainable development, which restricts helicopter use in densely populated areas both in terms of low-noise approach procedures, but also in terms of numbers of helicopter movements and flight windows open to them.[223]

For the PAV operation there will, certainly, be specific noise standards to be respected although these thresholds could be different in the single countries and could also differ depending on settlement structure and time of the day. Besides, the actual design of the PAV - the PAV should, of course, be as little noisy as possible - also the flight heights and routes as well as the location of the landing and take-off sites and their operational hours could be changed to allow for a quieter operation.

The actual regulation for air traffic in Germany, for example, pledges pilots, vehicle owners and operators of airfields to avoid all preventable noise emissions and to reduce the emission of unpreventable sounds to a minimum.[224] In addition, special consideration is given to the peace of sleep in the Air Traffic Act of Germany.[225] Paragraph 29b also addresses the aeronautical authorities and the air traffic management organisations binding them to work towards the protection of the society against “unacceptable” noise emissions from air traffic.

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[221] Berglund et al., (1999)

[222] london.gov.uk, (2006)

[223] Taverna, (2011)

[224] Bundesministerium der Justiz, (2010b)

[225] Bundesministerium der Justiz, (2010b)

What these "unacceptable" noise emissions could be can be extracted from a report by the expert advisory board for environmental issues in Germany. They report that single air traffic noise emissions with a maximum level of 50 dB(A) indoors and / or nocturnal energy average equivalent levels of 30 dB(A) indoors increase the likelihood of sleep disturbance and wake up events.[226] Although such figures are difficult to evaluate, they shall give a reference point on what noise levels we are talking about. Easier to apply in the myCopter context seems to be the specification of noise emission levels for outdoor situations. Here, the report states noise target levels for the close future, for interim, and long-term planning for Germany, with a clear trend to reduce the emission levels over time (see Table 3.9)

Table 3.9: Targets for noise levels during day and night times as suggested by the expert advisory board for environmental issues in Germany

Targets	Day	Night
near-term	short term events of max. 65 db(A)	55 dB(A)
interim	62 dB(A)	52 dB(A)
long-term	55 dB(A)	45 dB(A)

Source: SRU, (2008), p.385

The trend for Europe seems to go into the same direction with the "Night Noise Guidelines for Europe" naming even lower targets for their indicator $L_{night,outside}$ with 30 dB as their ultimate target to protect the public from adverse effects of night noise.[227] This indicator is used for monitoring long-term effects and summarises the acoustic situation over a longer period of time, and can be understood in this context as the yearly average of night noise. The A-weighted equivalent sound pressure level is used instead for rather short-term emissions like aircrafts, for example.

The framers of the German report regard their targets as rather conservative and speculate about the need for a revision referring to research results from the DLR concerning effects of air traffic on sleep disturbance. These experts call for a much lower noise level and report increased rates of awakening already starting above a threshold of 33 dB(A).[228]

The impression from the authors is that air traffic noise, despite technological improvements, will remain a sensitive issue especially if a high number of flight operations is expected to occur, which is the assumption of myCopter. This means that even if individual noise signatures of the PAVs were decreasing, the general trend of increased ground and air traffic, makes it very likely that this topic will remain of high priority.

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[226] Ortscheid and Wende, (2000) in SRU, (2008)

[227] World Health Organization, (2007)

[228] SRU, (2008)

3.4.4 Further Aspects

Further issues concerning environmental impact and sustainability of a future PATS could be the issue of bird strikes or general irritations of the fauna, toxic substance emissions independently from global warming potential, and also the visual impacts on the sky. The creation of take-off and landing sites as well as the provision of parking space would have to compete with other uses especially precarious in the already crowded inner city areas where also the visual impression of new built ground infrastructure could become a topic of concern. Finally is also the question of social segregation and reasonableness to ask because the PAVs seem to be at least at the beginning a technology which will not be affordable and accessible for all parts of the society but negative effects (noise, local emissions, climate change) will have to be carried by all.

3.5 Integration into the Current Transport System and into Infrastructure

One main goal of the project is to investigate how PAVs could be integrated into the current transport system and into infrastructure, both in the air and on the ground. In order to reach this goal, PAVs should, for example, not rely on extensive new infrastructure to be built and dual-mode vehicles should, therefore, be based on conventional ground vehicles with respect to size. Also, for the VTOL PAV a similar size as the one of existing automobiles could be important in order to be able to use ground infrastructure for parking and storing, originally designed for car use.

Despite the just mentioned thoughts about the dimension of the PAV the important question of how PAVs could be integrated into the urban ground-based environment and the current air space is addressed in more detail in the chapters 3.3.3-3.3.5 and chapter 3.2.3 respectively chapter 3.3.2.

4 What are the Central Intended Effectsmain intended effects of a future PATS Being in Place? -On Motivations and Opportunities

There are various reasons and motivations for engineers and entrepreneurs to develop personal aerial vehicles. On the individual side, an increasing dissatisfaction with the quality of the recent air transport system (perceived decreased reliability of air traffic, jam-packed airliners, insufficient frequencies on low-density routes, long waiting times at airports, etc.) plays an important role. Some see PAVs rather as a piece of sports equipment or as a “rich man’s toy” and intend to market their development with these target groups. Other inventors simply “follow their dreams.” All these obviously different intentions are, and will be, important drivers of recent and future PAV developments. We intend to discuss them in greater depth in a future project report.

In addition to the individual advantages of PAVs, some groups mention also societal benefits of these developments. According to the Out Of The Box report, produced by ACARE and funded by the European Commission, individual air transport is expected to “avoid the ever increasing congestion on European roads and to offer an alternative for the current transport system in new (sic!) European Member States”. NASA discusses the viability of PATS as an on-demand public transportation system, especially for rural and regional traffic in sparsely populated areas of the U.S. where public transport options usually do not exist and personal transportation is closely “tied” to automobiles, and, thus, promises PAV “to provide a benefit to a more significant portion of the public than current General Aviation aircraft”.

Congestion is a topic 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 to 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 costs. 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 Euros annually, by 2050.

Other effects which could emerge in the long term if a larger part of today’s road traffic would be transferred into the third dimension via PAVs would be the need for less road infrastructure on the ground. This might be of special interest since building of new road infrastructure is less and less a practicable solution for various reasons: In many European countries, new roads are a matter of public debate because of a growing concern about their impact on the environment. In addition, national and local governments are under increasing pressure due to public deficits and debts which limits their capability to invest in new ‘hard’ infrastructure. More cost-effective solutions would have to be found to overcome capacity problems in transportation systems. Therefore, an impact assessment of PAV / PATS should include an analysis of the effects of PATS deployment on road transport and individual travel times.

Another effect of PATS could be the potential for other life-styles with even further distances between living and working places being covered. Cohen (2010) calls this “more geographically extensive lifestyles”. Associated with this, a change in the urban framework could follow what he refers to by mentioning “hyper-suburbanized” settlement patterns. Other effects which could emerge in the long term, if really a larger part of today’s road traffic would be transferred into the third dimension via PAVs, would be the need for less road infrastructure on the ground.

One reason to look into individual air transportation is the motivation to disburden the infrastructural system on the ground, mainly, the often congested road system during peak hours. The PAV transportation option could bring time savings to the individual users on their way to and from work and, at the same time, reduce the amount of vehicles competing for space on the roads. These two effects, one on the individual user level, the other one on the broader infrastructural level will be discussed in the next section.

4.1.1 Effect on Road Traffic

For methodical reasons, a general assessment of the impact of PATS on European road traffic will be difficult. The impact of PATS may differ considerably, depending on the respective local situation. To gain a first insight into the potential effects of PATS deployment in densely populated areas, we will follow a case study approach.

In the first case study, we intend to focus on the Rhine Main area – in line with the weather considerations – around the city of Frankfurt. For yet to be identified main arteries into the city center, we will assume a substitution of 10 % of road traffic by PAVs in the morning and evening rush hours, and calculate the impact of this substitution on the traffic situation using assignment calculation methodology, and, at the same time, trying to determine the operational and infrastructural requirements of the modeled PAV traffic.

4.1.2 Effect on individual travel times

To picture the daily situation of commuters in practical, “narrative” scenarios were developed to structure and deepen the assessment. These travel scenarios were introduced in chapter 2. Right now, for the estimation on individual time savings, for a rough calculation, we only take two basic assumptions of these scenarios into account, namely the travel distance of 30 km and the average cruising speed of 150 to 200 km/h.

We assume a pre-trip time used for arriving at the vehicle, for getting it ready, and for preparing the flight. This pre-trip time is thought to be between 5 to 10 minutes depending on where the PAV is stored, where the take-off site is, and how automated the information about weather situation, etc. can be gathered. The pure flight time for 30 km distance at 150 km/h would be 12 minutes. Because gaining height and descending will occur at much lower speeds, 15 minutes were taken for the pure flight time. The landing, parking and arriving at the desired destination was thought to be quicker than the pre-trip phase because other users could take over the vehicle or the landing site is managed so that the user can get out and go while somebody else takes over the PAV for recharging, resp. parking. Therefore, 5 minutes are assumed in our numeric example for the after-trip phase.

Alltogether, this would sum up to 25 to 30 minutes for the whole way. This has to be compared to a car trip were you normally can start straight away and, assuming that a free parking place exists at the destination; you have no real after trip time to consider. Nevertheless, for a trip distance of 30 km we would need an average travel speed of 60 km/h by car to outplay the travel time of the PAV.

To put that into context to the actual situation on European roads here some numbers from a study form the international traffic information technology company ITIS Holdings published in 2008. They analysed the average speeds in 30 European cities by tracking cars within a 16 square mile area with GPS during a few months in 2007.[229] The results showed that cities like London have average speeds of around 19 km/h, Berlin was second last with around 24 km/h and Warsaw third last with 26 km/h. The speeds go up with Paris for example having 32 km/h, Prague 37 km/h, and Vienna 46 km/h. These speeds are average speeds, not only measured during peak hours, and also highly depended on the road infrastructure system existent in the different cities and on the alternatives which people have to use, namely, other modes of transport. But this still creates the impression that the 60 km/h average travel speed for a car might not be easy to achieve in many major cities, especially during rush hours.

[229] Olson and Nolan, (2008)

5 PAVs as an innovation – perspectives from literature

Transport is of utmost importance for our daily life and it has changed remarkably over the last 150 years, triggered by ground-breaking innovation for all modes of transport. For example in the aviation sector itself, the penetration of jet aircraft and the commercialisation of civil aviation surely were the most striking changes in this field - innovations that completely changed travel and mobility patterns of the citizens in Europe and elsewhere. Also for the future it can be expected that innovations will induce changes in the transport system. PAVs might be one of these future innovations.

There is a broad and growing body of literature on innovation processes, on factors influencing the success or failure of innovation and on the analysis of innovation systems. It is widely acknowledged that technological developments do not take place in an isolated realm but are embedded in society and are dependent on societal preferences and values.[230] The transport sector is an interesting field for studying innovations. Transport is derived demand; most of the daily trips are not undertaken for the trip itself but for fulfilling other purposes such as going to work, shopping or leisure activities.[231] Transport is a complex socio-technical systems, it is influenced by the mutual relationship between options provided by organisational and technical innovations on the one hand, and by the preferences, habits and routines of its users on the other hand. This complexity needs to be taken into account when assessing future innovations such as the development of PAV.

This is a scoping report and not the place for a detailed prospective analysis of the future developments of PAV in the transport system. However, it should be part of the scoping report to illustrate the relevance of experience and literature related to innovations processes. Therefore in the following some issues are raised and briefly illustrated which seem to be important for further work to be carried out in the course of this project. This is done along the following themes:

- Transport as a changing socio-technical system
- Transport as a system of “established surprises”
- Rogers’ criteria for the successful diffusion of innovations and their relevance for PAVs
- Transitions in socio-technical systems and the relevance for PAVs

These issues are briefly touched in the following sub-chapters.

5.1 Transport as a changing socio-technical system

Establishing PAVs in the transport sector would mean a significant change to the established technology-infrastructure system - as it was illustrated in previous chapters of this deliverable. However, significant changes are rather the rule than an exemption in the transport system. The transport system is not static, it has changed over time and still it is underlying changes. Some of these changes are desired, induced or accelerated by decision makers, such as the

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[230] see Halbritter et al., (2008), p.60

[231] see Banister, (2002)

development towards a sustainable transport system. The recent White Paper on transport sets ambitious targets for 2050.[232] Meeting targets such as for, example, banning oil-based cars form city centres, would again change the system.

Technological progress always played a crucial role for changing the transport system[233]. At present, information and communication technologies (ICT) are gaining importance and have a growing influence on the design of transport systems (e.g. public transport priority at intersections, public transport information, mobile phone ticketing, Car2Car communication etc.).[234] Further, for several reasons (climate change, peak oil) the need for alternatives to oil based propulsion in the next decades is increasing[235], and new fuels and propulsion systems are being developed. Changes in the transport system reflect the development of innovations and technological progress, but also response to changing external legislation (e.g. CO_2 limits, transport in the emission trading system). A wide range of policy measures have proved to be able to influence the transport system (congestion charging, car-sharing) and transport behaviour.

It is widely acknowledged that innovations and technological development are strongly driven by preferences, attitudes and paradigms of the various actors, in particular users, politicians and other policy makers, which makes transport a highly complex issue.[236] However, it is not only the technologies but also these goals, visions or paradigms for transport that change over time, and this has considerable implications for technological developments and organisational innovation. In this context, it is important to understand innovations and technological developments in context of paradigms, or guiding principles, that exerts large influence on the design and development of a socio-technological system, in our case the transport system. It is recognised that paradigms have the power to foster distinctive technological “trajectories”. Dosi et al. (Dosi, (1982) and Dosi et al., (1988)) discuss a “meta-paradigm” as a “dominant technological style whose ‘common sense’ and rules of thumb affect the entire economy.”

If this concept is applied to the transport sector, it becomes obvious that paradigms are indeed changing over time. For example, in the 1960s and partly also in the 1970s, in many European countries the leading paradigm for urban transport was to create a city that was optimised for motorised individual transport, with broad roads and parking spaces (see Figure 5.1). Public transport was considered as being old fashioned and in many cities tramway lines were removed. In the 1970s, there were calls for integrated transport solutions, whereas in the 1980s deregulation and liberalisation of access to the markets became important issues[237]. In the meantime, the paradigm of “sustainable transport” has become a well established key-concept.[238] Visions on the future transport system look quite different compared to the ones 30

[232] CEC, (2011)

[233] see Schippl et al., (2008)

[234] see Schippl and Weinberger, (2009)

[235] see Schippl et al., (2007)

[236] see Halbritter et al., (2008)

[237] see Viegas, (2003)

[238] see Banister, (2007)

or 40 years ago (see Figure 5.2). In general, the vision of sustainable transport is putting a strong emphasis on an attractive public transport system and, thus, on technologies supporting such a task. The Commission's 2001 White Paper states at the very beginning that "a modern transport system must be sustainable from an economic and social as well as an environmental viewpoint"[239]. Decoupling of economic growth from transport growth is a central target. Integration and modal shift are key concepts in the White Paper, whereas the 2006 Mid-Term Review of the White Paper slightly shifts the focus by introducing the concept of co-modality. The underlying idea is that all modes must become more environmental friendly, safe and energy efficient[240].

Figure 5.1: Visions of a future transport system of 1959 and 1961

Source: Bürgle, (1959)

Figure 5.2: Perspective of Malmös future transport system as an example for a sustainable transport vision

Source: Ljungberg, C. (2010).

[239] CEC, (2001) already in the 1992 Transport White Paper term "sustainable transport" was in the title CEC, (1992)

[240] CEC, (2006)

The White Paper from 2011 is sharpening the conceptual basis for the European transport policy by setting clear and ambitious goals to be achieved in 2050.[241] But in spite of the long time horizon that is a point of reference for many statements and goals in this White Paper, PAVs are not playing a role in this document, nor do they play a role in other long-term transport concept or policy programmes on European or on national level. Obviously, the relation of PAVs to sustainable transport, their possible role in the visions and paradigms relevant for the European transport future need to be clarified.

5.2 Transport as a system of "established surprises"

Up to now, PAVs do not appear in any official transport concepts in Europe. Obviously it is hard to imagine for many experts and decision makers that PAVs are becoming an established part of the transport system. However, it can be argued that most striking developments in the transport sector where not anticipated by larger parts of society as long as these development were in its infancy. In this context it is interesting to look at history, and at how other modes of transport where perceived by society before they had their take-off of phases in the innovation process.

Nearly in all modes of transport, examples can be found for developments that were surely not anticipated by most actors of the "incumbent" systems - transport can be considered as a system of "established surprises".

In some cases, even the inventors or developer of new technologies did not fully believe in a strong market penetration of new approaches. For example, it is reported that in 1901 Gottfried Daimler argued that the global demand for automobiles will not exceed one million vehicles.[242] In his view the limiting factor was the number of existing chauffeurs for driving these vehicles. Today we all know that Daimler definitely underestimated the potential of his own invention. It seems as if he did not fully anticipate

- that technological progress will be able to adopt the vehicles to societal needs, preferences and attitudes;
- that society would be able to adopt to the car-technologies, in terms of skills for driving them but also in terms of infrastructure and in terms of regulations and policies.

Another prominent quote is coming from the German Kaiser Wilhelm II, a person which was surely not known for his technologies skills. Nevertheless, he was an important societal person and stated in the early 20th century that the car will only be a temporary phenomenon. In his view, the future of individual transport would clearly belong to the horse. But also experts failed regarding their assessment of future developments in the transport sector. For example in 1898, in a Swiss Journal on Electrical Engineering it was stated that the future definitely

[241] CEC, (2011)

[242] See for example http://www.faz-institut.de/sites/default/files/Innovationsprojekte/Dokumente/Zukunftsmanager/Zukunftsmanager-3-2011-V2.pdf

belongs to the electric powered vehicles („Es steht außer Frage, dass die Zukunft dem elektrischen Wagen gehören muss“[243]).

Furthermore, many examples can be found that illustrate that not only the technologies but also regulatory frameworks became highly important for development of technologies. A well-known example is Britain’s Red Flag Act. In 1865 Britain introduced the 'Locomotives on Highways Act'. Better known as the 'Red Flag Act'. The act stipulated that all mechanically powered road vehicles must:

- Have three drivers.
- Not exceed 4 mph (6.4 kph) on the open road and 2 mph (3.2 kph) in towns.
- Be preceded by a man on foot waving a red flag to warn the public.

In 1896 the act was withdrawn and the speed limit increased to l4 mph (22 kph).[244] This opened the pathway to individual motorisation.

There obviously was a high degree in uncertainty regarding future developments in the transport sector. It was always difficult to assess the pros and cons of new modes of transport and the potential impacts of these technologies. Also railways need some time get accepted. In the mid 19th century many people, including doctors, considered railways as something really evil. It was believed that the relatively high speeds would harm human health, the smoke would harm birds and that cows close to railway station would produce less milk.[245]

“Surprises” or ground breaking innovations can also be triggered by external factors. An example is the history of the bicycle. It is reported that the work of Karl Drais, which is considered as the basis for the development of modern bicycles, was actually triggered by a shortage in food for horses in the mid 19th century (oat crises). This situation enabled him to frame his idea as an alternative to horse powered individual transport and to acquire resources for his project.[246]

There are many more examples that prove that the history of transport is full of surprises and wrong or misleading prospective assessments of innovation processes and their impacts. Last but not least a recent case should be referred to, which illustrates that not only technological but also organisational innovation can matter heavily when it comes to the design of the future transport system: Whereas it was believed for a long time that people want to own their car, the recent success of car-sharing schemes in several European countries illustrates that this preference for owing cannot be taken for granted anymore.

Moore describes the current aviation market to be in an “innovator`s dilemma” where only small improvements materialize who struggle to meet the ever increasing demand Moore, (2006). Looking at the history of transport a strong tendency towards faster and more convenient modes of transport is clearly visible. If you look at it from this angle, it is not

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[243] Schweizerische Blätter für Elektrotechnik, 1898

[244] http://www.carhistory4u.com/the-early-history/general-information/britains-red-flag-act

[245] http://www.planet-wissen.de/natur_technik/eisenbahn/geschichte_der_eisenbahn/index.jsp

[246] see Lessing, (2003)

unlikely, that there is some demand for faster modes, such as PAVs. But PAVs would indeed be a ground-breaking innovations. The examples above illustrate that it is difficult to assess how a system such as the transport system will change in future and that many different factors and criteria need to be taken into account for such an assessment.

5.3 Rogers' criteria for the successful diffusion of innovations and their relevance for PAVs

As in other areas, innovations of the transport systems have to be adopted by the users to become effective. Users decide on the rejection or the adoption of an innovation and hence on the success of an innovation. In his book on the diffusion of innovations Rogers, (2003), distinguishes between five criteria of innovations. These criteria influence individual decisions on adopting or rejecting an innovation, and thus explain the different rates of adoption:

1. *Relative advantage: is the degree to which an idea is considered better than the idea it replaces. It is not only the objective advantage, such as economic factors, which is important but also prestige factors, convenience, or satisfaction.*

It was already mentioned above, that increasing speed always has been an important trigger for innovations in the transport sector. But also other aspects mentioned by Rogers could be applied to PAV. It is imaginable that PAV are becoming a status symbol. But also the contrary is imaginable, if PAV would be perceived, for example, as a non-sustainable privilege of the upper class. In terms of convenience much is depending on technical progress, as it is illustrated in the previous chapters of this report (see for example Chapter3).

2. *Compatibility: is the degree to which an innovation is considered to match with existing norms and values. If compatible, the innovation will be adopted more rapidly than an incompatible innovation.*

Regarding this conceptualisation of compatibility, it is important whether PAV are able to cope with the idea of a sustainable transport system. For example Cohen (2010) argues that "personal aeromobility" might be considered as a challenge to sustainable transport and points at potential social controversies or "rival social aspirations regarding personal air transport, the pursuit of faster and more convenient forms of travel".

3. *Complexity: is the degree to which an innovation is considered as difficult to understand and use. Ideas that are easy to understand are adopted more rapidly than innovations where new skills and understandings need to be learned by the adopters.*

The way it is put here, complexity could be a considerable hurdle for PAVs. In contrast to other modes of transport, using a PAV would mean something completely new for most parts of society. Driving a car actually is not an easy task in itself, but we are used to it. For flying in the air, it strongly depends on the degree in automation to what extend new skills and understandings are needed.

4. *Trialability: is the degree to which an idea could be tried out prior to adaptation. An innovation that could be experimented with represents less uncertainty to the individual adopters*

Again this could be a hurdle in the beginning, since most people do not have the opportunity to use a PAV. Simulations and trainings could be crucial in this context.

5. Observability: is the degree to which effects of a new idea are visible. The more visible results are, the more likely the idea will be adopted; additionally visibility can stimulate peer discussions.

This is surely a highly important point for the success or failure of PAV. A peer group is needed that is making PAV “visible”. Once in use, a PAV definitely is visible in an urban area. However, effects such as noise could also be considered as negative by observers.

According to Rogers (2003), an innovation is more likely to be adopted and disseminated at the community and population level if it fulfils all these criteria at once. He states that the adoption of an innovation is not an instantaneous act but a process which an individual passes through. At the beginning individuals gain knowledge about the innovation to further form an attitude towards it and then make a decision whether to adopt or reject it. Finally individuals implement the innovation and at last confirm their decision. This set of criteria indicates that individual choices are influenced by much more than “rational” economic calculation. Norms and values are of importance, and so are factors such as visibility or traceability which are not directly related to rational economic arguments.[247]

5.4 Transitions in socio-technical systems and the relevance for PAVs

In this chapter the some of the literature related to the transition of socio-technical systems is referred to, since it basically looks at the entire system and its environment, but is also using the notions of “niches” in which new technologies might be able to develop. The related concept in this context is the multi-level perspective (see Figure 5.3) which has originally been developed by Rip and Kemp, (1998) and refined by Geels, (2004). It understands transition as “outcomes of multi-dimensional interactions” between three different levels: the micro level (or niches), the meso level (or regimes) and the macro level (socio-technical landscape).

The macro level relates to the slow changing exogenous environment which influences niche and regime dynamics. Overarching paradigms, macro economy, material infrastructure, environment, and demographics characterise this level. *The meso level* refers to socio-technical regimes like the dominant culture, practices, and rules that guide private action and public policy. *The micro level* relates to niches, such as individual or social actors, technologies, and local practices which differ from the incumbent regime. At the micro level novelties emerge in small markets, usually protected from mainstream markets.[248] According to Rotmans, (2010) fundamental changes of structure, culture, and practices in societal sub-systems occur relatively rarely, usually it takes decades to change (1-2 generations).

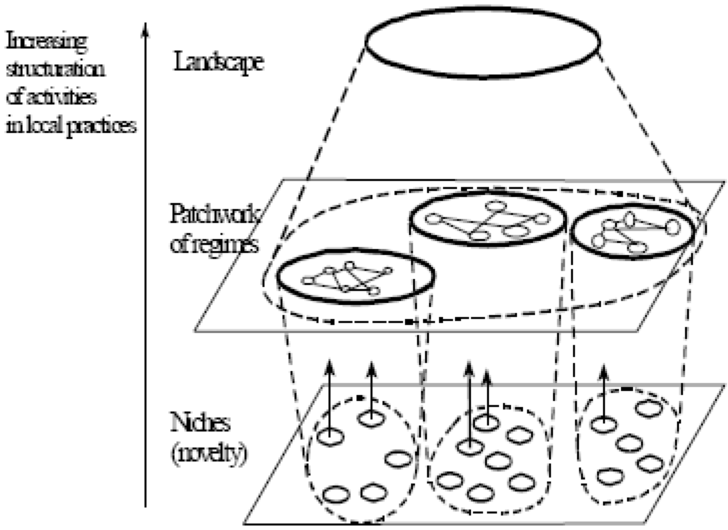
To analyse transitions it is useful to look at the mechanisms and events that are likely to lead to a transition. In earlier studies of Geels suggest a bottom-up pattern of transition where radical innovations emerge at the niche level, break through and finally depose the existing

[247] see also Puhe and Schippl, (2011)

[248] see Rothmans et al., (2001)

regime. More recent studies expect more encompassing pathways.[249] Those pathways are characterised by the main agents involved in the process and the type of action happening at different levels.

Figure 5.3 : Multiple level perspective



Source: Geels, (2005)

If applied to PAVs it seems as if the development of niches plays a crucial role to overcome the barrier of diffusion. According to Hoogma et al., (2002), such niches do not emerge spontaneously; they come about in the form of experiments, and pilot and demonstration projects. But this could be the place where early adopters get in touch with new technologies. This is where an early learning between users and developers can take place. This gives the opportunities for new socio-technical formation to first stabilise, than spread out and bring about a regime change or a transition to a more sustainable (transport) system.[250]

It is of utmost importance for the success or failure of PAV that early adopters can be identified and that their needs and preferences are taken into account when technological settings characterising a PAV are designed. Furthermore, to get established and become a part of the regime with its culture, practices, and rules, it seems as if PAVs need to cope with the notion of sustainable development – as long as this is the overriding paradigm in the transport sector.

[249] see Geels and Schot, (2007)

[250] see Kemp, (1994)

6 Outlook / Future Work

"The key problem is not about making a small vehicle fly, but rather how it should be operated"[251]. This statement from the Out of the Box study is in a way confirmed by our scoping report as well as the guiding questions asked in the myCopter proposal. The commuter scenario is and will be further developed as a kind of benchmark for the enabling technologies developed in myCopter. This is especially true for the tasks dealing with autonomous starting, landing and flying and by this with the human/PAV interface. The design of this interface is a crucial aspect with respect to the individual acceptance of potential early adopters. On the other hand we see the societal criteria of acceptability with respect to environmental issues. Even if there might be single technical parts to be improved or solved as for example to make the vehicles quieter, more energy efficient, lighter etc. the major challenges as highlighted in chapter 3 are safety, legal aspects concerning the vehicle itself, the airspace in which it operates and the qualification of the user but also operational challenges such as the ground infrastructure and environmental concerns regarding emissions of the PAVs (sound, GHG). The further work will address some of these key issues in more detail. The technical and operational challenges will be a main part of Task 7.2. "Technology issues" which has the main question of "what is needed to enable people flying a PAV and at the same time to make the complete system safe and reliable".[252] The potential and degree of autonomous operation, collision avoidance and traffic management will be important issues to investigate and assess. Strong interaction and overlaps are expected with the other work packages and lead to a "Design Criteria Report" for a user-friendly and "acceptable" PAV design.

Another task of the second and third year will be dedicated to find out more about the user perspectives and expectations towards PAVs and a PATS. In this task, group interviews will be carried out in three European countries and shall give input on potential PAV designs.

[251] Truman and de Graaff, (2007), p.28

[252] myCopter Proposal, (2010), p.45

7 Abbreviations

ADS-B	Automatic Dependent Surveillance Broadcast
AGL	Above ground level
ATC	Air traffic control
ATM	Air traffic management
CAS	Calibrated Air Speed
CTOL	Conventional Takeoff and Landing
EASA	European Aviation Safety Agency
E-LSA	Experimental Light Sport Aircraft
FAA	Federal Aviation Administration
FIR	Flight information regions
HFACS	Human Factors Analysis and Classification System
IAS	indicated air speed
ICAO	International Civil Aviation Organization
IMC	Instrument Meteorological Conditions
JAA	Joint Aviation Authorities
NASA	National Aeronautics and Space Administration
PAV	Personal Air Vehicle
PATS	
S-LSA	Special-light Sport Aircraft
SPS	Standard Problem Statements
SSTOL	Super Short Takeoff and Landing
STOL	Short Takeoff and Landing
UAS	Unmanned Aircraft Systems (UAS)
UIR	Upper Flight Information Region
VSTOL	Very Short Takeoff and Landing

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