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THE CHALLENGE OF MOBILITY IN EUROPE

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Executive summary

This paper briefly reviews the transport networks and socio-economic indicators affecting the development of transport and shows the share of different modes of transport in passenger transport volume in Europe.

Based on statistics and studies of mobility, carried out earlier in the framework of European programs, an assessment of accessibility and performance of main transport systems was made. Pointed out the need to fill the existing gap transport occurring in the range of 300 km to about 1200 km.

1. INTRODUCTION

Man’s natural need to reduce inconveniences effects in action that generates numerous movements. The ever changing, relatively temporal location of agents has been a part of human history and will, most likely, remain until the end of, what we call, the civilization. There are, however, various dimensions, various vehicles and subjects of movement, which we discover, facing the dawn of global information society. Expecting inevitable changes in human nature caused by the emergence of virtual worlds, we spend our lives in millions of traffic jammed cars.

Car luxury or engine power does not please as it did yesterday. Despite the efforts of manufacturers’ marketing departments, the prestige attached to road vehicle possession diminishes when a multitude of competing owners struggle for scarce parking places.

The real powers of a mankind for the sake of its survival and prosperity, which are in possession of everyone – creative minds – are in a continuous trial-and-error processes searching for optimal solutions of the day. Imagine a businessman on his five-hundred-kilometer-car-journey for a meeting, controlling time nervously and realizing “if only I had wings...”, “why do none of the airlines offer service from my region?”, “aren’t we here rich enough to be connected to high-speed train network?”. The ideas simply spark around...

And – here we are – the European Personal Air Transportation System is one of the proposals for the European society to fill the transportation gap that exists on interregional national and European destinations with underdeveloped transport network, where implementation of others modes of fast transport is irrational due to too low flow of passengers. A system that could improve air taxi business services to be more cost-efficient and transform its status to regular product thanks to the economy of scale and net-centric management.

This paper shows the current trends of European mobility focusing on areas where the aforementioned transportation gap occurs.
2. EUROPEAN GLOBALIZED ECONOMY
The European Union economy holds up relatively well due to sound fundamentals.¹

*Table 1. Economic growth and consumer price inflation in EU*

<table>
<thead>
<tr>
<th>Economic growth (GDP)</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor market (jobs created)</td>
<td>7.5M</td>
<td>7.5M</td>
<td>7.5M</td>
</tr>
</tbody>
</table>


In the long term, however, its one of the top positions in global rankings measured by GDP level², has experienced a more than a half-age decline, balanced only by means of a reliance on the political dynamic of enlargement.³ The productivity growth is constrained by restrictions concerning labour and product markets, lack of openness to foreign direct investments and barriers to access or the creation of new technologies and their diffusion, and especially for the near future, the turmoil in the financial markets and oil prices.

European welfare states stemming from ageing populations need to implement polices, defined by the revised Lisbon Growth and Jobs Strategy, which favors competition-friendly product market regulations, R&D activity and the quality of human capital. Globalization and Information and Communication Technology (ICT) revolution proved that small countries or small start-up companies can be technology leaders in specialized fields and international mobility of researchers and financial capital are main vehicles of diffusion.

"Globalisation tends to increase the economic inequalities between European regions. The metropolitan regions of the Pentagon where the major gateway cities are localised are actually the most likely to benefit from the opening up of EU27 + 2 territory to internationalisation.

² IMF (2007): EU27 - $14.7 trillion ; USA - $13.8 trillion ; China - $6.9 trillion ; Japan - $4.2 trillion
But globalisation does not necessarily have negative effects on all peripheral regions. Depending on their economic specialisation some peripheral regions can benefit from the development of tourist flows or from the relocation of traditional industrial activities for which they display comparative advantages." Nevertheless, to exploit benefits of comparative advantages of remote regions an effective transportation system is required also there.

3. TRANSPORT NETWORKS

The trans-European transport network (TEN-T) is one of the important pillars that secures the free movement of passengers and goods in the European Union. The revised Lisbon strategy intends to unblock major transport routes and ensure sustainable transport.

This policy direction pointed at the beginning of EUROSTAT’s 2007 Panorama of Transport immediately gives a quick image of situation - the European mobility channels are blocked or tend to be blocked, despite one of highest density in the world. Ground transportation takes c.a. 2% of the EU area and the tendency is to take more, while the existing routes and parking places are becoming congested. There are serious bottlenecks in the air; especially in ECAC core areas caused by the situation where 85% of air activity is generated by 43 main airports. High-speed rail seems to be an excellent solution to intensive passengers flow routes, however its infrastructure construction is very expensive. There are no serious offers for out-of-core long distance travelers, who are therefore forced to use cars and contribute to congestion in sensitive locations. If we are to be conscious of the scale and shape of the problems we need to focus on respective, main modes of transport separately.

3.1. Road transport

There are more than 4,8 million kilometers of roads and 60 000 km of motorways in the EU. According to European Spatial Planning and Observatory Network, million kilometers of roads have been built during the period of 1990-2003. The ever growing number of cars reaches 220 million and 5 million more vehicles are registered every year. The road transport consumes 83% of total energy used in transport industry.

The ESPON Project 2.1.1 evaluated road infrastructure in Europe as well developed, however distinguished some main bottlenecks. Any increase in terrestrial traffic on connections: Paris – Bilbao, Marseille –Paris, Marseille –Ruhr, London – Manchester – Liverpool – Glasgow and Dublin, Lisbon – Madrid will effect in significant increases in the travel times. There are also recognized two critical passages: Trans-Pyrenees and Trans-Alpine. Greece and Cyprus have worse road density with respect to the EU27+2 average in the Mediterranean area and the infrastructure of Baltic states was recognized to have poor links to the rest of Member States. The Central Area has extremely good road infrastructure, however noise, emissions of pollutants or land fragmentation become serious drawbacks. It is on the extreme to the Eastern Area where the density of motorways and expressways by population is comparatively very low with the European average. There exists not a real motorway network, and its construction costs vary from 5 million Euro per km (to e.g. 20 as in case of Poland in Silesia region).
Fig. 2. Road network in the EU27+2 prepared by EPSON Project 2.1.1.

Fig. 3. Rail road network in the EU27+2 [ESPON Project 2.1.1] extended by the up-to-date information on High speed train (HST) [UIC, 02.2008]
3.2. Rail network

The Eurostat’s Panorama of Transport says about 199 000 km (2003) of rail tracks with high population density lowland countries like Germany, France and Poland situated at the top of track length list and a country of numerous islands and mountainous regions - Greece - at bottom. The overall dynamics indicates 8% decrease in network length.

Sacrificing huge amounts of capital (hundreds of billions of Euro) Europe builds its high speed rail network. The situation of certain cities located on high-speed railway lines is a factor favorable. It is clear that the system of relations between Paris, Lyon, Avignon and Marseilles was modified by the high-speed train, including a strong modal shift in favour of rail. This characteristic is going to spread partially with the development of high-speed railway lines in other macro regions. There are regions, where the high speed network is not likely to reach even in many years horizon. E.g. Baltic states experience the same poor situation in rail linkage as in the road infrastructure.

For 50 000 rail cars, crossing a frontier still remains somewhat exceptional, and only a few locomotives are equipped with the multiple systems required to easily cross national borders (e.g. Thalys connecting Paris-Brussels-Amsterdam).

![Fig. 4. Air transport provided under Public Service Obligation rules,](image-url)
3.3. Airspace network

The air network dominates for professional mobility of more than 500km in the absence of high speed trains. Regions, as for example, Mediterranean islands depend on air transport links operated under Public Service Obligations (PSO) rules. These profile of service exists, however, in whole Europe. Many low-cost carriers (also in the Eastern macro region) use this possibility at the invitation of local authorities, which aid their businesses. The PSO form of activity is very carefully examined and controlled by the European Commission as it breaches the market competition paradigm.

One cannot easily talk about ‘network length’ in aviation. The virtual nature of ‘air corridors’ makes it harder to grasp the image than it is with any other mode. The network is changeable and morphing, according to traffic volume. A classification of airports on the basis of their technical or infrastructural features is not useful for statistical purposes, because airports are by their nature intermodal nodes. Anyway, that most of the traffic is generated at 112 “main” airports with a passenger volume of over 1,500,000 passengers annually and the rest of European airports and landing fields are generally unused (2570 according to EPATS). The airspace has its capacity as well. For an Air Traffic Management System it is defined as “the volume of traffic that could be accommodated with 1 minute per flight average delay.” The total gate-to-gate costs of Air Navigation Service provided by EUROCONTROL in 2005 reached €7.1 billion (about 0.8 €/km).

Fig. 5. Current capacity of airspace is very much constrained by fragmented approach to ATM – a heritage of national borders. Europe is on its way to reform this architecture within the SESAR Project.

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10 ESPON Project 1.2.1, Transport services and networks: territorial trends and basic supply of infrastructure for territorial cohesion, 2004, p. 23.
11 According to the EC 2408/92, which, as a result of local authorities initiative and willingness to pay, exempts certain services due to of socially desirable advantage from the EC Treaty general rule (Art. 87): “[…] any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort
4. VOLUME OF TRANSPORT IN EUROPE

The total volume of passenger-kilometers generated by three main modes of transport reached the level of 5 trillion. Enormous road traffic has increased its volume by nearly 18% during 1995-2004 period. Air transport has been very dynamic growing by 49%.

**Table 2. Passenger transport performance, by main transport mode EU-25, 1995-2004 (in billion passenger-kilometers)**

[Panorama of Transport, EUROSTAT, 2007, p.102]

<table>
<thead>
<tr>
<th>Year</th>
<th>Road</th>
<th>Rail</th>
<th>Air</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>4458</td>
<td>352</td>
<td>482</td>
<td>5292</td>
</tr>
<tr>
<td>2003</td>
<td>4399</td>
<td>347</td>
<td>415</td>
<td>5200</td>
</tr>
<tr>
<td>2002</td>
<td>4170</td>
<td>351</td>
<td>415</td>
<td>5156</td>
</tr>
<tr>
<td>2001</td>
<td>4277</td>
<td>355</td>
<td>441</td>
<td>5073</td>
</tr>
<tr>
<td>2000</td>
<td>4196</td>
<td>353</td>
<td>440</td>
<td>4989</td>
</tr>
<tr>
<td>1995</td>
<td>3717</td>
<td>324</td>
<td>324</td>
<td>4435</td>
</tr>
</tbody>
</table>

**Fig. 6. Transport mode share in 2004**

The EU-25 1 078 000 transport enterprises reached a turnover of €1024,3 billion, out of which 640 rail companies sold services worth €61 billion (6%) and 3200 air carriers sold services worth €100 billion (9,8%). Almost half of transport industry turnover is not generated by physical transport service selling companies, but by the auxiliary surrounding.

- One employee generated for its rail transport company added value of €37 962 on average.
- One employee generated for its air transport company added value of €74 943 on average.

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competition by favoring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the common market.” Jacques Barrot, Commission Vice-President responsible for transport, explained “[...]those obligations must not improperly close off a viable market from competition[...]”, http://europa.eu/rapid/EC press release, Reference: IP/07/539 Date: 23/04/2007.

12 Eurostat for 2004, EU-25
13 EPATS D1.1 T1.2 EPATS Airports and facilities database
14 PRR 5, Annex 6, EUROCONTROL, pp. A9-A13
15 PRR 2006, EUROCONTROL, p. 72.
5. ACCESSIBILITY

A “total track length” unfortunately does not answer the question of transport infrastructure. A major problem with this measure is that it disregards the infrastructure network quality. To overcome these problems, one might weigh infrastructure with certain characteristics in a potential function.

Fig. 7. Transport infrastructure quality expressed as summed potential accessibility of road, rail and air transport in the EU27+2, ESPON Project 1.2.1 by S&W, 2004

The regional accessibility defined\(^\text{17}\) by ESPON Project 2.1.1 for the purpose of the SASI model, takes the following form:

\[
A_i = \sum_j (W_j)^{c_{ij}}
\]

where \(W_j\) denotes the potential of region \(j\), and \(c_{ij}\) is a measure of ‘cost’ of travelling between the regions \(i\) and \(j\).

The potentials of the various regions are chosen equal to their populations, which corresponds with the idea that the accessibility to highly populated regions is more relevant than the accessibility to sparsely populated regions. The cost measure can e.g. be based on travel time and political and cultural barriers. The summation is over all possible regions, including the ‘own region’ \(i\).

\(^{17}\) The SASI model was build to explain locational structures and locational change in Europe in time-series/cross-section regressions, with accessibility indicators being a subset of a range of explanatory variables. See more: ESPON Project 2.1.1, *Territorial Impact of EU: Transport and TEN Policies*, 2005, p. 73-89
The travel costs between two regions are composed of four parts:
- the travel times between the regions
- the difference in the level of integration within Europe
- language differences
- cultural differences

The travel times between regions are computed using timetable travel times (rail and air transport) and road-type specific travel speeds (road). Aggregation over different modes (road, rail, air) takes places through the logsum impedance:

\[ c_{ijm} = \frac{1}{\Lambda} \ln \left[ \sum \exp(-\Lambda c_{ijm}) \right] \]

where \( c_{ijm} \) equals the travel costs between the regions \( i \) and \( j \) given that mode \( m \) is used. Note that these travel costs consist precisely of the above mentioned components.

The potentials \( W_j \) are chosen equal to the population size of the various regions.

Transport infrastructure quality of the EU27+2, expressed as a regional accessibility indicator matrix focusing on lower values of this measure, was taken under consideration in EPATS analysis to find the most possible spatial distribution of potential transportation gap.

6. MODAL CHOICE

The travelling public has available a wide choice of modes of transport including car, bus, train, ship and aircraft. By far the most significant advantage of air travel is the time saved by the fast cruising speed. Professor Bouladon of the Geneva Institute aptly described this in his analysis of transport gaps in 1967. [11]

The total trip time shown in Fig. 8 is a combination of delay caused by the infrequency of the service, the speed of travel and the wasted time due to the inter connection of services. Of the three ‘gaps’ identified, the short- and long-haul ones are directly targeted by the air transport industry. Reducing each of the component times contributing to the overall trip time presents opportunities for both operational and technical improvements in new air transport and continues to challenge aircraft designers, airline managers and airport operators. For short stages it is no longer acceptable to have long reporting times prior to boarding.

As we all know, for shorter journeys and where a suitable public transport system is not available the private car is the natural choice of travel. For journeys less than 300 km the car is the dominant mode of transport. In this market the train and bus are seen to be disadvantaged by the infrequency of service, by the out-of-pocket cost and the slow journey times (especially for distances greater than 250 km). As public transport services are developed into a frequent, fast and comfortable option (e.g. by the introduction of high speed trains), the competition to air becomes stronger in the mid-range, (250-900 km). Over about 900 km the time saving of air travel becomes attractive and air dominates the market. The total journey time is affected by schedule, delays and transfers between modes. The links to the airport (road, rail and public services), the appropriate time of departure and arrival have a major impact on the success of the transport service. For leisure travel the choice of mode is strongly influenced by ticket price and airport convenience, for business the value of time is the most important factor. This has led to the idea to develop an Intelligent Small Aircraft Transportation System. The concept is to use modern small planes and dense network of local airports, new information technology and navigation systems, and the Internet network to associate individual travel itineraries and time, and adapt to them, the type and size of aircraft and flight plans, and therefore reduce the wasted time caused by airport time access, boarding, schedule and infrequency of the service, interconnection and route. As personal disposable income increases this sector will become increasingly significant.
The influence of time saving is shown by the modal split (for business travel) between the three major transport forms of travel (Fig. 9). Above 250 km, implementation of EPATS will result in a further shift of car trip to aircraft.

**Fig. 9. Modal traffic split (source Airbus)**

7. CONCLUSIONS

Mobility is essential for Europe. Still 86% of all traffic in Europe is by road. Every year the number of cars in Europe increases with 5million (or 2.5%) whilst on average 100,000 KM are added to the European road system of 4.8 million KM. This causes increasing traffic jams all over Europe.

The widespread accessibility of high speed mode of transport is a prerequisite for the sustainable development of European Regions.

Europe needs a new, supplementary mode of transport. A mode that is harmonized with general trends (door-to-door, multimodality, energy efficiency). A mode that will give us a new tool to manage the challenge of mobility.
BIBLIOGRAPHY


[8] http://epats.eu – European Personal Air Transportation System - EPATS D2.1 EPATS Potential transfer of passenger demand to Personal Aviation; EPATS D1.1 T1.2 EPATS Airports and facilities database


1. INTRODUCTION

The large US SATS (Small Aircraft Transportation System [1, 2, 3] and EU supported EPATS (European Personal Air Transportation System [4, 5]) projects target to develop and introduce new transportation system based on the newly designed small and smart aircraft mostly personal used in completely redesigned and rebuilt airport and ATM systems [2, 3, 5, 6, 7]. Introduction of such innovative system can be characterized by innovation diffusion process [8, 9, 10].

The diffusion of innovation is the process by which an innovation is communicated through certain channels over time among the members of social system [11]. The penetration of the new innovative system into society and economy can be characterized by “S” curve [12]. In case of earlier time of diffusion, when only the relatively small number of users, called innovators and early adaptors are applying the new system, the evaluation of efficiency of the new system plays a determining role.

Generally, it seems the efficiency can be defined and applied for evaluation of the new technology easy. However, the efficiency means different meaning for different group of people, like designers, operators, users, owners, stakeholders, or simple “neutrals”, namely for those who does not belong no one from the named groups. So, the new system must be evaluated with use of different terms, different methods, as technical or energetic efficiency, benefits, etc.

This short paper tries to summarize the different definitions of efficiency and their use for evaluating the EPATS and their impacts on the EPATS development process.

2. THEORETICAL CONSIDERATIONS

In the EU a one % growth of GDP generates increasing in passenger and freight transport about 0,4 and 2,2 % respectively. The transport is one of the Europe's strengths contributes more then 13 % of EU GDP and it is giving job up to 18 million persons [13].

The air transport is the major contributor to the transport employment. In Europe 1.5 million jobs induced directly by air transport [14].

Air transport as a capital-intensive business, productivity per worker is very high – indeed it is three and a half times the average in other sectors (Fig. 1.).
It is true, too, the transport uses the 30% of energy consumption, 98% of which is depend on oil. The transport is the largest sector of economy that pollutes the carbon-dioxide, playing determining role in climate change [15].

![Fig. 1. Transport as a capital intensive business](image)

The EU has a strong plan for developing the effective, affordable and sustainable transport systems and European transport networks [16]. However, the established transport systems tend to their capacity limits. Even the air transport has a problem of airport and air traffic management capacities [17]. The future transport systems should make possible the people and goods mobility with increasing the affordability, accessibility, efficiency, sustainability and security. The future transport must use the air more widely. The some part of personal transport must be climb to the third dimension, into the air [2, 5, 6, 7, 18].

The PATS is a new system changes our mind about the air transport, bringing to us a new vision on the personal used aircraft that can be own, rented and piloted by common people having limited training and knowledge in aeronautics [2, 3, 5]. We can say that the PATS is the US Ford T, French “Duck” or VW Beetle for the future aviation that will bring the high technology, on-demand, fast and effective transport to public. However the PATS has influence not only on the society, but on the economy and on the future of our community, too.

From the engineering point of view the systems, products, events can be characterized with use of ratio of the effective or useful outputs to the total input that is called as efficiency [19]. Generally speaking, the efficiency describes that what we can have for which.

The efficiency can characterized by using the different indicators. For example, the price efficiency is the degree to which the prices of assets reflect the available marketplace information. It is easy to understand, there are too many different indicators can be applied to evaluation of the efficiency.

It seems that the efficiency can be defined easy as the state, quality or grade of being efficient. The efficient means performing or functioning in the best possible manner. With use of another words, efficiency is the competency in performance. So, it is the ability to accomplish any task with a minimum expenditures (use of time and efforts). Shortly, the efficiency is the degree to which a system or component performs its designated functions with minimum consumption of resources.

On the other hand it is a difficult task to evaluate the efficiency, because this term has different means for the different peoples, while transportation system itself has determining role in economy and society [20].
The efficiency depends on the:
- performance, characteristics chosen for its grading,
- needs and requirements defined by individuals, society and economy,
- available scientific results, technology and
- possible alternatives (comparison to other systems).

The efficiency of the new transportation system can be investigated on the different levels, i.e. levels of interest and levels of dimensions. In first case the evaluation of efficiency depends on the target goal, namely the future transportation system can be evaluated from energy, cost, individual (or personal requirements), society and community point of views (Fig. 2.). In second case, the dimensions of the systems can be classified as the vehicles, given transportation system (EPATS), general transport, sector of economy and economy.

![Fig. 2. Fields of interest in evaluation of the future transportation system](image)

The comparison of the different transportation modes can result to different ranking depending on the levels of interest and dimensions. Even the efficiency is not the simple term.

As it can be seen, the efficiency depending on the competence in performance, can not be defined and determined easy, because too many characteristics having influences on it. Therefore the efficiency must be defined for different levels of interest and dimensions, and can be described by quantitative and/or qualitative characteristics. Even instead of term efficiency some others, like influence, impact, demand, accessibility, affordability, acceptability, etc. can be defined. In some case only the benefit analysis can be performed.

3. EFFICIENCY DEFINITIONS

The general definition of the efficiency has given already, since it is the state, quality or grade of being efficient. At the same time, there are not references trying to determine and evaluate the efficiency generally. A series of papers deals with the energetic efficiency, efficiency of operation, etc. [21 – 24], analyses the trends of air transport developments [25 – 27] and applies the special models [8, 10, 18, 28 – 33] for investigation of the different characteristics of the air transportation system.

Our preliminary studies show that, in practice, the efficiency can be defined differently for each subspace shown in Figure 3.

The elements of the cub of efficiency evaluation can be defined with use of some references or dictionary (like [19, 33].

Impact is the striking of one thing against another. It is well known from innovation theory that the introducing the new system always generates conflicts with the earlier established, so called conservative systems. In our case it means that the PATS has impact on the general aviation, airport systems, applied ATM and other transportation means (like road transport) by changing the way of using the personal transportation, etc.
The influence is the capacity or power of persons or things to be a compelling force on or produce effects on the actions, behavior, opinions, etc., of others. The influence is wider effect on the others than impact. While impact can be evaluated as the conflict with other system, the influence includes all the effects. It is easy to understand that, the PATS will initiated many positive effects on the other transportation means, too. New airport networks will be established, general aviation should be increased radically, new ATC/ATM system must be developed, etc. even the road and railway transport development will be redefined after introducing the PATS.

The demand characterizes the state of being wanted or sought for purchase or use. So, the PATS performance that covers the requirements of possible users of the new air transportation system in ratio for which the users are willing to pay can define as the demand. So, the demand model must evaluate the new PATS as the new system for which the users are ready to pay. Of course, such characteristics are depending on the affordability, accessibility, etc. describing the user friendly system.

The benefit is something that is advantageous or good. The investigation of the benefits of PATS deals with the advantageous of introduction of the new transportation system. Often, when the efficiency, namely grading of the goodness, can not be realized, or can be determined with use of too much information, only, the benefit analysis can apply.

Figure 3. shows that all the effects, as impact, influence, demand, benefit and efficiency depend on the point of view and size.

With use of energy or energetic point of view, the new system PATS must be investigated and evaluated on the grades of energy consumption.

The cost is the most common used characteristic for evaluating the different systems. It is well understood by people, and mostly use by companies for evaluating their works, their results.

The individual interest of people mostly depends on the cost. However, the individuals are evaluating the transportation systems on the safety characteristics, time effects (as from door to door speed), affordability, accessibility, etc.

Accessibility is a general term used to describe the degree to which a system is usable by as many people as possible without modification. Accessibility is about giving equal access to everyone. Affordability means that the given system covering the minimal needs of users can be afforded, i.e. it is within the one’s financial means. The grade of capable or worth of being accepted figures by acceptability.

Of course from the definitions of terms accessibility, affordability and acceptability it is clear the using of the new system like PATS depends on the design performance, needs in such systems and cost of offered service and incomings of people, or better to say the amount of money (expenditures) that can be used by people for transportation purposes.
The interest of society is slightly different from the interest of individuals. For example, use of land [25, 35], externalities [36] associated with new systems, etc. can characterize society requirements. Here, an external cost is a cost not included in the market price of the goods and services being produced, i.e., a cost not borne by those who create it. It means that, the price of using the PATS, like air taxi ticket price or rent a plane price are not included any expenses may born on society levels like expenses induced by health problems caused by effects of transportation systems on the people.

For the society the most important quality of the new transportation system under development may be the sustainability. Probable the most used term of sustainability is given by WCED: „...we must meet the needs of the present in ways that do not compromise the ability of future generations to meet their needs” [37].

The sustainability can be characterized by using the sustainability performances indicators and sustainability performance index [38 – 40].

<table>
<thead>
<tr>
<th>Indicator</th>
<th>a variable selected and defined to measure progress toward an objective [41].</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicator data</td>
<td>values used in indicators.</td>
</tr>
<tr>
<td>Indicator type</td>
<td>nature of data used by indicator (qualitative or quantitative, absolute or relative.</td>
</tr>
<tr>
<td>Indicator system</td>
<td>a process for defining indicators, collecting and analyzing data and applying results.</td>
</tr>
<tr>
<td>Indicator framework</td>
<td>conceptual structure linking indicators to a theory, purpose or planning process.</td>
</tr>
<tr>
<td>Indicator set</td>
<td>a group of indicators selected to measure comprehensive progress toward goals.</td>
</tr>
<tr>
<td>Index</td>
<td>a group of indicators aggregated into a single value.</td>
</tr>
</tbody>
</table>

In our study the society as term is used as country level. It is not only the group of people, but it includes economy, environment, etc., too. With applying this approach the community is the group of countries, like EU. The community is a greater population than society and less than humanity. The community can generate special needs and requirements. For example the community would like to be a first in introducing of the new systems, like PATS.

The efficiency of the PATS can be investigated depending on the size of effected field of interest. With use of most simple approach, the vehicles are investigated, only.

![Fig. 4. The 14 indicators in the initial set of STPI made by Gilbert at all [41]](image_url)
The operational system of PATS includes the small airport nets [5, 42], operational and maintenance organisations and facilities [6], as well as the ATC/ATM applied [7].

The given system of new innovative transportation system, as an subsection of economy contains the design and production organisations, logistic support, etc. So, the given system includes all things having influence on the affordability, accessibility, operability.

The sector of economy in our case means transportation system generally. The total transport system can be characterised by inter-operability, inter-modality, etc. [43, 44].

Interoperability refers to ability of given system to use in different countries in different technical and economical conditions.

Transfer of persons and goods between modes of transport to obtain the maximum advantage is known as inter-modality. Competition has generally been a force against inter-modality in the past. Moreover, vertical management of the sector by each mode has exacerbated the situation. Finally, the biggest size of area in which the PATS may use is the economy generally. Of course, the real biggest area is the community economy, in which the economical, sociological and political goals of the community may determine the grading of the transportation systems.

The community view can be defined by a special scientific groups, like it was done by ACARE [43].

4. CRITERIA AND THEIR EVALUATION METHODS

With use of approach shown in Figure 3., the new innovative system can be evaluated with using of the several hundred characteristics, performance indicators and criteria. Our goal is to evaluate the efficiency of the EPATS. Therefore, the investigation of the sub-matrix describing the efficiency only is targeted. This means there are 25 sub-elements must be studied. So, at least 25 criteria must be defined. Here, we try to summarise the definitions of the criteria recommended for application. The possible ways of measurement or determination of the criteria are described, too.

**Energetic coefficients**

*Sub-space: vehicle - energy*

*Criteria:* energy used for one flying hours, transporting a unit commercial load, one passenger or the transport work solved by using one unit of energy.

\[
C_{e1} \rightarrow \frac{1(\text{or kg}) \text{ of used fuel}}{\text{flying hour}}
\]

\[
C_{e2} \rightarrow \frac{kWh}{tkm} \text{ transport work (transport of one tonna commercial load for unit distance)}
\]

\[
C_{e3} \rightarrow \frac{\text{energy used}}{\text{energy used}} \frac{\text{transport of one passenger for unit distance}}{\text{kWh}}
\]

\[
C_{e4} \rightarrow \frac{tkm}{kWh}
\]

\[
C_{e5} \rightarrow \frac{\text{transport of one passenger for unit distance}}{\text{kWh}}
\]

*Measurement:* these criteria can be determined with use of the general performance data of the vehicles. For example, the \(C_{e4}\) can be determined with use of data maximum boarding fuel, \(W_{bf}\) minus aero-navigation reserve, \(W_{anr}\) and over the maximum payload, \(W_{kl}\) times by maximum range with full payloads, \(R_{max \cdot kl}\):

\[
C_{e4} = \frac{W_{bf} - W_{anr}}{W_{kl} R_{max \cdot kl}}
\]
Sub-space: operational system – energy

Criteria: the same criteria can be defined as for the sub-space vehicle – energy, but in these cases the energy consumption must include the energy used during the operation of the PATS systems, i.e. energy used during maintenance, running the ATC/ATM systems, etc.

Measurement: the energy used in operation of the PATS can be calculated as the annual use of energy at airport and maintenance facilities, $W_{op}$, for operation of small aircraft applying in PATS and related to the total annual transport work realized by the given number of small aircraft.

$$C_{ve} = \frac{Nn(W_{op} - W_{off}) + W_{cap}}{NnW_i R_{max}}.$$  

For example:

Where $N$ – number of aircraft operated at the given airport, $n$ – is the number of average flight of one small aircraft.

Sub-space: given system - energy

Criteria: In this larger system of investigation the energy applied during production of the aircraft and other elements of the PATS must be added to the energy used for applying the total PATS.

Measurement: all the energy consumption must be related to the unit of transport work.

Sub-space: economy sector – energy

Criteria: Even in this field the same type of energetic coefficients can be defined as it was done earlier, however, the energy consumption should be calculated as the total energy used by this transport section of economy. So, the energy applied by road and rail transport used for traveling to and out of airports and any other extra energy need for applying the PATS must be included into the energy consumption. This means that all types of direct and indirect energy consumption must be taken into account. For example energy consumption of car used by administrative persons working for rent a plane system must be added to the total applied energy.

Measurement: the calculation of the total energy consumption associated by using the PATS is quiet difficult task. However it can be solved, if the system would be divided into more clear sub-parts that can be investigated individually.

Sub-space: economy – energy

Criteria: in this case the total energy consumption will be really totally calculated with taking into account the external energy, like energy used for constructions realized near the airports, built of connected road and rail transport systems, or energy used for built and operation of the hospitals, where those persons will be cured who will have health problems initiated by introduced new personal air transportation system.

Measurement: the energetic coefficients of this level of investigation can be calculated not so easy. The methods developing for external cost calculation or investigation of the real sustainability may apply on this level.

Cost

Sub-spaces: vehicle - cost, operational system – cost, given system – cost, economy sector – cost,

Criteria: The costs or cost coefficients are very similar to the energetic coefficients, when instead of energy the spent expenses must be taken into calculation. Of course, cost can be calculated by using the very different approaches as it shown in Figure 5.. In case of investigation of the aircraft itself, the cost is the direct operational cost. Generally, the transportation system PATS can be grade on the total operational cost including direct and indirect costs. However, for users, the expenses of traveling are more important then any other characteristic of the
transportation mean. So, the users are choosing the transportation system, or completing their real travel as the combination of the different transportation means minimizing the traveling cost. The general transportation system as the logistic support of economy must be developed with using the minimum expenses. So, the external costs must be included into the evaluation of the transportation sector of economy. Nowadays, very often, the sector is evaluated with using terms of sustainability. Finally, the economy must be really sustainable, therefore all the costs associated with using the natural resources for realizing the transportation of goods and people must be taken into account.

Fig. 5. Cost evaluation hierarchy

Measurement: All the earlier defined formulas of energetic coefficients can be applied for calculation of the cost coefficients on the supposition that the energy would be changed for cost determined for the same conditions.

Individual requirements

Sub-spaces: vehicle – individual requirements, operational system – individual requirements, given system – individual requirements, economy sector – individual requirements, economy - individual requirements

Criteria: The EPATS system is based on the on-demand flights. However, the characterization and evaluation of the individual requirements are the very complex problems. The different groups of people have different priorities in grading the traveling possibilities. They are making decision on the traveling forms depending on the time effects, costs, accessibilities, safety, etc.. As it is well known from the innovation diffusion theory, the first users of the new technologies are the innovators and early adaptors. So, we have to centric our investigation on them. For them the time-effect may most important factor. Therefore the individual requirements can be characterized by time used for given travel, time of traveling.

EPATS from the individual requirements point of view can be evaluated by applying the time coefficients that may be calculated as the energetic coefficients with replacing the energy or power by time. Here the small aircraft direct flying time, time from airport to airport, time from door to door traveling, time used generally for travel or transportation and time associated with operation of transportation systems for supporting the economy.

Instead of the time effects the average speed can be defined and applied, too.

Measurement: principally the time used for traveling depends on the distance of traveling, too. On the other hand, the direct flight time depend on the aircraft performance, aircraft flying
characteristics, while time from airport to airport depend on the operational characteristics of the aircraft (like line-up maintenance), operational system (economical operation, ATC/ATM) and operational conditions (like weather conditions). Time from door to door includes the time-effects influenced by using the different transportation modes during the combined traveling or transportation. Generally the transportation time depends on the inter-operability (time used for adaptation of the transportation systems to the conditions of different countries), harmonization of the time-tables (giving slots), etc. Finally, the community can have economical, social and political priorities that can cause some extra time in use of the new transportation systems. These time-effects must be included in to time-coefficient calculation, too.

**Society**


*Criteria:* for society, the development, establishment and operation of the sustainable transport may the most important, today. The sustainability can be characterized by using several different indicators, like use of fossil energy, emissions, greenhouse gas emissions, totals motorized movement of freight and people, urban land used, length of paved transportation systems, etc. These indicators show the given indicator related to the total or relative (determined for unit) transportation work. Often, the sustainable transportation systems are characterized generally by emissions. The sustainability of the small aircraft can be characterized by their emissions (weight of pollutants) during its direct operation (flights). The EPATS generates pollutants emitted by aircraft, technical systems applied at airports, waste of energy by ATC/ATM, etc. Of course, the covering of the individual requirements (as using the washing rooms, eating, etc) cause some extra pollutant distribution, too. On the total transportation system level, the pollutants born during the aircraft production, airport building, airport and ATM devices productions, etc. the transportation system generates pollutants not only their operation, but during construction of the infrastructure, mining the materials for aircraft and system elements production, and so on. On the community level the pollutants born because the people life must be taken into account, too.

*Measurement:* It is seems clear, how to define the sustainable transport indicators. They are the coefficient defining as the quantity of controlled emission related to the unit of the transportation work. On the other hand the calculations of the sustainability (emission) coefficients are very complex problems, because the real emissions

**Community**

Sub-spaces: vehicle - community, operational system – community, given system – community, economy sector – community, economy - community

*Criteria:* in our approach to investigation of the EPATS, the community is the EU. So, the community is the group of countries, group of societies having the same common interest and goals. One of the most important goal of EU is to be a leader in technology development. Therefore, the EU must support specially the EPATS as the new, innovative transportation system opening new market and making possible the real free movements of people and products in Europe. The EPATS must be characterized by criteria grading the common interest of community and members (persons and enterprises, institutions) of community. Such criteria can be given as ratio of the criteria developed for evaluation of the society and personal requirements. So, the efficiency on the community level can be characterized by ratio of emission over time of using the system.

*Measurement:* The community interest coefficients can be calculated very simple as ratio of emission and time coefficients.
5. USING THE EFFICIENCY DEFINITIONS AND CRITERIA IN EPATS PROJECT.

As it was described the investigation of efficiency of the radically new, innovative projects is a very complex problem that can be solved depending on the goal, point of view and size. The applied efficiency coefficients are changing with use of the latest results of sciences and technologies. Therefore they must be calculated as calendar time functions.

On the other hand, the EPATS is a really new system that has not established, yet. Therefore, there are not available initial data for making evaluation. Even, there are not enough data for describing the establishing and development of the EPATS. So, the future development and use of EPATS, as the new system may evaluate with use of some forecast models of its impact, demand, etc. Such models are quit complex and depend on the applied scenarios.

Principally, there are many different performance indicators, efficiency coefficients defined earlier can be applied for investigation of the EPATS. Some of them like the different energetic and cost efficiency coefficients or some other indicators as impact of increasing in GDP on the air traffic, land used for given type of transportation means, number of airports and airfields in unit land area, etc. can play very important roles in understanding the EPATS demand.

Choosing the efficiency coefficients can be realized on rational way shown in Figure 6. The recommended method is based on the investigation of the cube of efficiency evaluation given by Figure 3. Choosing the most important indicators and criteria must be based on the general investigation of the possible performance indicators, creating the performance indexes and efficiency coefficients with using the results of developed foresight and forecast models.

With accordance to our preliminary analysis, the most important efficiency coefficients are in the diagonal plane of the efficiency evaluation cube, namely:
- efficiency coefficients recommended for the evaluating the small aircraft are the energetic coefficients, ration of energy and transportation work: (fuel or energy used for unit tkm or passkm work), Ce;
- the PATS system can be qualified with use of cost coefficients (direct, total or total LCC for unit of tkm or passkm work), Cc;
- the priority of chosen transportation mean must evaluated with use of time-effect coefficients (flight time, block time or door to door time used for transformation related to unit distance), Ct.

![Fig. 6. Rational choosing the efficiency coefficients](image)
- from the economy sector and society point of view, the new transportation system can be graded depending on the emission coefficients (mass of pollutant materials related to unit of tkm or passkm), Cem;
- on the economy level and from the community point of view, the transportation system can be characterized by quality coefficients determined as multiplication of the emission and time-effect, coefficients, Cq = CemCt.

All these coefficients can be given in different form as it was discussed and shown in energy coefficients sub-point of the point 3.

6. SOME COMMENTS OF THE POSSIBLE EFFICIENCY EVALUATION

The previous chapter contains the definition of the different efficiency coefficients recommended for using in EPATS efficiency evaluation. However the calculations of these coefficients for different transportation means are very complicated tasks that can not be easy solved because a lack of information required for calculations.

Here are some recommendations for determining the defined efficiency coefficients.

Energetic coefficients

In simplified case, when the fuel consumption in direct operation must be calculated, the energetic coefficient may be determine quit easy. There are several formulas especially had been developed for energy consumption evaluation (like[22]).

The aircraft fuel consumption decreases continuously (Figure 7.) Today, the conventional air transport has fuel consumption related to the passkm not more then road transport (Figure 8.). With accordance to EPATS, we can declare that, the weight and drag of the new small aircraft will be much more smaller then analogical characteristics of the modern cars, because the use of the latest technology and developed aerodynamics.

![Fig. 7. The original Rolls Royes figure representing the fuel efficiency of the modern aircraft](45, 46)
If the energetic coefficients were determined for the total system, then calculations will be much more complex, because who, how and when has taken into account the use of energy during the infrastructure, for example road system construction in form of energy consumption related to one passkm.

Fig. 8. Specific energy demand of different transportation means [25, 32]

Cost evaluation

The modern air transportation engineering deals with the total life cycle cost related to unit of work. Such approach includes all the direct and indirect costs determined for total time of usage. Nowadays everybody can understand that the low cost airlines can carry the passengers at price level that is lower than using the car. However, the air travelers must pay for everything like it is shown in Tables 1 and 2.

Table 1. Real costs associated with flight

<table>
<thead>
<tr>
<th>Budapest</th>
<th>Berlin return flight May, 2005</th>
<th>Payment</th>
<th>% from total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air ticket (Air Berlin)</td>
<td>32 EUR</td>
<td>17.6</td>
<td></td>
</tr>
<tr>
<td>Taxes</td>
<td>127 EUR</td>
<td>69.8</td>
<td></td>
</tr>
<tr>
<td>Printing the ticket (travel huro)</td>
<td>23 EUR</td>
<td>12.6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>182 EUR</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Lowest price for return journey London – Paris for travel between 2-5/12/2002. [47]
The latest available technology makes possible to develop EPATS on the cost level of the middle size car [29]. However, the cost of EPATS must cover absolutely everything associated with use this new system, while for example the road system construction only partly covered by car owners.

Of course, the costs can be evaluated on the total life cycle, or / and on the total system levels. In last case for example all the costs associated with the deployment and operation of the given transportation system must be taken into account. For example the infrastructure investment [48] or the externalities [36] must be evaluated.

![Fig. 9. Door to door trip speed (MPH) as function of range (miles) [3]](image)

**Time effects**

The comparison of the different means from the time effect point of view must based on the door to door speed, or total traveling time. In this case we will have something like it is demonstrated by Figures 9 and 10. From the Figure 9, from the figure 9, it is clear, the time spent on travel is approximately four hours for from 500 km up to 2000 km with using the different transportation systems, different vehicles.

Of course the time effect very depend on the accessibility, affordability and other similar performances [3, 48].

**Emission coefficients**

In terms of performance measurement - as it is defined by [50] - indicators of sustainable development must comply with the followings:

- an explicit set of categories linking vision and goals of the future;
- a limited number of key issues for analysis;
- a limited number of indicators of progress;
- standardized measurement;
- indicators related to the spatial context;
- ongoing assessment integrated into the decision-making.

On the other hand the indicators for the investigation of the sustainable transportation must show to decision makers and authorities what they can do [51].
Many different approaches are described by references for generating the performance. All of them are based on the DPSIR (Drivers – Pressure – State – Impact – Response) principle, as shown in Figure 5. Generally, many different indicators or performances can be defined (Fig. 11.). However, the large number of indicators make it difficult to use them for comparison of the different transportation means. It would be better to introduce one index describing the transport sustainability, generally.

If we will take into account all the effects having influences on the use of the resources, then we will have quite interesting results. For example, one B747 can produce 18 billion psskm. during the year, that is equal to production of the 12 thousand middle upper size car. The fuel consumption approximately is the same for air and car users. However, the empty (dry) weight of cars would be about 120 times more than aircraft empty weight. Even, if were calculated that the aircraft production uses relatively 10 times more natural resources, the production of the defined number of cars needs 12 times more resources. If we will take into account the infrastructure investment cost, or land used by different transportation systems (Fig. 12), we can make decision, the air transport can not be camper to the road one in case of long distance travel.
Quality coefficient

The recommended quality coefficients summarize the society acceptance (emission coefficients describing the sustainability) and individual interest (time effect applying the golden rule of our era: time is money).

Of course, as it was outlined, many different characteristics can use for efficiency evaluation. The new US program PAVE (Personal Air Vehicle Exploration) project offering web based benefit analysis (Fig. 13.).
There is a big question, how to increased the efficiency and deployment level of EPATS? We can recommend to use the following methods:
- dissemination of the results of the given EPATS projects demonstrating the needs, technology availability, operational philosophy, establishing the system, profitability of services provided by companies strating their activities in new transportation system,
- taxation; loan financing schemes and partial loan guarantee schemes, operating either within the commercial banking system or as specialized development institutions or revolving funds for accelerating the EPATS deployment,
- use of advisory and consulting companies supported by EU for help in the companies starting their busines in this new areas,
- utility demand-side management (DSM) programs.

7. CONCLUSIONS

EPATS is the radically new, innovative transportation system making possible the on-demand transport giving real freedom in movements of goods and people. This system opens a new market, initiates a lot of new jobs.

The benefits and efficiency of the new system can be evaluated with using the different performance indicators, including the flight performance, operational characteristics, fuel and energy consumptions, expenses, use of natural resources, land, etc., influences on the economy, environment and so on. There is no one and most important indicator. However, a special hierarchy was found in system of performance indicator given in form of efficiency evaluation cub. This hierarchy makes possible the systematic investigation of the new transportation system EPATS that results to the reduction of the number of indicators in forms of indexes called as efficiency coefficients.

The efficiency coefficient are depending on the sizes of the investigated system (aircraft, EPATS, total transportation system, sector of economy and economy), point of view (energy, cost, personal requirements, society, community), scientific and technological level as well as time.

Finally, we have defined 5 different efficiency definitions, efficiency (energetic, cost, time effect, emissions and economic) coefficients that can be given in different forms depending on the evaluated form of transportation, size of system and time for which those coefficients would have calculated.

The results of shortly described analysis will be used in efficiency evaluation of the new transportation system, EPATS.

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Executive summary

This paper describes the methodology and results of studies carried out on mobility in European Countries by the authors in the framework of EPATS project (European Personal Air Transportation System). The objective of these studies was to analyse the main characteristics of the mobility in Europe when particularly focusing on the mobility features on the connections where personal aviation could potentially operate. Besides this general analysis of mobility in Europe we also focus on the mobility analysis in two particular countries: France and Poland. Both indeed belong to the countries with the highest traffic level in old European countries and new European countries.

The mobility analysis made at a EU 15 level highlights that the long-distance journeys characteristics change according to the customer profile: business and leisure traveler do not travel the same way (difference in terms of transport mode, duration, traveler features (age, gender, etc.)). Characteristics of long-distance mobility therefore vary a lot according to the trip purpose.

We identify that 15 223 connections between 28 countries can be considered as EPATS potential connections. All together these potential connections represent 24% of the total existing NUTS 2 connections in Europe.

Despite the lack of detailed data on the traffic occurring on these connections the analysis manage to provide very interesting and important information on the current traffic levels and modal splits. The total traffic on the potential EPATS connections is 2400 billion passengers amongst whom 436 million travel to and from France and 93 million to and from Poland. The analysis also highlights the large market share of the road transport mode on these connections since 79% of the passengers travel by car. The air transport market share often exceeds the road one for distance over 1500 Km and reaches 100% for distances over 2000 Km.

The road transport mode preponderance on the potential EPATS connections hence tend to mean that the traditional air transportation is often less competitive than the road transport mode. But could a different way of travelling by air such as the personal aviation be an alternative to the traditional air transport as well as to road transport.

The answer to this question is the next step of the analysis aiming at assessing the traffic that could be potentially transferred to EPATS by 2020 as well as the EPATS aircraft fleet that would be necessary to satisfy this demand.

1. INTRODUCTION

In modern society, the need to travel within Europe is more and more important, and is expected to increase. The extension of the European Union to 27 members amplifies this phenomenon. However, current transport modes have limitations and suffer already from congestion in some places: most large airports are congested or could quickly reach their maximal capacity. Conversely, other areas, especially in Eastern Europe, are hardly accessible.
Moreover, society is evolving: passengers are becoming more exigent in terms of time and cost, but their behaviour is also changing: a phenomenon of individualisation is taking place little by little, meaning that people want to have a choice. Future mobility therefore cannot be entirely satisfied by current transport systems, such as hubs, railways or highways.

A new transport mode is thus needed, and from this perspective, a new concept, the Personalized Aviation, has been proposed. It would consist in realizing long-distance trips in a short time at an acceptable cost, thanks to the use of small aircraft (jet, turboprop, pistons) departing from small airports. These aircraft, operating in all weather conditions, could deserve any kind of location, but their interest would be overall to serve inaccessible areas. The concept of personalized aviation implies the development of a system. This system is called “EPATS”: European Personal Air Transportation System which is a complex collection of systems, procedures, facilities, aircraft and people, working together. EPATS would be developed especially in regions where the airlines are extremely little present and where high-speed trains do not work, owing to the low flow of passengers.

At first, EPATS will help to meet the needs of a society that is more and more mobile and demanding, by increasing passenger choice. Then, EPATS aims at improving the accessibility of some areas in Europe and at attenuating the disparities relative to networks development. This system proposes an alternative mode to road transport by private car. But EPATS is also a means to make a stronger aeronautical Europe by developing technologies needed for this kind of aircraft and by strengthening general aviation. Lastly, EPATS should increase the operational capacity and the efficiency of air transport system.

Our objective is to analyse the main characteristics of the mobility in Europe when particularly focusing on the mobility features on the connections where personal aviation could potentially operate. Besides this general analysis of mobility in Europe we also focus on the mobility analysis in two particular countries: France and Poland. Both indeed belong to the countries with the highest traffic level in old European countries and new European countries. With 5.2 billions of passengers in 2000 (on trips over 100 km) France belongs to the top 4 of old European countries while with 1.4 billions of passengers (Figure 1-1), Poland is the new European country with the highest traffic level in 2000 (Figure 1-2). Both countries are therefore particularly interesting to be analysed in terms of mobility features as representative of old and new European countries.

![Figure 1-1. Traffic in number of passengers in 2000 in old European countries (Source ESPON)](image-url)
Knowing the general features of the mobility in Europe is essential before going deeper in the mobility analysis when focusing on particular areas. That is why we start this paper by providing an overview of European mobility aiming at giving global traffic levels as well as at identifying the main features of this general mobility (modal split, trip duration, travelled distances, etc.). More generally, it is also particularly interesting to analyse the main determinants of this mobility.

Once knowledge of European mobility is better, the next step consists in analysing more closely the mobility features in areas where the use of the personal aviation is relevant. We therefore identify the connections between NUTS 2 (Nomenclature of Units for Territorial Statistics – NUTS 2 indicates the regions populated by 800 thousand. to 3 million inhabitants) in Europe that are the most relevant in the EPATS context while taking into consideration criteria of accessibility, economic attractiveness and traffic level. Then we analyse more precisely the mobility features on these connections from available traffic data.

2. EUROPEAN MOBILITY OVERVIEW

2.1. Traffic and Evolution

Data on passenger transport in EU-25 has become increasingly available since 1995. Before this date, we do not have enough information for the whole countries. The analysis first of all focuses on the traffic evolution in EU 15 only, to have a large overview on transport activity in Europe since 1970. In a second step the analysis outlines the recent evolution of traffic in EU 25 and provides an insight of the current situation in transport.

2.1.1. Traffic evolution in EU-15 from 1970 to 2001

During the period 1970 – 2001, passenger transport in European Union 15 has more than doubled: it has been multiplied by 2,28, going from 2 117 billions to 4 834 billions passenger-km\(^1\). This corresponds to an average annual growth of 2,7 %. Transport growth was particularly strong at the beginning of the period, as shown in Table 2-1 (+ 3,4 % per year from 1970 to 1980), but since the 1990’s, the annual growth has slowed down and does not exceeded 1,8% per year.

\(^1\)Passenger-km = unit of passenger traffic. It represents the movement of one passenger over one kilometre.
However the growth in passenger traffic significantly differs between transport modes. Figure 2-1 points out this gap between modes: the growth of air traffic in passenger kilometers (intra EU 15 + domestics) was significantly stronger than that of the other modes between 1970 and 2001. Indeed, air transport increased by 766 % over the period, while transport modes such as bus / coach, Tram / metro and Railway hardly grew by 50 %. At the same time, the level of car traffic was multiplied by more than two between 1970 and 2001, in terms of passenger km. Besides, the annual growth in car traffic (+ 2.9 % per year) is quite close to that of transport in general. This growth of individual road transport, particularly strong between 1970 and 1990, is mainly due to an increase in the level of motorization.

More precisely we observe two different trend in terms of growth rates evolutions: while the dynamic growth of the air market decreased over the period (5,7 % traffic growth per year between 1990 and 2001, versus 8,4 % between 1970 and 1980), the growth rates of rail transport, particularly low between 1980 and 1990, increased over the last 10 years because of the development of the high speed rail network.

This growth difference between modes generated an evolution in modal split. Figure 2-2 shows that the shares of air and road traffic in the total passenger km traffic continually increased since 1970: car transport was and is dominant over the other modes, with a market share of 73,8 % in 1970, reaching more than 78 % in 2001. The rise in the air transport market

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Table 2-1. Passenger Traffic Growth by transport mode in EU 15 between 1970 and 2001
(Source: European Commission Ref 13)

<table>
<thead>
<tr>
<th>Period</th>
<th>Average annual growth rate (%)</th>
<th>Mode of transport</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Car</td>
<td>Bus - Coach</td>
</tr>
<tr>
<td>1970 - 1980</td>
<td>3.7</td>
<td>2.6</td>
<td>0.3</td>
</tr>
<tr>
<td>1980 - 1990</td>
<td>3.4</td>
<td>0.6</td>
<td>1.8</td>
</tr>
<tr>
<td>1990 - 2001</td>
<td>1.7</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>1970 - 2001</td>
<td>2.9</td>
<td>1.4</td>
<td>1.1</td>
</tr>
</tbody>
</table>

---
share is even more outstanding: it rose from 1,6 % to 5,9 %. Conversely, the market shares of Bus / Coach, Tram / Metro and Railway widely fell from 23 % to 16 %.

![Modal Split Evolution for passenger transport in EU 15](image)

**Figure 2-2. Modal Split Evolution for passenger transport in EU 15**
(Source: European Commission Ref 13)

2.1.2. Traffic in EU-25

A very large share of traffic is concentrated in European Union 15, which accounts for 81 % of the total population in EU 25 (source: DG Tren). However this share tends to decrease, as shown in Figure 2-3: in 1995, EU 15 citizens made 88% of the total EU 25 traffic in passenger km, versus 85 % in 2001. Because of new member country development, we can reasonably assume a continuation of this trend from 2005.

![Difference of traffic between EU 15 and EU 25](image)

**Figure 2-3. Difference of traffic between EU 15 and EU 25**
(Source: Ref 12)

Now, let's have a look at the current situation of transport in European Union 25. Over the period 1995 – 2004, we observe the same general trend as for the EU 15 in the late 90’s: the yearly average growth rate in passenger traffic in EU 25 is 1,9 % (vs. 1.8% in EU 15). Moreover, the modal split for EU 25 in 2004 is close to the modal split of EU 15 in 2001.

Indeed as shown in Figure 2-4, the individual road transport is preponderant with a market share of 76 % (vs 78% in EU 15 in 2001). Air transport market share reaches 9 % (vs. 6% in EU 15 in 2001), and transport by rail only 6 % (same share than in EU 15 in 2001). The market share of other modes (metro, bus, coach and tram) is about 10 %. 

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Finally, the traffic reaches 5689 billions of passenger-km in EU 25 in 2004, which corresponds to 12 370 pkm per capita each year.

However, characteristics of this mobility can change according to the trip distance. That is why it is important to differentiate two types of trips:
- Short-distance trips that concerns trips with a travel distance less than 100 km. They can correspond to trips linked to daily activities such as work, education or shopping but can also be more occasional trips;
- Long-distance trips concerns trips with a travelled distance above 100 km. They can be realized within a weekly, seasonal or annual activity: holidays, professional meeting, visiting family, etc.

In the scope of EPATS, only the long-distance passenger traffic is pertinent. That is why we focus our analysis on long distance mobility.

2.2. Long-distance journeys

After this large overview of passenger transport in Europe, we can now study in detail the features of long distance trips. Due to the lack of mobility statistics at a EU 25 level this long-distance mobility overview is mostly made at a EU 15 level.

The main source providing useful information for the analysis of the long-term mobility is DATELINE. Dateline is a European Project that realized a survey in all the EU 15 states about long-distance travel within Europe and that created a important database relative to the characteristics of the European long-distance journeys. The survey was carried out in 2001 – 2002.

When performing this mobility overview it would be particularly interesting to make comparison in terms of traffic features between EU 15 and France and Poland that are both countries that we consider in the estimation of the EPATS potential market. Unfortunately the DATELINE database does not contain information for Polish travel, which makes comparison impossible. This long-distance mobility overview therefore mainly focuses on EU 15 and French travellers and is completed with Polish data each time it is available.

When dealing with long-distance journeys it appears necessary to consider two kinds of journeys:
- Business Journey
- Leisure Journey

Indeed, leisure and business journeys have their own specificities and concern persons with different goals and budget.
They are defined as follows:
- Business Journey = journey realized for business purpose (professional conference, congress, meeting...). This definition does not include commuting journeys or professional travel (e.g. flight attendants, pilots, truck drivers, sea captains etc.). Business journeys represent about 20% of the whole long distance journeys (Source Dateline).
- Leisure Journey = journey realized in all other cases, for instance to visit friends or relatives, for holidays, sport, shopping, etc.

The analysis of long-distance mobility provides elements on the share that long distance trips represent in the total number of trips, but also on the characteristics of these long distance trips in terms of modal split, distance, duration, number of people travelling together and also the share of journeys abroad.

2.2.1. Share of long-distance journeys

“Long distance journeys” is the segment of mobility which increased the most during the last half century. Many determinants such as the rapid development of air transport or the increasing level of motorization, but also the development of tourism contributed largely to the strong growth of long distance mobility: in France, the long distance traffic increased by 108% between 1973 and 1993 (corresponding to an annual growth of 3.6%), while short distance traffic only increased by 66% (source: INRETS Ref 15). Despite fast growth, long distance traffic only represents 40% of the total travelled passenger-kilometres (source: INRETS Ref 15).

According to the Dateline survey, the rate of European people travelling at least once in 2001 on long-distance reaches 70%. More precisely, 69% of the European citizens made at least one leisure journey. Besides, only 5% of the European citizens made at least one trip for business purpose in 2001. In France, the departure rate is slightly higher, as shown in the following table:

Table 2-2. Departure rate in 2001 in Europe and France (Source: Dateline)

<table>
<thead>
<tr>
<th></th>
<th>Europe</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>all reasons</td>
<td>70%</td>
<td>77%</td>
</tr>
<tr>
<td>leisure journeys</td>
<td>69%</td>
<td>76%</td>
</tr>
<tr>
<td>business journeys</td>
<td>5%</td>
<td>11%</td>
</tr>
</tbody>
</table>

In addition, each French inhabitant makes on average 3.8 long distance journeys yearly, from Dateline: 3 journeys for Leisure reasons, and 0.8 for Business reasons. Unfortunately, we are not able to determine this average number of journeys for Europe, but we can assume that it does not differ too much from French results.

2.2.2. Long distance features

Modal Split of journeys

Train, car and aircraft are the three main transport modes used by Europeans on long-distance journeys. The analysis of the modal split between these three modes clearly shows the preponderance of the individual road transport mode since 71% of the traffic of EU 25 long-distance travellers (in number of passengers) is performed by car. Train is the second most used transport mode with a 19% share. The preponderance of the individual road transport mode is moreover higher in France and Poland (Figure 2-5). Another important difference in modal split between EU 25 and France or Poland is the traffic share of air transport. Indeed this transport only represents 3% of the domestic French traffic and 1% of the domestic Polish traffic.
The lower use of the air transport mode in France compared to EU 25 is particularly marked for journeys exceeding 1000 Km. Indeed while representing 64% of the traffic over 1000 km in EU 25, the air transport mode is only used in 31% of the domestic journeys exceeding 1000 Km in France (Figure 2-7). On the other hand, the low share of the air transport mode in domestic Polish journeys can be explained by the non existence of domestic journeys exceeding 800 Km. Until 800 Km the modal share of air transport is quite close to the corresponding modal share in EU 25 or France (2-6).

Another main difference between EU 25 and French behaviours also arises on distances exceeding 1000 Km where French travellers tend to use, to a larger extent, individual road transport modes than Europeans (Figure 2-7).
However, these general modal splits can vary a lot according to the purpose of the trip that is why it is particularly interesting to go deeper in the analysis when differentiating business from leisure trip purposes. The following graphs show the modes distribution by travelled distance category. The travelled distance corresponds to the distance of a one way trip.

**Business Journeys**

In business travels the individual car dominates the other modes on short distances, i.e. distances comprised between 100 and 400 km. Above this limit of 400 km, businessmen widely prefer aircraft, because of their higher speed which wastes less time. Train is interesting to a lesser extent for medium distances (200 – 600 km). The other modes (Bus, coach, ship,..) are hardly used by the business passengers, due to their low speed and their lack of convenience.
A similar analysis on the behaviour of French travellers in long-distance trips tends to show significant differences with the European behaviour. This difference mainly comes from the larger use of rail transport by French people than by typical European people, what can be explained by the large French high-speed rail network. However, we have to be careful when considering Figure 2-9 since the sample of French business travellers extracted from DATELINE is very small which means that shares of modal traffic may not be representative of the real modal split of French business travellers.

Figure 2-9. Modal split of business journeys of French people by distance category
(Source: Dateline)

Leisure Journeys

Figure 2-10. Leisure Journeys - Modal Split by distance category in Europe
(Source: Dateline)
The modal split of leisure journeys mainly differs from business journeys due to the preponderance of the car in main distance categories. The high flexibility of a car compared to the other transport modes explains this predominance up to 800 km. From this distance air transport takes over. As opposed to business travellers, leisure travellers do not hesitate to use transport by coach and bus because of their low price. Finally, the train is mainly used on distances comprised between 200 and 800 km.

As in case of business travel, the main differences in modal split between European and French people mainly comes from the larger importance of rail transport mode. However it is important to note that this higher modal share of rail is not at the expense of the individual road transport. Indeed the traffic share of cars is always higher for French travellers than on average in Europe. On the other hand French travellers are less inclined to use the air transport mode for leisure purposes than European travellers.

![Figure 2-11. Modal split of leisure journeys of French people by distance category](source: Dateline)

All these graphs therefore show the difference of behaviour between business and leisure passengers, and outline the fact that business travellers care about time much more than other travellers.

**Travelled distance**

Whether it is for business or leisure travel, about three journeys in four are realized at less than 400 km from home (Figure 8). Then, the percentage of journeys by distance category clearly decreases. Lastly, journeys above 1000 km represent 5 to 7 % of the long distance journeys made by European travellers. This graph therefore points out the preponderance of trips below 400 km, and also shows that business and leisure journeys are distributed in the same way.
When comparing the French travelling behaviour with the European one we observe that French tend to travel less for leisure purposes between 100 and 200 km than Europeans while they travel more on the other distance categories (Figure 2-13). Conversely, French tend to travel more for business purposes on very short distances (100-200 Km) and less on longer distances than Europeans.

In addition, we can also note that the average distance of French trips has been increasing for more than 20 years: average distance of 346 km in 1982 and of 406 km in 1994. (Source INRETS Ref 16)

As the Europeans and the French ones, the distribution of the number of trips made by Polish decreases until 700 Km (Figure 2-14). The main difference comes from the lower share of trips between 100 and 200 km compared to the cases of France and Europe. Indeed they only represent 32% of the trips (as well for leisure as business purposes) while this share exceeds 40% for Europe.
Another particularity of Polish trips lies with the very low number of business trips made by Polish travellers.

Figure 2-14. Journeys distribution of Polish travellers by distance category and purpose
(Source Buczak Ref 1)

Travel Duration

Figure 2-15 shows that journeys distributions by duration evolve in opposite direction according to the journey purpose: businessmen prefer journeys with short duration, and more particularly journeys undertaken in the day (38 % of all journeys). Conversely, leisure travellers realize only 16 % of journeys in the day, and even less journeys with only one night. They like long trips better. Besides, they especially enjoy travels with a duration of at least 4 nights: almost one leisure journey in two lasts 4 nights or more. This trend in the distribution of journeys according to the duration is similar in 2001 for French travellers (source DATELINE) than for European ones. However, the duration of leisure travels (lasting at least one night) tends to decrease for a few years (Cf. Annex 1). Moreover, the number of long trips (> 3 nights) in 2005 has considerably fallen in respect to 2004: - 3.1 %, while short trips have decreased by 1.9 % (Cf. Annex 1).
This distribution is easily understandable when referring to the different purposes of leisure journeys: Figure 2-16 outlines the importance of Holiday journeys (= journeys undertaken for the purpose of a holiday and including at least four overnight stays). They represent 41% of all leisure journeys:

![Figure 2-16. Leisure journeys distribution by purpose](Source: Dateline)

Two other purposes also stand out: visiting friends or family (21%) and general leisure (18%).

**Average number of co-travellers per journey**

Little information on the number of persons travelling together is available. A European study (Ref 10) relative to the features of long-distance travel only provides such information for some European countries in 1999. This study shows large differences from one country to another. For instance Danish people, who are relatively autonomous and independent, travel alone in 40% of the cases. Conversely, Spanish and Austrian prefer travelling in groups of at least 3 people. (source European Commission Ref 10).

**Share of journeys abroad**

According to Dateline, among the leisure journeys, 24% take place abroad. However, this share differs noticeably between European countries, as shown in Table 2-3:

<table>
<thead>
<tr>
<th>Home country</th>
<th>AU</th>
<th>BE</th>
<th>DA</th>
<th>EI</th>
<th>FR</th>
<th>GM</th>
<th>GR</th>
<th>IT</th>
<th>LU</th>
<th>NL</th>
<th>PO</th>
<th>SP</th>
<th>SW</th>
<th>SZ</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of journeys abroad</td>
<td>11.7</td>
<td>70.8</td>
<td>13.2</td>
<td>50.1</td>
<td>16.9</td>
<td>13.0</td>
<td>35.8</td>
<td>6.2</td>
<td>21.1</td>
<td>100.0</td>
<td>50.0</td>
<td>12.0</td>
<td>7.8</td>
<td>26.6</td>
<td>57.8</td>
</tr>
</tbody>
</table>

*Note: The countries with the highest rate of journeys abroad are stressed in red, whereas journeys with the lowest rate are in blue.*

The smallest countries (Luxembourg, Belgium and Switzerland) appear as the countries the most mobile abroad. Conversely, in the largest countries such as Spain, Greece or France citizens prefer staying in their home country and undertake few trips to foreign countries. This is mainly due to two factors: the size of the country and its diversity (sea, mountains, etc.).
2.3. Conclusion on the European mobility overview

Beside highlighting the strong global traffic increase over the past decades (especially in air transportation) and the preponderant share of long-distance trips (>100 Km) that represent 70% of the total European traffic, the overview of the European mobility also particularly stresses the differences in the characteristics of these long-distance trips according to the trip purpose.

The analysis indeed shows that leisure and business trips only present similarities in terms of journey distribution according to the traveled distance. As well for leisure as business purposes, around 74% of the trips are made between 100 and 400 Km.

The other trip characteristics are generally significantly different according to the leisure or business purpose:

- If the use of the air transport mode always increases with the traveled distance, the boundary distance from which the air transport market share exceeds 50% is significantly lower in case of leisure trip. This boundary is indeed 600 Km for business trips and 1000 Km for leisure trips.
- The trip duration is often shorter for business purposes. For instance the share of trips with at least 4 nights duration is 2.5 times higher in the case of leisure trips.
- Both trip purposes also significantly differ in terms of the age of the travellers since the share of travellers over 65 and below 25 is 3.5 times higher when the people travel for leisure purposes.
- The gender distribution also varies a lot between trip purpose since male travellers represent 76% of business travellers vs. 57% of leisure travellers.

The characteristics of the long-distance trips made by French people are very close to the general European characteristics. The main differences concern the modal split:

- the larger use of road transport mode on distance exceeding 1000 Km by French than by European travellers
- the larger use of the rail transport mode than European due to the important French high-speed rail network.

Comparisons between Europe and Poland appear to be very difficult to make due to the lack of data on the features of the Polish mobility. The analysis however manages to show the very low market share of air transport in Poland since only 1% of Polish travellers use this transport mode. In addition trips for business purposes only represent 1% of the total trips made by Polish travellers.

More generally, detailed data on long-distance trips made to and from all the 27 European countries is lacking. This lack of data is therefore an incontrovertible obstacle to the realisation of a total mobility analysis at a EU27 level.

3. MAIN FACTORS INFLUENCING MOBILITY

As we showed in section 2, the mobility features can change a lot according to countries, trip purpose, etc. More generally speaking the mobility is driven by numerous determinants that can be sorted into three categories:

- The demographic determinants: what are the characteristics of the traveller, in term of age, gender, occupation, localization, etc.? 
- The socio economic determinants: GDP, households level of income, etc.
- The transport supply = what is proposed to the traveller: infrastructure / service (price, speed, quality, etc.)...

3.1. Demographic determinants

The goal is to identify and analyse demographic and socio-economic determinants by leaning on the observations at a micro level. Thus, three main factors, Demography, Economy and
Localisation, are investigated thanks to the study of the travellers’ characteristics. In this section, we mainly base on the French surveys and we principally use as mobility indicators the departure rate, the number of journeys per year and the duration of the travel, by population group. These indicators are shown in Annex 2. Leisure travel is overall concerned.

The demographic growth is naturally a factor of mobility. In the future, the demographic growth is expected to be much lower than in the past. Thus, there is reason to believe that it will generate a slowdown of the transport demand growth. The features themselves of the demography are also important.

3.1.1. Gender

When considering EU 15 we observe a significant difference in travelling volume between genders since 60% of the total journeys are made by men. Moreover this share tends to stay constant whatever the considered distance class.

Nevertheless, behaviours are different in France, since the traffic volume is equally distributed between men and women, i.e. women tend to make the same yearly number of long-distance trips as men.

![Figure 3-1. Journey distribution between genders by journey duration (Source Dateline)](image)

![Figure 3-2. Journey distribution between genders by journey purpose (Source Dateline)](image)
The higher number of journeys made by male travellers in EU 15 is also confirmed when differentiating the journeys according to their duration. The share of female travellers indeed increases with the journey duration (Figure 3-1). This trend is particularly marked for French travellers since while only around 40% of the journeys undertaken in the day or journeys with one night are made by women, this percentage is around 50% for other journey durations. This lower share of short duration journeys made by women can be mainly explained by the significant lower share of women travelling for leisure purposes compared to men (Figure 3-2), since we already showed that business trips often have short durations.

### 3.1.2. Age

When basing the analysis on the Dateline database we clearly observe that most mobile European people are between 25 and 64 years old. These travellers indeed make 93% of the business journeys and 76% of the leisure journeys.

This trend is confirmed in France by an INRETS study (Ref 15) comparing the holiday departure rates of French people. Young people (less than 30) and people aged 70 and over have the lowest departure rates. In addition, the number of long distance journeys and the travel duration is growing with the age, with exception of the group “70 and over”. The high level of mobility of the 60 – 70 group is not surprising: it corresponds to the advancement of the retirement age. These people have no occupation and their good health enables them to move.

### 3.2. Socio-economic determinants

Mobility growth is strongly linked to GDP growth, but for a few years, decoupling between both growths tends to appear, as shown in Figure 3-4. Decoupling corresponds to the difference between GDP and passenger transport growth.

However, this decoupling has not exceeded 0.5% per year. Much more data would therefore be needed to approve this trend. For some countries for example in Poland, the increase in passenger transport may be higher than GDP growth.
At a “micro” scale, the impact of economy on mobility is illustrated by the behaviour of people according to their type of occupation and to their income of course (cf. Annex 2).

3.2.1. Occupation

The fact of having an occupation supports mobility: 80% of working people realizes leisure journeys, whereas only 65% of people that have never worked participate each year to leisure journeys.

The category of occupation is also a determining factor. Managers and intellectual professions are the most mobile categories, with a rate of departure comprising between 87 and 93%. The income and the cultural level indeed favour the need and the capacity to travel. But some constraints linked to the type of occupation (farmer, craftsmen, owner of a shop) also explain the fact that some categories can not travel as they want.

Lastly, we can notice that the employed in the public sector travel more than in the private sector. It results partially from the higher number of free days in public sector.

3.2.2. Location

The home location is also an important factor in the transport demand. Indeed, the level of mobility (departure, frequency) increases with the size of the agglomeration. Several reasons for this phenomenon: firstly, big cities represent stress, pollution, proximity, etc. People living all the year in city need generally to rest in quieter places (sea, mountain, countryside...). It also corresponds to a need of nature. Secondly, the transport system is more developed in and around the cities than in the countryside: airports are closer; High-Speed Train connects easily large cities, whereas small cities have only traditional trains. Thirdly, we can assume a higher level of income in big cities, which could as well justify their higher mobility.
3.2.3. Income

Mobility grows with the level of income: travel (journeys + accommodation) are expensive, thus money is an important parameter in the choice to realize a travel.

Departure Rate in France (INRETS Ref 15) show that the 34% of the richest of the population undertake 50% of the journeys.

Hence, one of the main determinants influencing transport mode choice while planning a journey is the level of wealth and individual income of travelers. The value of time, comfort needs and accommodation costs depend on this basis. These factors, expressed in monetary units, play important role in travel costs calculation, and their level depends, also, on chosen mode. His or her low income and low value of time determines a traveler for rational choice of less expensive mode, that cruises at lower speeds. The more one earns the faster and the more expensive vehicle is more advantageous solution. Staying aligned with these rules, the income distribution should be known when planning a transportation system. The more detailed information, the greater possibility to satisfy the needs.

Table 3-1. European average gross wages. [Source: UNECE]

```
<table>
<thead>
<tr>
<th>Indicator country</th>
<th>GDP per capita</th>
<th>Population</th>
<th>Active population</th>
<th>Work activity</th>
<th>Monthly gross wage</th>
<th>Yearly average gross wage</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tbody>
</table>
```

“EU+” means all countries providing data concerning active population except for the USA
Available data

The internet data search for European detailed income information revealed that the United Nations Economic Commission for Europe\(^2\) is the only free of charge, income data provider. The data is quite old (year 2000) and considers means of gross monthly wages\(^3\). Some of the information had to be extracted from other sources to fill the UNECE data list gaps\(^4\).

The outcome distribution approximations

When calculations of all distributions for each countries are done using exponential function and Pareto power law theory, the average European gross wage distribution is compared to the one of the USA. The results, shown below on Figure 3-5, indicate that the USA has more population earning higher wages than the average of 27 Member States of European Union, but it may be caused by different year of the EU and the US income data (2000 and 2004). The estimated distributions approximations are taken in consideration for further works.

\(\text{Figure 3-5: Comparison of EU27 and USA gross wages distributions using exponential function and Pareto power law theory.}\)

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2 http://w3.unice.org/pxweb/DATABASE/STAT/2-ME/3-MELF/3-MELF.asp
Wages and salaries are defined as the total remuneration, in cash or in kind, payable to all persons counted on the payroll, in return for work done during the accounting period. In the ECESDB the data refer to Average monthly gross wage. Average monthly gross wage covers all earned incomes (basic wages and salaries, payments additional to wage or salary, direct remuneration and bonuses, payments for days not worked, remuneration for being on call to work, and other wage or salary components) all charged to be paid to employees for the related period. The data are based usually on a sample surveys - monthly, quarterly and annual. Information on compilation methods and practices in individual countries can be found in the IMFs Special Data Dissemination Standards (SDDS) available on the Internet at http://dsbb.imf.org/Applications/web/sddshome/ (IMFs Special Data Dissemination Standards (SDDS)).

3 Gross Average Monthly Wages for: Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom are derived by dividing Average Gross Annual Earnings in Industry and Services (Of full-time employees in enterprises with 10 or more employees) by 12.
Gross earnings are remuneration (wages and salaries) in cash paid directly to the employee, before any deductions for income tax and social security contributions paid by the employee. Data is presented for full-time employees in industry and services.

3.3. Transport infrastructure in Europe

The transport infrastructure is an essential parameter in mobility for several reasons: firstly it impacts on the decision to travel or not (the phase of generation is directly concerned). Secondly, supply has effects on the choice of the transport mode (i.e. on the phase of modal split).

The existence and development of such infrastructure are strongly linked with transport policies. That is why it is particularly interesting to deal with such European policies when focusing on transport infrastructure.

3.3.1. Transport policy objectives

The European transport policy has developed considerably over the last fifteen years. The border opening allowed the free circulation of persons, and thus stimulated the passenger’s transport growth within Europe. This development of mobility went hand in hand with an improvement of transport systems: advancements with regards to security, passenger’s rights and facilities have been performed. But this strong growth has its limits and impacts negatively on pollution, congestion and accidents. The goal of the EU’s common transport policy is therefore to develop transport systems that meet with a triple challenge: a economic, social and environmental challenge. More precisely, the European transport policy aims at providing users transport systems with the following features:

- Efficient and effective
- Affordable
- Offering high quality: more security, safety, facilities, comfort, less congestion
- Consolidating passenger’s rights

These transport systems should ensure a high level of mobility within European Union while taking into account environmental matters such as pollution, accidents, congestion, in other words the negative effects of transport. To summarize, a sustainable mobility is needed. Adopted by the European Commission in 2001, the White Paper “European transport policy for 2010: time to decide” develops these objectives and identifies the main problems relatives to transport development. It then proposes policies to confront these difficulties.

“The White Paper offers a dynamic plan of action to achieve a better balance of transport modes which will ease bottlenecks and congestion, and reduce pollution.”

How to take up such a challenge?

- Many infrastructure projects, called the trans-European transport networks (TENs) have been launched for around ten years. They enable time-saving, reduction of pollution and a balanced approach to land settlement. Even though considerable progresses have been made in the network advancement, it remains plenty to do if we want to finish the realization of all the European corridors by 2020.
- Research and Technological innovations must be much more developed in order to make transport more environmentally friendly. They should optimize each mode’s own potential and limit their negative side-effects. Galileo is an example of innovation programmes led by the European Union, in line with the transport white paper’s objectives. Furthermore, research in engine technology must be carried on so as to make the engine more efficient and more economical in energy. The use of alternative energy source has to be strengthened.
- The modal transfer to transport modes less polluting (particularly for long distance and urban trips) must be enhanced in order to balance better the transport modes.
- Co-modality, i.e. the efficient and optimal combination of transport mode will also help to perform the objectives set by the white paper.
- Lastly, measures and standards must be set in order to make movements safer and to fight against pollution as well. France often plays a role in the setting up of these standards;
Evolving context

The objectives of the European transport policy remain unchanged, nevertheless the general context has evolved, notably between 2001 and 2007:

- The European Union has enlarged: the UE is gone from 15 to 27 countries in 2007. Such an enlargement has important consequences on the network framework. New axes have appeared. In addition, the new member countries have priorities that totally differ from EU15’s whereas the states of EU 15 focus on problems of pollution, congestion or land use, the main concern of the new member is to improve their accessibility.

- The issue of environment has become a priority: during the last years, environmental pressure applied on the governments have been intensified in order to show that environment has to be taken into account. Indeed, transport is the sector that increased the most its CO2 emissions between 1990 and 2004: + 29 %. The share of transport in CO2 emission accounted for 21 % in 1990 to reach 26 % in 2004 (84 % come from road). Conversely, sectors such as industry, household and services, have seen their share in CO2 emission decreasing (Source: Eurostat).

- The international context has evolved: the terrorism threat has intensified and is now a priority in the transport: as a result of the 11th of September, many measures have been taken, especially in airports (for example, the new law in Europe relative to liquid products).

The transport policy impacts directly on the supply, and the supply itself conditions the transport demand.

![Figure 3-6: Comparison of CO2 evolutions by sector](Source: Ref 12)

3.3.2. Infrastructure

Infrastructure development played an important role in the past growth of mobility, and should continue in this way.

During the last half century, the development of transport systems was mainly profitable to fast networks:

- The length of motorways in EU15 has more than tripled, as shown in Figure 3-7 it went from 16 000 km in 1970 to 55 700 km in 2004. This development combined to the growing motorization of households explains the predominance of car over the other modes.

- Although the length of railways decreased during this period (-15 % in 35 years as shown is figure 11), the high speed rail network appeared in 1981 has strongly developed: high-speed lines reach now 4 800 km. The high speed rail network is expected to increase in size: between 2007 and 2009 12 lines have to be constructed.

- The number of airports has considerably grown since 1960 (source: Ref 11).
3.4. Conclusion on the mobility determinants

Although we observe links between the mobility evolution and features and some economical, demographic and infrastructure factors, the previous analysis is not able to quantitatively measure these links. This is mainly due to the lack of detailed data on the European mobility features and evolution. A deeper analysis of the mobility determinants would then first of all require to get relevant data to estimate how the association of some identified factors can impact the level and the characteristics of the European traffic.

4. Mobility in Areas where EPATS is Relevant

EPATS aims at opening up some European regions by providing a new way of travelling in areas badly served by air transport and not connected to the high-speed train network. Evaluating the mobility level in areas where EPATS would operate requires:

- Identifying the potential connections on which EPATS would operate
- Evaluating and analyzing the traffic levels on these potential EPATS connections

4.1. EPATS potential connections

If a bad level of accessibility can be considered as an essential feature of the potential EPATS connections this element is not sufficient to identify these connections. Indeed, thanks to the implementation of interactive transportation system EPATS would be pertinent on all connection where there is a need of individual transport.

The ESPON project provides accessibility indicators that describe the location of an area with respect to opportunities, activities or assets existing in other areas and in the area itself, where “area” may be a region, a city or a corridor.

The multimodal potential accessibility indicator has been calculated in the ESPON project for all NUTS 3 regions of the EU (see map 4-1). Again, accessibility has been standardized to the average accessibility of the EU space. Regions colored in green have a below-average multimodal potential accessibility, regions in yellow and red an above average accessibility.

Several regions in Germany, Austria and France have below average accessibility values, some of them are even extremely peripheral. Many regions in Portugal, Spain, Ireland, Scotland, Wales, Norway, Sweden, Finland, Southern Italy and Greece have very low accessibility values. Those regions do not have good access to international flight services. Nearly all regions of the candidate countries do have below average accessibilities. The only exceptions are the capital cities and partly their surrounding regions because of international airports and important
connections. For all other regions the combined effect of low quality surface transport infrastructure and lack of air accessibility leads to the low performance in terms of accessibility. In general, the enlargement of the European Union leads to a decrease in average accessibility.

The number of km per person per road by obligated (business) trips has been also calculated for all NUTS2 of the EU space. See map 4-2. Regions colored in dark greens are the ones corresponding to the periphery of the EU space, and so the distances to their destinations are generally higher than the ones the regions situated in the centre of this space.

As shown by comparison of maps 4-1 and 4-2, where multimodal accessibility potential is small, the traffic is dominated by car. This area colored in dark green are the regions, where cars can be replaced by small aircraft and where there is greatest potential for EPATS development.

Map 4-1. ESPON Multimodal potential accessibility 2001, [ESPON project 1.2.1,2001]
According to ESPON project the potential accessibility is a construct of two functions, the activity function representing the activities or opportunities to be reached and the impedance function representing the effort, time, distance or cost needed to reach them (impedance function) (Wegener et al., 2002). For potential accessibility the two functions are combined multiplicatively, i.e. are weights to each other and both are necessary elements of accessibility:

\[ A_i = \sum_j W_j^a \exp(-\beta c_{ij}) \]

where \( A_i \) is the accessibility of area \( i \), \( W_j \) is the activity \( W \) to be reached in area \( j \), and \( c_{ij} \) is the generalized cost of reaching area \( j \) from area \( i \). \( A_i \) is the total of the activities reachable at \( j \).
weighted by the ease of getting from $i$ to $j$. The interpretation is that the greater the number of attractive destinations in areas $j$ is and the more accessible areas $j$ are from area $i$, the greater is the accessibility of area $i$. Occasionally the attraction term $W_j$ is weighted by an exponent $\alpha$ greater than one to take account of agglomeration effects. The impedance function is nonlinear. Generally a negative exponential function is used in which a large parameter $\beta$ indicates that nearby destinations are given greater weight than remote ones. The accessibility model used here (based on Spiekermann and Wegener, 1996) uses centroids of NUTS 3 regions as origins and destinations. The accessibility model calculates the minimum paths for the road network, i.e. minimum travel times between the centroids of the NUTS 3 regions. For each NUTS 3 region the value of the potential accessibility indicator is calculated by summing up the population in all other regions including those outside ESPON space weighted by the travel time to go there.

The aggregation over modes is introduced in the impedance function of the accessibility model by combining the information contained in the modal accessibility indicators by replacing the generalised cost $c_{ij}$ by the ‘composite’ generalised cost

$$c_{ij} = -\frac{1}{\lambda} \ln \sum_m \exp(-\lambda c_{ijm})$$

where $c_{ijm}$ is the generalised cost of travel by mode $m$ between $i$ and $j$ and $\lambda$ is a parameter indicating the sensitivity to travel cost. This formulation of composite travel cost is superior to average travel cost because it makes sure that the removal of a mode with higher cost (i.e. closure of a rail line) does not result in a - false - reduction in aggregate travel cost.

Finally the following general formula is obtained:

$$A_i = \sum_j \left( f_1(\text{Opportunities}) \ast \sum_m f_2(c_{ijm}) \right)$$

The method developed to identify these EPATS potential connections is the following:

1. We compute the multimodal accessibility level of all European NUTS 2 connections by multiplying the accessibility level of both NUTS2 origin and NUTS2 destination given by ESPON
2. We keep NUTS 2 Origin_Destination (O_D) connections for which the multimodal accessibility level is below the average accessibility level in all European connections
3. We compute economical activity levels of each connections by multiplying the GDP levels of both NUTS2 O-D given by ESPON
4. We keep connections for which economical activity level exceeds the average value on all the considered connections or if the traffic flow exceeds the average traffic flow on the considered connections (assumption which requires future considerations and deeper analysis)
5. We finally keep connections with a distance less than 2500 km which is the maximum range of EPATS aircraft

This methodology is then applied on 28 countries: Austria (AT), Belgium (BE), Bulgaria (BG), Cyprus (CY), Czech Republic (CZ), Denmark (DK), Estonia (EE), Finland (FI), France (FR), Germany (DE), Greece (GR), Hungary (HU), Ireland (IE), Italy (IT), Latvia (LV), Lithuania (LT), Luxembourg (LU), Netherlands (NL), Norway (NO), Poland (PL), Portugal (PT), Romania (RO), Slovakia (SK), Slovenia (SI), Spain (ES), Sweden (SE), Switzerland (CH), and United Kingdom (UK).
We then obtain that 15,223 connections among the 62,483 total NUTS 2 connections in all the 28 considered countries are EPATS potential connections. All together these potential connections represent 24% of the total existing NUTS 2 connections in Europe. Figure 4-1 presents the total EPATS potential connections between the 28 countries.

Among all these identified potential connections 63% are made to or from 5 European countries: France, United Kingdom, Italy, Germany and Spain. With 2,223 connections to or from French NUTS 2, France is the country concerned by the highest number of EPATS connections while Poland is in eighth position with 607 potential connections to or from Polish NUTS 2.

Separating domestic and international connection we found that domestic connections do not represent more than 17% of the total EPATS potential connections (Figure 4-5). All together, domestic connections only represent 9% of the total EPATS connections. This means that most of the EPATS connections are made between two different countries. Figure 4-6 gives the number of other countries with which each country has potential EPATS connections. This figure shows that 16 among the 29 considered countries have connections with more than 17 other countries.
4.2. Current traffic flows on EPATS connections

Existing traffic levels on the EPATS potential connections can be expressed in two different units: in number of passengers and in number of passenger-kilometers. Both units providing different information on the traffic features and levels it is particularly interesting to differentiate them in the mobility analysis. The current traffic levels on potential EPATS connections are in addition considered for two transport modes: individual road transport and air transport modes. Rail transport mode is indeed not pertinent on such connections with low accessibility levels (meaning bad connections with the rail and in particular high-speed rail network).
Using the results of research on interregional mobility in Europe, carried out in ESPON project (ref. 9) we calculate the traffic on EPATS connection. In total in 2000, the traffic on all the potential EPATS connections is 4 billion passengers and 2400 billion passenger kilometers.

The road traffic is predominant when being expressed in terms of number of passengers, since 79% of the total passengers traveling on potential EPATS connections travel by car. However the market share of road transport decreases dramatically in terms of passenger kilometers since it only represents 47% of the total PKM traffic. Air transport mode is indeed mainly used on connections for which the distance between NUTS2 exceeds 1000 Km. Indeed, on one hand connections with distances exceeding 1000 Km represent 79% of the total potential EPATS connections. On the other hand, the air transport market share is predominant on such connections since the number of air passengers exceeds the road one on 10 009 among the 11 989 connections with a distance exceeding 1000 Km (i.e. on 83% of the connections exceeding 1000 Km).

As well in terms of number of passengers as in PKM, the highest traffic levels are to and from Italy, Spain and France. These three countries also are the ones with the highest domestic traffic levels as well in terms of passengers as in terms of PKM.

### 4.3. Some remarks on mobility in areas with poor accessibility level

Regions considered in the context of EPATS are therefore many regions mainly marked by their low accessibility level, as written in the ESPON project (Ref 9): ‘multimodal potential accessibility (see map 4-1) locates regions with clearly above average accessibility mainly in an arc stretching from Liverpool and London via Paris, Lyon, the Benelux regions, along the Rhine in Germany to Northern Italy. However some agglomerations in more remote areas such as Madrid, Barcelona, Dublin, Glasgow, Copenhagen, Malmö, Göteborg, Oslo, Rome, Naples Thessalonica and Athens are also classified as being central or at least intermediate because their international airports improve their accessibility. At the same time the European periphery begins in regions that are usually considered as being central. Several regions in Germany, Austria and France have below average accessibility values, some of them are even extremely peripheral. Many regions in Portugal, Spain, Ireland, Scotland, Wales, Norway, Sweden, Finland, Southern Italy and Greece have very low accessibility values. These regions do not have good access to
international flight services. Nearly all regions of the candidate countries do have below average accessibilities. The only exceptions are the capital cities and partly their surrounding regions because of international airports and important connections. For all other regions the combined effect of low quality surface transport infrastructure and lack of air accessibility leads to the low performance in terms of accessibility. In general, the enlargement of the European Union leads to a decrease in average accessibility. […]

For example, the mountainous areas like the Massif Central, the Alps in Austria or the Carpates have a low accessibility, by contrast with river basins as in the northern Italy with the Pô. The case of coastal areas is more contrasted, according to local particularities. […]

The coherence of the Nordic network appears clearly with the role of gateway of Kobenhavn. The Baltic States are clearly related to the Nordic triangle, even if the connections could be improved as for example, from Stockholm to the Baltic states capitals. Indeed, the connections between the Baltic States and continental Europe according to this indicator are inexistent.

In the Iberic Peninsula, a high level of integration is reached between Madrid and the major Spanish and Portuguese cities, but the gap with continental Europe is here[...].”

The mobility analysis on the potential EPATS connections has however to be restricted to a general traffic analysis without providing more detailed information on the mobility features. Indeed, a deeper knowledge of the mobility features on these connections would need detailed data that currently miss.

5. CONCLUSIONS

When presenting the main characteristics of mobility in EU15, the overview of the European mobility shows the importance of the long-distance traffic (i.e. over 100 Km) in the total traffic since 70 % of European travellers have made long distance journeys in 2001. In addition, the analysis also clearly highlights that the long-distance journeys characteristics change according to the customer profile: business and leisure traveller do not travel the same way (difference in terms of transport mode, duration, traveller features (age, gender, etc.)). Characteristics of long-distance mobility therefore vary a lot according to the trip purpose.

The analysis also highlights that providing a similar mobility analysis at a EU27 level is unfortunately not feasible due to the lack of detailed data on long-distance traffic. As a consequence, data is lacking to perform a detailed deep mobility analysis on the connections where the personal aviation would be pertinent, i.e. on connections associating bad accessibility levels, economic attractiveness and significant traffic flows.

We identify that 15 223 connections between 28 countries can be considered as EPATS potential connections. All together these potential connections represent 24% of the total existing NUTS 2 connections in Europe.

Despite the lack of detailed data on the traffic occurring on these connections the analysis manage to provide very interesting and important information on the current traffic levels and modal splits. The total traffic on the potential EPATS connections is 2 400 billion passengers amongst whom 436 million travel to and from France and 93 million to and from Poland. The analysis also highlights the large market share of the road transport mode on these connections since 79% of the passengers travel by car. The air transport market share often exceeds the road one for distance over 1500 Km and reaches 100% for distances over 2000 Km.

Forecasting of interregional & intra-European personal transportation, especially including EPATS small aircraft transportation requires exhaustive knowledge on interregional passenger traffic as well as on socio-economic situation including complex and authoritative information concerning wealth and income distribution of population.
During passenger flow and their structure analysis (modal split, directions and distances, volume, purpose and wealth (income) structure of travellers), the following, available sources were used: domestic and European Statistical and transport Institutions databases (Eurostat, Eurocontrol, AIS), Research Institutes and Research and Development Facilities compilations, European Programmes framework research analysis, especially including: ESPON, DATELINE, TREMOVE, SCENES, EUNET, ASSESS and numerous internet publications and data.

Despite huge amount of gathered data and analyzed it was not possible to depict complete image of interregional passenger traffic structure in the European Union. Its main sources are:

- lack of source and complex information concerning long distance personal car travel (volume and O-D travel directions), which constitute more than 70% of passenger traffic
- incoherence and gaps in data concerning air traffic, especially air-taxi and on-demand traffic.
- lack of authoritative information on total existing airport infrastructure. The available complete information is limited to 420 communication airports only, which number reaches 20% of total existing airports in Europe,
- no data gathering, storing and formatting procedure compatibility in Member States publications
- no authoritative knowledge on wealth and personal income structure in respective regions especially in terms of the top last quintile and percentile of distribution (i.e. people who use the fastest, individual modes of transport) 
- the existing data concerning transport infrastructure and flow are far from reality in many cases, especially in new Member States of the Union. This data is also correlated with income distribution in respective regions (lack of knowledge on number of travels, distances and mode of transport according to income distribution)
- no complex and reliable models describing accurately interregional and inter-sub regional passenger flows

The abovementioned state-of-art created need for many assumptions (data published in the above mentioned European programmes reflect the reality and income distributions take shape of Lorenz-Pareto law) and using passenger flow models adequate to the current knowledge and allocated resources. Main EPATS system passenger traffic flow directions, their volume and characteristics should be taken with reserve and used for orientation where the main areas of system implementation are. These areas, including EPATS characteristics are one of the initial assumptions for a new conception of air traffic management and control system planned in the SESAR programme.

Main reason of lack of complex and authoritative information on European interregional passenger traffic is the lack of particular transport and economic objectives and no Central European Institution coordinating achieving transport system development strategy. The importance of it is arising especially outside main communication channels, despite a fair number of undertaken researches and participating research centres. This knowledge cannot be acquired basing on fragmented and not always compatible data gathered and processed according to particular, own Member State methods. Transport system is interconnected among all countries and requires complex and homogenized operation procedures as well as statistical and research, similarly to Single European Sky. Attempt in reaching databases concerning transport and passenger flows of particular Member States is at the mercy of statesmen goodwill and prone to failure, putting aside the quality of very diversified data in terms of definitions, criteria and format. One of the result are divergences of the outcomes of abovementioned programmes.

Coherent and sustainable European Union transport system development and implementation of tailored to this development policy of balanced development of European regions, which is one of the main aim of EPATS project, requires undertaking common initiative at the European Union level, Member State and regional powers in order to create a common platform of
planning, coordinating and surveillance of research concerning European transport system, mobility, accessibility to public goods and future needs of personal transport forecasting.

According to the abovementioned, it is proposed:

1. Creating European Centre for Personal Interregional Transport as a common research platform of the EU Members and taking responsibility for preparation of fundamentals for political decisions taking regarding interregional personal transport development.

2. Planning and initiating research on EPATS interactive transport system aligned to research on 4-dimensional flight planning system. EPATS Interactive Transportation Management Centre (ITMC) initiative should be correlated to System Wide Information Management – Inter-Operability Centre (SWIM-IOP)

3. Planning and initiating European interregional passenger transport modelling and forecasting using authoritative mobility database especially taking under consideration EPATS transport subsystem.

4. Including adequate research to the prepared ESPON 2013 programme in order to verify potential EPATS connections and forecasted volume of transport transferred from personal car transport.

5. Initiating a close cooperation among European programmes responsible for personal air and surface transport in interconnected topics and including common goals. It is especially valid for ESPON 2013, SESAR and EPATS programmes. It is coherent with SESAR and ESPON 2013 performers intentions, which the application for further research writes the following sentences: “A user oriented approach shall be adopted for the ESPON 2013 Programme. The ESPON 2013 Programme shall through a strong involvement and awareness be raising offer targeted analytical deliveries upon demand, responding to needs.”

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Executive summary

A mode choice model that generates on demand small aircraft travel forecasts between NUTS-2 regions connections of 28 EU countries based on interregional passengers mobility and value of time and vehicle performance characteristics is presented. The paper explains Small Aircraft Transport demand modeling at the EU mobility and airspace levels. The model is based on the assumption, that the passenger chooses the mode of transport, which minimizes their generalized cost of travel. The model has been developed under the project EPATS (European Personal Air Transportation System) funded by EU Commission. The model gives an instrument to evaluate the potential transfer of passenger demand to personal aviation by 2020 and the fleet of EPATS aircraft that would be needed to satisfy this demand.

The estimations have been made first at European level and then at national level for domestic traffic of two European countries: France and Poland.

1. INTRODUCTION

In modern society, the need to travel within Europe is constantly on the increase, and is expected to continue growing. The extension of the European Union to 27 members will further intensify this development. However, current transport modes have limitations and are already suffering from congestion in some places: most large airports are congested or could quickly reach their maximum capacity. Conversely, other areas, especially in Eastern Europe, are hardly accessible.

Moreover, society is evolving: passengers are becoming more demanding in terms of time and cost, but their behaviour is also changing: individualisation is gradually becoming the byword, meaning that people want to have a choice. Future mobility therefore cannot be entirely satisfied by current transport systems, such as hubs, railways or highways.

It is well known that a decision about whether and how to travel is made by considering several elements of the trip. The most important are mode accessibility and trip purpose, followed closely by travel duration and affordability of available alternatives. The more difficult issue is determining to what degree any of these factors influences travel decisions. In our analysis we have made attempts to give a monetary measure to these factors, which allowed the calculation of the generalized travel costs, including both material and non material costs. The major non material cost of travel in our model is the passenger time value.

A new transport mode is thus needed, and with this is mind, a new concept, called Personal Aviation, has been developed. This would consist in taking long-distance trips in a short time at an acceptable cost, thanks to the use of small aircraft (jet, turboprop, pistons) departing from small airports. These aircraft, operating in almost all weather conditions, could serve any kind
of location, but their main point of interest would be in serving inaccessible areas. The concept of personal aviation implies the development of a system. This system is called “EPATS”: European Personal Air Transportation System, which is a complex collection of systems, procedures, facilities, aircraft and people, working together. EPATS would be developed especially for regions with little to no airline service, and where high-speed trains do not represent a viable alternative, due insufficient passenger numbers.

At first, EPATS will help to meet the needs of a society that is more and more mobile and demanding, by increasing passenger choice. Then, EPATS aims at improving the accessibility of some areas in Europe and reducing disparities caused by uneven development of networks. This system proposes an alternative mode to road transport by private car. But EPATS is also a means to make a stronger aeronautical Europe by developing technologies needed for this kind of aircraft and by strengthening general aviation. Lastly, EPATS should increase the operational capacity and the efficiency of air transport systems.

2. POTENTIAL EPATS CONNECTIONS

EPATS aims at opening up some European regions by providing a new way of travelling in areas badly served by air transport and not connected to the high-speed train network. Evaluating the mobility level in areas where EPATS would operate requires:
- Identifying the potential connections on which EPATS would operate
- Evaluating and analyzing the traffic levels on these potential EPATS connections

A bad level of accessibility can be considered as an essential feature of the potential EPATS. We consider a bad level of accessibility when the level is below the average.

The ESPON project (Ref 28) provides potential accessibility indicators that describe the location of an area with respect to opportunities, activities or assets existing in other areas and in the area itself.

Potential accessibility is a construct of two functions, the activity function representing the activities or opportunities to be reached and the impedance function representing the effort, time, distance or cost needed to reach them (impedance function) (Wegener et al., 2002). For potential accessibility the two functions are combined multiplicatively, i.e. are weights to each other and both are necessary elements of accessibility.

The potential transfer to EPATS of passenger demand is estimated on connections where EPATS is relevant. Such connections are identified in the mobility analysis performed in the EPATS project. The results shows that 15 223 connections among the 62 483 total NUTS 2 connections in all the 28 considered EU countries are EPATS potential connections. All together these potential connections represent 24% of the total existing NUTS 2 connections in Europe. These are connections where the intensity of passenger traffic is too small to handle the mass public transport and where passenger transport is mainly carried on cars.

3. ESTIMATION METHOD

3.1 GLOBAL APPROACH

The essential air transport In EPATS system will be done outside main airways, in the airspace and at the airports, so far, not used. Most of the flights will be done between airports of NUTS2 (280) and NUTS3 (1180) regions, that do not have direct scheduled air connections, nor hi-speed train.

Pistons, constituting most of the fleet, will fly in the airspace below 6 000m, turboprops at 6 to 8 thousand and only very light jets will operate at levels typical for large passenger aircraft, i.e. above 9 000 m. The basic problem of ATM-ATC is securing possibilities to start and land in all weather conditions at poorly equipped airports and safe execution of flights in uncontrolled (self controlled) space.

The size of the passengers’ traffic between regions was taken from the ESPON project.
The forecasted demand of EPATS aircraft is based on the following assumptions:

- The average traveler has knowledge about available transportation alternatives and make rational choice in terms of money and time needed to complete the trip. Globally the choice is based on user perceived benefit.
- The bases of demand prognosis are current and future data concerning: interregional passengers mobility for each mode of transport and particularly car, regional socioeconomics data, household income distribution, value of time distribution and transportation system operational and economics characteristics.
- The demand model is based on minimization of travel costs for a given level of services.
- Remote regional authorities, social and commercial organizations, and local airports and aircraft owners are interested in air transportation services and are planning development of small aircraft transportation system.
- The EU recognizes the EPATS as “public good” and assists in realization of coherent economic European space development. The EU includes the EPATS in the transportation, regional and research programs, as an important element of the European Transportation System.

Generalized costs minimization method requires building a model, which enables to calculate and choose such modes of transport structure, that minimize generalized costs of travel in a given time and space in the range limit of missions, security and environmental requirements. **Generalized costs include inside (user) and outside (social, taxpayer) generalized costs.**

**While inside generalized travel costs include:**

- Transportation costs (user out of pocket total).
- Externalities cost (taxpayers - which reduces user out-of-pocket costs).
- Value of travel time (which depends on personal incomes and travel objective).
- Additional costs linked to travel (other expenses overnight accommodation, per diem costs).
- Subjective values like preferences and comfort expressed in monetary unit and explaining costs or benefits described by an indicator corresponding to transport costs.
- Transportation Public subsidy which reduces user out-of-pocket costs.

The elements of public costs, which will be taken into account in the model, will depend on scenario chosen. In our model, the outside (taxpayer) costs will be taken from previous research works and analyses concerning social costs of functioning of respective transport systems undertaken both in Europe and the United States.

**The transport choice model will include the following elements and sub models:**

- Travel choice determinants: socioeconomic characteristics of region, including Lorenz curve (income distribution).
- Characteristics of road, rail and airport network.
- Trip generation – to set up the magnitude of travels by mode, distances, income category basing on a statistic data base analysis.
- Transportation costs model of respective modes involving outside costs, as a function of distance.
- Fuel consumption model and harmful gas emissions (ecology restriction).
- Transport security analysis of different modes and tables of respective periods (assessment of security restriction).
- Travel cost model of respective modes as a function of distance and value of time (or an EPATS/car indifference curve for passenger).
- Results aggregation and indication of the most advantageous modal split for a given case calculations.
Data relating to socioeconomic characteristics, transport networks and their nodes, accessibility to communication modes and population mobility of European countries (NUTS 0), their regions (NUTS 2) and sub regions (NUTS 3) will be drawn from the results of previous research realized in the European framework programs: ESPON, EUNET, DATELINE and SCENES.

Data considering network of all existing airports in the European Union, because of lack of detailed materials in this area (especially small general aviation airports and unused military installations) will be gathered from available sources and prepared separately. Outside costs information about functioning of transport system will be gained from available statistical data and compilations about Europe and the United States (the US data will be adequately transformed for European conditions).

The existing differences between the EU Member States will be accommodated for cost calculation, while the cost estimation model will be the same for all countries and will be the subject of a separate analysis and agreements.

The travellers flow density of selected interregional connections will be estimated by widely used gravity method and verified by traffic analysis and survey.

A transport mode choice model is a model of total costs of travel of passengers belonging to a specific bracket of income, realized for specified purpose (business, private), door-to-door (D-D) using alternative modes of transport. The model allows a calculation answering the question which of the modes fulfils the conditions of the cheapest mode for a given route, purpose and traveller’s income. According to the fact, that the costs are involved in a given mode characteristics, and the characteristics of the mode will be settled in the requirements, calculations will be carried out in a feedback relation. There are three following modelling approaches projected for part of studies over the EPATS demand forecasting.

3.2. Generalized Cost

The developed estimation method is based on the minimization of the generalized cost. When a traveller with a value of time compares two transport modes, mode i and mode j, he will choose the one having the smallest generalized cost, i.e.:

\[ C_{i} < C_{j} \]

Or if:

\[ C_{i}\text{access} + V_{i}\times T_{i}\text{access} < C_{j}\text{access} + V_{j}\times T_{j}\text{access} \]

Now, let's have a look at the different elements that makes up the generalized cost.

3.2.1. Travel time

The travel time \( T_{\text{travel}} \) can be separated into four distinct parts:

- Access time \( T_{\text{access}} \) to the transport mode = access time to the transport terminal + time spent at the terminal for procedures (checking, waiting, boarding)
- Egress time \( T_{\text{Egress}} \) = Time spent at terminal after arriving (Transfer Time, Time for picking up luggage) + Time to go from terminal to destination point
- Transport time \( T_{\text{journey}} \) = time spent in transit only
- Additional time \( T_{\text{additional}} \): this should be taken into account only in the case of car travel. It corresponds to the potential breaks the traveller can take while driving.

The function is therefore (With \( d \) = travelled distance, \( Vm \) = Average speed):

\[ T_{\text{travel}} = T_{\text{access}} + \frac{d}{Vm} + T_{\text{Egress}} + T_{\text{additional}} \]
3.2.2. Travel cost

The direct cost borne by the passenger (= Out-of-pocket cost) is composed of:
- Access cost \(C_{\text{Access}}\) = cost to access the terminal. This cost is fixed.
  Note: It is assumed that the passenger goes to the terminal by car.
- Egress cost \(C_{\text{Egress}}\) = cost to leave the terminal and reach the destination. This cost is fixed.
  Note: It is assumed that the passenger goes from the transport mode to his destination point by car.
- Transport cost \(C_{\text{Transport}}\) : varies with the distance. This unit cost is the price per km paid by a passenger to use a transport service (commercial aircraft, EPATS) or to use his personal car.
- Potential additional cost \(C_{\text{Additional}}\) such as accommodation cost (for car when stopping in a hotel)

\[
C_{\text{Total}} = C_{\text{Access}} + \text{Distance} \times C_{\text{Transport}} + C_{\text{Egress}} + C_{\text{Additional}}
\]

3.2.3. Value of Time

The value of time varies according to the purpose of the trip since Business and Leisure passengers do not have the same level of value of time. In average, a business passenger has a value of time 3 or 4 times higher than a leisure passenger. This means that they do not have the same travelling budget.

The “Business market” can be segmented as well, since there are several types of business travellers: when travelling by plane, some businessmen buy flexible and refundable tickets, while others take economy-class tickets. The difference in price can be quite significant; thus we have to distinguish between Business Travellers as follows: “Economical Business Travellers”, and “Typical Business Travellers”.

Unfortunately we did not have any information regarding the relative rapport between these 2 categories; for the purpose of this analysis, we have assumed that 30 % of business travellers are economical business, and 70 % are typical business.

3.3. Principles of the estimation method

The developed estimation method consists in linking the indifference curves to the expected results i.e. to the potential transfer of passenger-km. The Indifference Curve is a representation of “value of time” versus “distance” and is the limit between the areas of preference for the modes. This is illustrated by the following graph:

![Figure 3-1: Example of indifference curve between car and EPATS](Data source: ESPON)

The passenger-km distribution versus value of time and travelled distance, for each transport...
mode (Aircraft / Car) is obtained as shown in Figure 3-2

**Figure 3-2: Methodology of the construction of passenger-km distribution table**

*Note: The schema gives in blue the links and in green the sources.*

**Figure 3-3: Developed estimation method**
The combination of both previous elements (indifference curves between two modes and passenger-km distribution by value of time and distance) can be used to obtain a modal split. We can use a model split to compare EPATS with another transport mode, and determine a passenger's preferred choice. The model split is a good way to easily determine the potential transfer of passenger-km to EPATS (see Figure 3-3).

4. SCENARIOS

We consider to perform estimations in the context of ASSESS scenarios that have been developed in order to evaluate the effects of the White Paper measures (ref 30). The particularity of the ASSESS study is that the scenarios share common assumptions concerning the macroeconomics trends (Population, GDP, Fuel price, etc). Actually, the scenarios differ in term of degree of implementation of the White Paper policy measures: there are the Null, the Partial, the Full and the Extended scenarios.

The Null scenario (N-scenario) assumes that none measure of the White Paper has been implemented, neither at the European level nor in the Member States.

Partial implementation scenario (P-scenario) includes measures already implemented and the ones likely to be implemented before 2010.

Full implementation scenario (F-scenario) includes all 78 measures introduced in the White Paper and in the White Paper action program.

Extended scenario (E-scenario) is a kind of mix between the partial and the full implementation scenario.

5. EPATS AIRCRAFT

Six EPATS aircraft types are considered in the estimations: ACP-1 - Single-Engine Piston, ACP-2 - Twin-Engine Piston, ACT-1 - Single-Engine Turbo-prop, ACT-2 - Twin-Engine Turboprop, ACJ-1 - Twin-Engine Very Light Jet (<5000 kg), ACJ-2 - Twin-Engine Light Jet (< 7000 kg). Table 5-1 presents the main characteristics of these EPATS aircraft.

Table 5-1: EPATS aircraft characteristics (Source - Ref 31)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>V-REF*</th>
<th>ACP-1</th>
<th>ACP-2</th>
<th>ACT-1</th>
<th>ACT-2</th>
<th>ACJ-1</th>
<th>ACJ-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pas. Scattering (PS)</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>19</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Max PayPayload [kg]</td>
<td>285</td>
<td>475</td>
<td>855</td>
<td>1805</td>
<td>475</td>
<td>855</td>
<td></td>
</tr>
<tr>
<td>Useful load [kg]</td>
<td>530</td>
<td>560</td>
<td>1850</td>
<td>2400</td>
<td>1100</td>
<td>2200</td>
<td></td>
</tr>
<tr>
<td>Takeoff weight [kg]</td>
<td>1300</td>
<td>2000</td>
<td>4500</td>
<td>7200</td>
<td>2700</td>
<td>6600</td>
<td></td>
</tr>
<tr>
<td>T/O Field length [m]</td>
<td>600</td>
<td>600</td>
<td>1000</td>
<td>1200</td>
<td>800</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Initial gradient [m/m]</td>
<td>0.12</td>
<td>0.18</td>
<td>0.14</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
</tr>
<tr>
<td>Cruise speed [km/h]</td>
<td>320</td>
<td>350</td>
<td>550</td>
<td>550</td>
<td>700</td>
<td>750</td>
<td></td>
</tr>
<tr>
<td>Climb speed/Cruise speed CC</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Cruise altitude FL</td>
<td>100</td>
<td>250</td>
<td>250</td>
<td>250</td>
<td>350</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Range [km]</td>
<td>1000</td>
<td>1000</td>
<td>1500</td>
<td>1500</td>
<td>2500</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td>ATM Capability: SESAR level</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>SFC [l/km]</td>
<td>0.09</td>
<td>0.10</td>
<td>0.20</td>
<td>0.30</td>
<td>0.55</td>
<td>0.30</td>
<td>0.55</td>
</tr>
<tr>
<td>Operational costs [Euros/h]</td>
<td>0.5</td>
<td>200</td>
<td>300</td>
<td>1000</td>
<td>1300</td>
<td>1300</td>
<td>2000</td>
</tr>
<tr>
<td>Certification basis</td>
<td>CS-23</td>
<td>CS-23</td>
<td>CS-23</td>
<td>CS-23</td>
<td>CS-23</td>
<td>CS-23</td>
<td>CS-23</td>
</tr>
</tbody>
</table>
6. RESULTS

The potential transfer of passenger demand to EPATS was then estimated by applying the methodology presented below (Ref 31). Estimations were obtained at European level and at national levels for France and Poland. These estimations are given in terms of traffic (expressed in number of passengers, number of passenger kilometres and number of flights) that would be transferred to EPATS and in terms of number of EPATS aircraft that would be necessary to operate to satisfy this demand.

At both European and national level, ACP-2, ACT-2 and ACJ-2 aircraft types proved to be aircraft generating the highest potential transfer of traffic to EPATS. That is why we considered only these three aircraft types in our estimations.

Estimations of the number of flights as well as estimations of the EPATS fleet have been derived from the estimated number of transferred passengers to EPATS and from the category of EPATS aircraft that is considered on each connection. We attributed one category of aircraft per NUTS 2 connection using the following rule:
- Piston aircraft used for trip distances between 200 and 300 Km
- Turboprop aircraft used for trip distances between 300 and 1000 Km
- Jet aircraft for trips between 1000 and 2500 Km

6.1. Europe

When applying the developed methodology based on the generalized cost concept on these potential EPATS connections, we estimated that the total transfer of traffic from road and air transport modes to EPATS would reach 50 million flights in Europe in 2020 (Table 6-1), made by around 110 000 personal aircraft (Table 6-2). 66% of these EPATS aircraft would be Piston aircraft, 13% Turboprop aircraft and 21% Jet aircraft.

Table 6-1: Estimated transferred traffic to EPATS
(Data sources for estimations: ESPON, ASSESS)

<table>
<thead>
<tr>
<th>Unit of traffic</th>
<th>Original transport mode</th>
<th>Trip purpose</th>
<th>Trip scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millions of PKM</td>
<td>ROAD Business</td>
<td>150 380</td>
<td>150 271</td>
</tr>
<tr>
<td></td>
<td>AIR Typical Business</td>
<td>2 956</td>
<td>2 961</td>
</tr>
<tr>
<td>Thousands of PAX</td>
<td>ROAD Business</td>
<td>150 380</td>
<td>150 271</td>
</tr>
<tr>
<td></td>
<td>AIR Typical Business</td>
<td>2 956</td>
<td>2 961</td>
</tr>
</tbody>
</table>

Table 6-2: Estimated EPATS fleet
(Data sources for estimations: ESPON, ASSESS)

<table>
<thead>
<tr>
<th>Aircraft type</th>
<th>Null Scenario</th>
<th>Partial Scenario</th>
<th>Full Scenario</th>
<th>Extended Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACP-2</td>
<td>75 161</td>
<td>75 108</td>
<td>75 675</td>
<td>76 842</td>
</tr>
<tr>
<td>ACT-2</td>
<td>14 873</td>
<td>11 149</td>
<td>14 964</td>
<td>15 178</td>
</tr>
<tr>
<td>ACJ-2</td>
<td>23 598</td>
<td>23 581</td>
<td>23 765</td>
<td>24 139</td>
</tr>
<tr>
<td>Total</td>
<td>113 632</td>
<td>109 838</td>
<td>114 405</td>
<td>116 159</td>
</tr>
</tbody>
</table>

In total, we estimate that at least (see Table 6-3)
- 32.7 million flights will be performed with Piston aircraft at Flight level 250
- 13.7 million flights will be performed with Turboprop aircraft at Flight level 250
- 3.7 million flights will be performed with Jet aircraft at Flight level 350

Table 6-3: Number of estimated flights by EPATS aircraft type
(Data sources for estimations: ESPON, ASSESS)

<table>
<thead>
<tr>
<th>Numbers of flights by aircraft type</th>
<th>Null Scenario</th>
<th>Partial Scenario</th>
<th>Full Scenario</th>
<th>Extended Scenario</th>
<th>Flight Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACP-2</td>
<td>32 750 968</td>
<td>32 727 881</td>
<td>32 975 426</td>
<td>33 483 705</td>
<td>250</td>
</tr>
<tr>
<td>ACT-2</td>
<td>13 738 963</td>
<td>13 729 869</td>
<td>13 825 500</td>
<td>14 027 589</td>
<td>250</td>
</tr>
<tr>
<td>ACJ-2</td>
<td>3 702 893</td>
<td>3 700 219</td>
<td>3 729 094</td>
<td>3 787 762</td>
<td>350</td>
</tr>
</tbody>
</table>

Three countries would have the highest level of traffic transferred to personal aviation: Spain, Italy and France. The potential number of passenger kilometres transferred to EPATS to and from each of these three countries would be 4 to 5 times the average level of traffic on the 21 considered European countries. The predominance of Italy and Spain can be mainly explained by the high level of domestic EPATS traffic in these countries that would represent more than
50% of the total traffic to and from these countries. However, the high traffic level to and from France would not only be related to the 32% of domestic traffic but also to the high traffic level with Spain, Italy and United-Kingdom (that would represent 27% of the total EPATS traffic to and from France).

Besides the importance of the domestic EPATS traffic in Europe that would represent 82% of the flights, it is also interesting to note the existence of some connections between countries that would potentially have a high level of EPATS traffic. Table 6-4 presents the 10 connections between European countries with the highest estimated traffic level. It is in particular interesting to stress the importance of the traffic level between Portugal and Spain and between France and Spain, that would represent 60% of the total number of flights on these TOP10 destinations.

Table 6-4: Connections between European countries with the 10 highest estimated EPATS traffic
(Data sources for estimations: ESPON, ASSESS)

![Table 6-4](image)

6.2. France

When focusing the estimations on the domestic traffic in France we estimated that the total transfer of traffic from road and air transport modes to EPATS would reach 5.4 million flights (Table 6-5) in 2020 with 10,500 aircraft (Table 6-6) (81% of piston aircraft, 17% of turboprop aircraft and 2% of jet aircraft). Estimations are performed on 302 French domestic connections.

Table 6-5: Estimated transferred traffic to EPATS on French domestic EPATS connections
(Data sources for estimations: ESPON, ASSESS)

![Table 6-5](image)
Table 6-6: Estimated EPATS fleet in France  
(Data sources for estimations: ESPON, ASSESS)

<table>
<thead>
<tr>
<th>Aircraft type</th>
<th>Null Scenario</th>
<th>Partial Scenario</th>
<th>Full Scenario</th>
<th>Extended Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACP-2</td>
<td>8 460</td>
<td>8 460</td>
<td>8 656</td>
<td>8 566</td>
</tr>
<tr>
<td>ACT-2</td>
<td>1 819</td>
<td>1 811</td>
<td>1 843</td>
<td>1 833</td>
</tr>
<tr>
<td>ACP-2</td>
<td>219</td>
<td>219</td>
<td>242</td>
<td>222</td>
</tr>
<tr>
<td>Total</td>
<td>10 507</td>
<td>10 500</td>
<td>10 723</td>
<td>10 622</td>
</tr>
</tbody>
</table>

In total, we estimate that in France at least (see Table 6-7):
- 3.6 million flights will be performed with Piston aircraft at Flight level 250
- 1.7 million flights will be performed with Turboprop aircraft at Flight level 250
- 42 000 flights will be performed with Jet aircraft at Flight level 350

Table 6-7: Number of estimated flights in France by EPATS aircraft type  
(Data sources for estimations: ESPON, ASSESS)

Table 6-8 shows the 10 connections between NUTS 2 on which are estimated the highest traffic levels. If “Traffic” is used as the sorting criterion (millions of PKM, Thousand of passengers or number of flights), the highest traffic level would always occur between Midi-Pyrenees and Aquitaine regions. More generally speaking, high levels of EPATS traffic would occur to and from these two regions since they appear three to four times in the list of Top 10 French EPATS connections.

Table 6-8: Highest estimated EPATS traffic level on French NUTS 2 connections  
(Data sources for estimations: ESPON, ASSESS)
6.3. Poland

When focusing the estimations on the domestic traffic in Poland we estimated that the total transfer of traffic from road and air transport modes to EPATS would reach 26.5 million flights in 2020 (Table 6-9) with 59,000 aircraft (Table 6-10) (96% of Piston aircraft and 4% of turboprop aircraft). Estimations are performed on 70 Polish domestic connections.

Table 6-9: Estimated transferred traffic to EPATS on Polish domestic EPATS connections (Data sources for estimations: ESPON, ASSESS)

<table>
<thead>
<tr>
<th>Unit of traffic</th>
<th>Original transport mode</th>
<th>Trip purpose</th>
<th>Null Scenario</th>
<th>Partial Scenario</th>
<th>Full Scenario</th>
<th>Extended Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millions of PKM</td>
<td>ROAD</td>
<td>Business</td>
<td>37 218</td>
<td>37 076</td>
<td>37 443</td>
<td>40 125</td>
</tr>
<tr>
<td>Thousand of PAX</td>
<td>ROAD</td>
<td>Business</td>
<td>125 942</td>
<td>125 463</td>
<td>126 705</td>
<td>135 781</td>
</tr>
<tr>
<td>Number of EPATS flights</td>
<td></td>
<td></td>
<td>26 660 348</td>
<td>26 558 842</td>
<td>26 521 849</td>
<td>21 743 117</td>
</tr>
</tbody>
</table>

Table 6-10: Estimated EPATS fleet in Poland (Data sources for estimations: ESPON, ASSESS)

In total, we estimate that in Poland at least (see Table 6-11):
- 236 million flights will be performed with Piston aircraft at Flight level 250
- 3.3 million flights will be performed with Turboprop aircraft at Flight level 250

Table 6-11: Number of estimated flights in Poland by EPATS aircraft type (Data sources for estimations: ESPON, ASSESS)

Table 6-12: Highest estimated EPATS traffic level on Polish NUTS 2 connections (Data sources for estimations: ESPON, ASSESS)
Table 6-12 shows the highest EPATS traffic levels on Polish connections, when focusing on the Partial scenario that would lead to the lesser level of transferred traffic to EPATS. This table clearly shows that whatever the considered unit of traffic, the connection between Mazowieckie and Malopolskie regions would have the highest level of EPATS traffic. With the Lodzkie region, the Mazowieckie region would be involved in 4 connections belonging to the TOP 10 of EPATS traffic in Poland.

7. CONCLUSIONS

While estimations obtained at a European level only concern transfer of business traffic to EPATS, national estimations can consider an additional transfer of leisure traffic. This is the case, for instance, in France where, even though the EPATS business traffic would be predominant, 2% of the transferred PKM would originate in leisure travel.

In addition to factoring transferred leisure traffic into the equation, performing national estimations (on domestic and intra-European traffic) improves the accuracy of the estimations for Europe. Indeed, using national data (i.e. for the French and Polish estimations) representing the specific behaviour of national travellers refines European estimations. Hence, when comparing estimations between domestic connections (in France and Poland) obtained in the European and in the national estimations, we observed that the European estimations tend to underestimate the traffic and fleet levels compared to national estimations.

Hence, the rough estimations obtained using a European model could be significantly refined if we were to apply the methodology at national level (on domestic and inter-countries traffic) to all European countries. The EPATS traffic in Europe would then be the sum of the national estimations.

However, it is important to note that the relevancy of these national estimations will depend on the availability of all the necessary mobility data. Not only quantitative but also qualitative data on the European mobility would be essential when aiming at improving the developed methodology of estimation. Indeed, if available, qualitative data such as comfort, frequency, punctuality, etc... will be included in the generalized cost formula so as to better characterize travellers behaviours.

An additional methodology improvement would also concern the way to identify the type of EPATS aircraft needed for each flight. A deep analysis on the most accurate aircraft type according to the traffic volume and characteristics should be perform to refine the fleet estimation per aircraft type.

As a consequence, getting detailed and accurate mobility data as well as improving the way to allocate a type of aircraft by flight will then be the essential conditions for refining estimations of the potential level of transferred traffic to EPATS in 2020.
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EPATS AIRCRAFT MISSIONS SPECIFICATION

Alfred Baron
Institute of Aviation

Executive summary

These missions requirements for EPATS aircraft have been developed taking into account the future needs of the market analysis carried out under the project EPATS. Aircraft mission requirements are derived from passenger traffic and the level of wealth of the population. A wide range of public revenue, operating costs of different types of aircraft and passengers flow rates cause the need for appropriate diversification of types of aircraft operating in the System. This paper presents the results of these analysis.

1. INTRODUCTION

With the expanding European Union and ever greater mobility in and between its member States, alternatives to long distance car trips and scheduled air transport need to be considered. Even with the emergence of high speed railways, these benefit only the large cities. With this in mind, general aviation can provide an alternative. Small aircraft providing affordable, personal air transport services will greatly improve accessibility and economical potential between central and remote areas. This will also alleviate ground traffic and relieve the already congested air traffic at large commercial hub airports by allowing operations from smaller non hub airports. People will be able to travel to and from destinations closer to their home and work in a more efficient way.
2. EPATS AIRCRAFT CATEGORIES AND THEIR MAIN MISSIONS

The EPATS aircraft performances vision is based on analysis of forecasted market needs, evaluation of existing aircraft, trends in technology development, and on the existing knowledge and long experience in aircraft design. Trade off studies and costs analysis was made to verify it.

The EPATS aircraft fleet consists of the following aircraft categories:

**Piston aircraft**

It will comply CS-23 requirements for normal and commuter category with news amendments concerning reinforced safety and environment. The dominant position of piston aircraft (70% of all, nowadays) will gradually decline together with population income increase in favor of jets. The cheapest, available in price of high class personal car, one engine aircraft will partially replace car in travels on distances 300-500 km as a private aircraft. These aircraft will be piloted by user bearing a VFR, private pilot license the most often, although they will comply EPATS requirements and have IFR capacity for commercial operation.

Two-engine aircraft will operate as an air-taxi with costs comparable to a ground taxi. These will be used for one day business trips on routes connecting remote, peripheral regions on distances 300-700 km. The aircraft will be piloted by VFR/IFR commercial pilots. Their customers will be mainly small enterprise managers.

**Turboprop aircraft**

It will comply CS-23 requirements for normal and commuter category with news amendments concerning reinforced safety and environment. 9 – 19 - seaters, operated by small carrier companies will serve direct, regular air connections, characterized by low intensity of traffic (5000 – 10 000 passengers yearly), between peripheral regions on distances 300 - 1500 km, to hubs. These aircraft will also provide charter service on routes with low, irregular flow of passengers (tourism, seasonal travel to work abroad, sport, cultural events, etc.). Costs of travel using these aircraft should be comparable with costs of traveling by low-cost carriers and should be available to most of the citizens.

**Jet aircraft**

It will comply CS-23 requirements for normal category with news amendments concerning reinforced environment and jet propulsion. Two main categories for utilization is planned: Small 3 – 5-seaters, Very Light Jets with maximum take-off weight below 5000 kg will be used as airtaxi providing transport from any to any region in country or the EU and as executive (the aircraft should be viewed as a productive machine). Cost efficiency could be reached by high value managers and 7 - 9 - seaters will operate in the area of whole Europe as a corporate and business airline charter - regularly scheduled flights between city pairs deemed profitable.

The structure of EPATS aircraft fleet, the types of operations and regulations and dominants missions are shown in diagram below Fig. 1.
3. MISSIONS REQUIREMENTS

Mission requirements for commercial personal aircraft are derived from the potential demand for high-speed transport and possibilities for satisfying it. Demand for transport modes is generated by population mobility. The choice of mode depends on its accessibility and individual preferences of traveler, which, apart from out-of-pocket costs, are the outcome of multiple determinants. The most important of the determinants are the following: time of travel, comfort, safety, preferences. All of the determinants have some monetary value, which may be expressed by financial costs or benefits. Passenger is likely to pay more if his travel time is shorter (value of time) or his travel comfort is higher (comfort value) or pay less at the expense of preferences or safety.
Finding the right mission for a transport mode is done by the determination of serviced routes (ranges), time (speed), capacity (passenger seats), level of comfort (cabin size, toilet, pressurization, vibrations, noise, flight quality), frequency of service, operational conditions, estimation of limits of travel: costs, energy consumption, construction, operation and environmental regulations. These tasks are an outcome of the forecasted passenger flow, that is estimated between locations (regions, cities) in the environment of existing transport infrastructure (roads, train, airports) and for passengers with the respective income distribution (value of time).

There are the following relations:

- ranges are determined by the distribution of length of connections between serviced airports,
- speed and level of comfort are determined by the length of connections and travelers income distribution,
- number of seats and frequency of service are determined by the passenger flow intensity, operational conditions are determined by the current and forecasted airport infrastructure and air traffic control and management state.
- Cost limitation is derived from population income distribution (which percentile of population benefits from the proposed mode of travel).
- Energy consumption limitation is a consequence of sustainable transport policy. It is assumed that the energy consumption of EPATS aircraft needed for one passenger-kilometer per time unit will not be significantly different from personal car.
- Interregional connection distribution, population income, passenger flow intensity, diversification of airport infrastructure and air traffic management and control systems determine one optimal choice for mission requirements and limitations for every interval. The more diversified aircraft types, the better fit for demand. However, in practice, the higher diversity generates higher manufacture and operation costs; these are the reasons for aircraft type limitation, together with their elasticity for specialized versions adjustments. A possibility to provide an easy function adjustment (number of seats, level of comfort, range) to the labile transport demand constitutes one of the main instruments of carrier operation cost decrease.

Main parameters of mission requirements are:

- **number of passenger seats** of a given type of aircraft developed from the number of trips done between respective regions by passengers having income correlated to the cost of travel by a given type of aircraft,
- **aircraft speed** as a function of travelers time value, distances, airport accessibility, time of waiting (passenger is interested in door-to-door time of travel, it is rational, therefore, to increase average speed, simultaneously limiting block speed that generates costs mainly),
- **typical mission profile**, see Fig. 3
- **aircraft range**, which comes from the distribution of serviced routes (interregional connections) see Fig. 2,
- **start and landing characteristics** adjusted to the existing regional and local airport network covering possible modernization plans,
- **comfort level** (cabin space, toilet, pressurization, noise level, vibrations, ride quality,…), estimated at a number of levels depending on the average time of flight, target passenger income interval and generally accepted standards,
- **flight conditions** depend on the existing and forecasted state of airport infrastructure, airspace structure and air traffic control and management systems. For second stage of EPATS development (2025), the conditions will be determined during SESAR project realization and EPATS airports requirements estimation. During the first stage of EPATS (2015) flight conditions will not be significantly different from the present practice.
Points in Figure 2 indicate the average daily volume of passenger flows traveling by car from Polish Region “Pomorskie” to other regions of the country and the EU expressed by their distance. Data were taken from the European project ESPON. Graphs show the capacity of different types of aircraft expressed by number of passenger seats available, depending on the range. Figure gives an overview of the categories of aircraft - expressed in number of seats and range – that would be needed to replace the existing road traffic to air traffic in an effective manner.

**The mission requirements constraints are:**
- specific energy (fuel) consumption (as a measure of sustainable transport development conditions),
- aircraft price (limited by market demand),
- operation costs (limited by users economic efficiency),
- maintenance (labor hours per flight hours),
- life cycle,
- regulation requirements concerning aircraft construction (FAR-23, CS-23), operation (FAR-135).
Fig. 3. Typical aircraft missions profile.

Recommended technical characteristics.

Technical Specification for aircraft are derived from mission requirements and their technical feasibility. They describe characteristics of an aircraft, that are necessary to achieve mission requirements and concern design tasks: crew, configuration, weight, size, propulsion system, performance, control, equipment, avionics, modular construction that allows to fit different configuration, etc. TS is a result of project studies and mission feasibility analysis as well as assumptions concerning possibilities of planned research-development programs realization. Technical specification for EPATS aircraft family will be prepared in the context and with the feedback from:

- airport infrastructure requirements,
- future ATM-ATC requirements.
<table>
<thead>
<tr>
<th>Aircraft Class</th>
<th>Single Engine*</th>
<th>Twin Engine Piston</th>
<th>Twin Engine Turboprop</th>
<th>Twin Jet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Number</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Primary Missions</td>
<td>Private and Business trips and Air-Taxi-on demand passenger services for mid class (short range)</td>
<td>Air-Taxi-on demand passenger services for mid class (short range)</td>
<td>Commuter-on demand and scheduled passenger services on low density passenger flow, affordable for population majority</td>
<td>Commuter-on demand and scheduled passenger services on low density passenger flow, affordable for population majority</td>
</tr>
<tr>
<td>Seating**</td>
<td>1+3</td>
<td>1+5</td>
<td>1+9</td>
<td>1+19</td>
</tr>
<tr>
<td>Cabin With [m] High [m]</td>
<td>&gt;1.30</td>
<td>&gt;1.30</td>
<td>&gt;1.80</td>
<td>&gt;1.85</td>
</tr>
<tr>
<td></td>
<td>&gt;1.30</td>
<td>&gt;1.30</td>
<td>&gt;1.70</td>
<td>&gt;1.75</td>
</tr>
<tr>
<td>Lavatory</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Pressurized</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>All weather perform</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>TO Weight [kg]</td>
<td>&lt;1300</td>
<td>&lt;2000</td>
<td>&lt;5000</td>
<td>&lt;7200</td>
</tr>
<tr>
<td>Cruising speed [km/h]</td>
<td>350</td>
<td>&gt;350</td>
<td>&gt;550</td>
<td>&gt;550</td>
</tr>
<tr>
<td>Cruise altitude[FL]</td>
<td>80-200</td>
<td>150-250</td>
<td>150-250</td>
<td>250-300</td>
</tr>
<tr>
<td>BFL [m]</td>
<td>&lt;600</td>
<td>&lt;600</td>
<td>&lt;1000</td>
<td>&lt;1000</td>
</tr>
<tr>
<td>Range Full Payload [km]</td>
<td>&gt;1000</td>
<td>&gt;1000</td>
<td>&gt;1500</td>
<td>&gt;1500</td>
</tr>
<tr>
<td>SFC at Ver [l/seat.km]</td>
<td>&lt;0.035</td>
<td>&lt;0.035</td>
<td>&lt;0.04</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>DOC [Euro/seat.km]</td>
<td>&lt;0.15</td>
<td>&lt;0.12</td>
<td>&lt;0.20</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td>Price [1000 Euro]</td>
<td>&lt;200</td>
<td>&lt;400</td>
<td>&lt;1700</td>
<td>&lt;4200</td>
</tr>
<tr>
<td>Specification***</td>
<td>CS-23A</td>
<td>CS-23A</td>
<td>CS-23A</td>
<td>CS-23A</td>
</tr>
</tbody>
</table>

**FIXED OPERATION TIME**

<table>
<thead>
<tr>
<th>Pre-flight Check-list Engine start warmup</th>
<th>5</th>
<th>8</th>
<th>8</th>
<th>12</th>
<th>12</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embarquement</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Climb to cruise level (CT)</td>
<td>10</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Eng. Shutdown, parking</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Debarquement</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>
* Concerns both piston and turbo engines
** The first figure means air-crew number as well as command station, the second the certificated number of passenger seating
*** A -means with news amendments concerning reinforced safety and environment for travel aircraft
* A single engine aircraft is assumed to be at the same safety level as multi engine airplanes and be approved for commercial transport of people (air-taxi). In order to do it, such an aircraft in case of engine failure has to catch up on the limited propulsion redundancy by other means of safety. Apart from enforcing propulsion reliability, emergency-landing possibilities should be extended, both, in classical as well as unconventional meaning (e.g. using a parachute emergency system). Preparing for such a possibility requires lower aircraft weight and speed in comparison to a multiengine aircraft. Such aircraft is estimated to have less than 1500 kg, cruising speed lower of 350 km/h and with the stalling speed of no more 100 km/h enabling safe emergency landing. In practice, this condition may be rationally fulfilled by the light, propeller driven aircraft.

Tab. 2. EPATS aircraft avionics equipment list [4]

<table>
<thead>
<tr>
<th>Engine</th>
<th>PISTON</th>
<th>TURBOPROP</th>
<th>JET</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ENGINE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class number</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>CMOMMUNICATIONS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dual 8.33 kHz VHF radio</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>SWIM dual data link</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>WiMax</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>broadband services</td>
<td>o</td>
<td>o</td>
<td></td>
</tr>
<tr>
<td><strong>NAVIGATION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>dual GNSS/w SBAS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>dual DME</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>RVSM</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>P-RNAV FMS</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>4D RNAV FMS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ILS receiver(s)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>SURVEILLANCE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADS-B In/Out 1090ES</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>enhanced ADS-B</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>TAS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>TCAS II</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ELT 406 MHz</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>FDR &amp; CVR</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>TAWS-B</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>TAWS-A</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>lightning detection (sferics)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>weather radar</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>HUMAN MACHINE INTERFACE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IFD (PFD/MFD/audio/AP)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>HUD/SVS/EVS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>EFB</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Equipment list

A summary of the proposed avionics required for EPATS is provided in Table 1. This is listed per aircraft class and class number; please view Table 1 again for mission roles and aircraft specifications defined for the various classes. Check marks (√) represent equipment that is needed to enable EPATS to fly in the SESAR airspace of the future as well as to fulfill the envisioned mission. For the upper class twin jets, an (O) mark represents an option for these aircraft class. Because these twin jets perform the high value executive mission, the options are available to satisfy customer demand where necessary. [4]

4. REQUIREMENTS FOR NEW TECHNOLOGIES

The technical level of General Aviation aircraft, including small aircraft used for passenger transport is significantly different from the technical level of passenger and military aircraft. It is forecasted that the increased demand for small aircraft for passenger transport will need to use new technologies. Based on the results of studies conducted in the framework of the European project EPATS and other related projects, such as: ESPON, CESAR, SESAR, SATS, NextGen, it can be expected that the technological development of small aircraft will progress very quickly. Comparing to the reference list aircraft the EPATS 2020 aircraft characteristics will differ as follow:

- Increased comfort: lower noise and vibrations, smoother flight (improved ride quality due to active control), larger and more ergonomic cockpit (especially in single engine aircraft).
- More intuitive and easier to fly
- Single control station – one pilot flight crewmember (possible thanks fully Automated flight control and air traffic management system)
- All Electric Aircraft configuration and fly-by-wire
- Implementation of lighter and smaller, highly reliable propulsion systems requiring less maintenance and manufactured at significantly lower production costs.
- Implementation of piston engines fueled by bio-fuels.
- Increased propellers efficiency (more than 0,85).
- Using new technologies and materials in airframe to decrease weight and manufacture costs.
- Using module components increasing possibility of equipment retrofit and aircraft type adaptation to meet market demand. The baseline aircraft should give possibility to produce derivative versions (for example: different fuselage length will have common wing, empennage, cockpit, engine,...)
- Introducing higher level of equipment and structure elements unification and standardization.
- Decrease of minimum speeds (through new aerodynamic solutions).
- Reducing the chance of "pilot error" and if an accident occurs, more crashworthy.
- Increasing flight safety through introduction of more rigorous requirements of CS-23 for EPATS aircraft (including some CS-25 regulations).
- Automated flight control and air traffic management system (allowing one pilot crew).
- Integrated flight management system (flight planning, alerts on restricted air space, air traffic control frequencies and terrain variations, report fuel capacity and weight allowance, inform about weather,...). Easy access to flight information and situation by PFD (Primary Flight Display) and MFD (Multi Function Display) use.
- Reducing fuel consumption through more efficient power systems, lower airframe weight and new aerodynamic solutions
- Lower purchase price – reached thanks to new technological solutions applied in respective stages of full life cycle, increased production scale and appearing cooperation possibilities in the EU
- Lower operating costs – through lower fuel consumption, costs of purchase and maintenance.
5. EPATS AIRCRAFT REQUIREMENTS DEVELOPMENT PHASE

The Operational Requirements of EPATS aircraft will be elaborated in two phases. At the first phase of EPATS development (2015) the ATM-ATC and Operational Capabilities of the aircraft will be similar to that of current advanced small aircraft. See Reference Aircraft below.

At the second phase the proposed ATM-ATC and Operational Capabilities Envisioned for 2020 are conformable to those of US SATS and they are:

- Aircraft will be capable of operating in low–visibility conditions airports without radar cover or assistance from air traffic control towers. Aircraft will require neither ground-based navigation aids nor approach lighting.
- Aircraft operations will be contained within existing airport terminal areas and protection and noise exposure zones. Operations will be environmentally compatible with communities near airports.
- Operators will vary widely in training, experience, and capability, having skills ranging from those required to pilot an airline to those required to drive an automobile. Automation and new flight control concept will replace human manipulation and decision making as primary control inputs. Onboard computers will provide realistic, real time tutorials and training, even during flight.
- Digital data link capabilities will provide the operator and aircraft with real-time and integrated weather, traffic, and airport information for dynamic modifications to flight plans.
- Interactions with air traffic management and control will be largely automated and will not require positive control. Aircraft will operate autonomously, providing guidance for self-separation from other aircraft and obstacles. EPATS users will interface with air traffic services only to the extent that they operate in controlled airspace and airports. A fully digital communication system will be in place, alleviating frequency congestion difficulties. Aircraft separation and sequencing will be accomplished by interaction of aircraft systems using the Global Positioning System (GPS) and automatic dependent surveillance and broadcast messages (ADS-B).
- Primary navigation service will be provided by GPS at all altitudes. Terrain and obstacle databases with data up-link capabilities, automation, and intuitive displays of the information in the cockpit will aid operators in avoiding collisions. Dynamic approach procedures will be calculated by onboard computers in real time to any runway end or touchdown point.
- New materials and engine and airframe designs, as well as mass production of aircraft, will allow for greatly reduced aircraft acquisition, maintenance, and operating costs. Ride smoothing and envelope-limiting protections will ensure ride comfort and safety.

Cost limitation is derived from population income distribution (which percentile of population benefits from the proposed mode of travel). Energy consumption limitation is a consequence of sustainable transport policy. It is assumed that the energy consumption of EPATS aircraft needed for one passenger-kilometer per time unit will not be significantly different from personal car. Interregional connection distribution, population income, passenger flow intensity, diversification of airport infrastructure and air traffic management and control systems determine one optimal choice for mission requirements and limitations for every interval. The more diversified aircraft types, the better fit for demand. However, in practice, the higher diversity generates higher manufacture and operation costs; these are the reasons for aircraft type limitation, together with their elasticity for specialized versions adjustments. A possibility to provide an easy function adjustment (number of seats, level of comfort, range) to the labile transport demand constitutes one of the main instruments of carrier operation cost decrease. The diagram below shows the process of creating requirements for aircraft and determining demand for them.
EPATS aircraft missions requirements and potential demand scheme

NUTS Socio-economic data *
- inhabitants
- GDP
- Income distribution
- Time value distribution

NUTS Geographic & transport Infrastructure data *
- Surface
- Capital coordinates
- Roads
- Airports data & coordinates
- Distances between airports
- ATM/ATC
- Accessibility to airports

Inter-NUTS (Interregional) Trips data *
- Nexus generated trips by means: a mode: time value
- Inter-NUTS trips distribution by distances: a means: a mode: a time
 value

Specific transportation costs (price) and main characteristics of current mode of

EPATS Aircraft Missions Requirements, Operational Capabilities and forecasted fleet as
2020

Feasibility study & Research Programme

EPATS Aircraft Specifications and specific transportation costs

Travel time
Travel costs

Current mode of transport / EPATS aircraft indifference cost curves calculation (Trip value of time via
distance)

\[ C_{\text{trav}} = \frac{(C_{\text{transport}} - C_{\text{transport min}})}{(T_{\text{transport}} - T_{\text{transport min}})} \]

From trips distributions and indifference curves evaluate the preferred mode of transport

Calculate the number of EPATS aircraft and operations needed to substitute current mode of
transport

If the results is not satisfied change EPATS Aircraft Requirements

* For current year and 2020 forecast. Data sources: ESPON, EUNET, DATELINE, SCENES, EUROSTAT and others
1. Calculated using Gravity Model
2. From statistical data and calculation
3. Travel costs includes transportation cost and accommodation costs
   Time travel includes all elements of time from origin to destination
4. Taking the replacement need of existing old business and personal aircraft (above 20 years) into account.
6. REFERENCES AIRCRAFT AND VISION 2020

In the initial period of implementation of EPATS the existing aircraft and airports network will be used. In the tables below are included these planes, which are closest to meet the missions requirements, and which are susceptible to modernize equipment and systems of CNS, as assumed Vision 2020 and a timetable for implementation of new ATM services Among the most important parameters that were taken into consideration when choosing the reference planes were: specific fuel consumption and direct operating costs.

The list of aircraft included in the tables does not exhaust all possible planes for use in the EPATS.
<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Single-Engine Turboprops</th>
<th>Multi-Engine Turboprops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>Epic Dynasty</td>
<td>Pilatus PC-12</td>
</tr>
<tr>
<td>Price [1000€]</td>
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<td>2.24</td>
</tr>
<tr>
<td>Characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seating</td>
<td>1+5</td>
<td>1+9</td>
</tr>
<tr>
<td>Dimensions Internal [m]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>4.57</td>
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<tr>
<td>Width</td>
<td>1.40</td>
<td>1.53</td>
</tr>
<tr>
<td>Height</td>
<td>1.49</td>
<td>1.47</td>
</tr>
<tr>
<td>EST. Cabin Volume [m³]</td>
<td>9.033</td>
<td>11.005</td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price [1000€]</td>
<td>695</td>
<td>695</td>
</tr>
<tr>
<td>Output [kW]</td>
<td>230</td>
<td>234</td>
</tr>
<tr>
<td>SFC</td>
<td>0.333</td>
<td>0.332</td>
</tr>
<tr>
<td>TBO [hr]</td>
<td>3,000</td>
<td>3,500</td>
</tr>
<tr>
<td>Weights [kg]</td>
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<td></td>
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<tr>
<td>Max. TO</td>
<td>3,314</td>
<td>4,740</td>
</tr>
<tr>
<td>Max. Payload</td>
<td>613</td>
<td>1,123</td>
</tr>
<tr>
<td>Useful Load</td>
<td>1,673</td>
<td>1,950</td>
</tr>
<tr>
<td>Max. Fuel</td>
<td>8,56-10,70 (12,27)</td>
<td></td>
</tr>
<tr>
<td>Performance</td>
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<td></td>
</tr>
<tr>
<td>Max. Cruise Speed [km/h]</td>
<td>630</td>
<td>500</td>
</tr>
<tr>
<td>Service Ceiling [FL]</td>
<td>310</td>
<td>300</td>
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<tr>
<td>Rate of Climb [m/min]</td>
<td>480</td>
<td>489</td>
</tr>
<tr>
<td>TO Distance to 15 m [m]</td>
<td>488</td>
<td>(917)</td>
</tr>
<tr>
<td>IOC (pmxkm)</td>
<td>0.269</td>
<td>0.186</td>
</tr>
<tr>
<td>SFC = Block [litre/(pmxkm)]</td>
<td>0.070</td>
<td>0.052</td>
</tr>
<tr>
<td>Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range (max. payload) [km]</td>
<td>2,870</td>
<td>2,583</td>
</tr>
<tr>
<td>Manufacturer Model</td>
<td>Single - Engine Jets</td>
<td>Multi - Engine Jets</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Price [1000€]</td>
<td>1.060</td>
<td>2.407</td>
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<tr>
<td>Certification Year</td>
<td>2007</td>
<td>2000</td>
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<tr>
<td>Characteristics</td>
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<td></td>
</tr>
<tr>
<td>Seating</td>
<td>2+3</td>
<td>2+8</td>
</tr>
<tr>
<td>Dimensions Internal [m]</td>
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<td>1(2)-0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2+9/11</td>
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<tr>
<td>Length</td>
<td>3.52</td>
<td>5.26</td>
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<tr>
<td>Width</td>
<td>1.42</td>
<td>1.65</td>
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<td>Height</td>
<td>1.44</td>
<td>1.57</td>
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<tr>
<td>EST. Cabin Volume [m³]</td>
<td>7.218</td>
<td>13.020</td>
</tr>
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<td></td>
<td></td>
<td>12.713</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.254</td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engine</td>
<td>Williams FIJ33-1A</td>
<td>Williams FIJ11-2A</td>
</tr>
<tr>
<td>Williams PW610F</td>
<td>PW615F</td>
<td>PW535B</td>
</tr>
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<td>Price [1000€]</td>
<td>6.99</td>
<td>2x12.5</td>
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<tr>
<td>Output [kW]</td>
<td>2x1.0</td>
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<td>SFC</td>
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<td>4000</td>
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<td>TBO [h]</td>
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<td>5000</td>
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<td>Weights [kg]</td>
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<td>Max. TO</td>
<td>2300</td>
<td>1200</td>
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<tr>
<td>Max. Payload</td>
<td>2719</td>
<td>6300</td>
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<tr>
<td>Useful Load</td>
<td>3925</td>
<td>7634</td>
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<tr>
<td>Max. Fuel</td>
<td>1200</td>
<td>908</td>
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<tr>
<td>Performance</td>
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<td></td>
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<tr>
<td>Max. Cruise Speed [km/h]</td>
<td>583</td>
<td>630</td>
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<td>Service Ceiling [FL]</td>
<td>250</td>
<td>790</td>
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<tr>
<td>Rate of Climb [m/min]</td>
<td>1044</td>
<td>1320</td>
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<tr>
<td>TO Distance to 15 m [km]</td>
<td>620</td>
<td>762</td>
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<tr>
<td>DOC [max/km]</td>
<td>0.208</td>
<td>0.200</td>
</tr>
<tr>
<td>SFC [litre/(pax*km)]</td>
<td>0.094</td>
<td>0.009</td>
</tr>
<tr>
<td>Range</td>
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<td></td>
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<tr>
<td>Range (max. payload) [km]</td>
<td>1426</td>
<td>2226</td>
</tr>
<tr>
<td></td>
<td>1426/1019</td>
<td>3093</td>
</tr>
<tr>
<td></td>
<td>1865</td>
<td>2139</td>
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</tbody>
</table>
## EUROPEAN PERSONAL AIR TRANSPORTATION SYSTEM - EPATS VISION 2020

<table>
<thead>
<tr>
<th>EPATS Components</th>
<th>Current state (2008)*</th>
<th>Preparatory, Research &amp; Development Phase (2020)</th>
<th>Implementation Phase (2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airworthiness Standards</td>
<td>FAIR-23 (IAR-23) Normal and Commuter category</td>
<td>Enhanced CS 23 Standards</td>
<td>Personal Aircraft Airworthiness Standards</td>
</tr>
<tr>
<td>Aircraft Types</td>
<td>Single and multi-engine piston, turboprop and jet aircraft</td>
<td>4 to 19 seatings, single and multi-engine piston, turboprop and jet aircraft</td>
<td>New Technically Advanced Small Aircraft (TASA)</td>
</tr>
<tr>
<td>Structure</td>
<td>Mainly metallic structure with thousands of parts. Design concept from 1960th</td>
<td>Integral components - lower number of parts, mainly composite, automatically formed and/or monolithic part produced from a single metallic block mechanically or chemically, Modular structure and versatility, Crashworthiness features requirements, Optimized relationship between size, weight, fuel capacity, engine thrust and EPATS missions requirements. Reduction of weight: 20%, Reduction of manufacturing cost: 30%</td>
<td>New Technically Advanced Small Aircraft (TASA)</td>
</tr>
<tr>
<td></td>
<td>Related structure weight: 100 - 150 kg per seat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Related structure cost: ~250 Euro per kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerodynamics</td>
<td>Aerodynamics concept from 1960th</td>
<td>High / low speed capability via the variable geometry airfoil (in the form of high lift design on leading and trailing edge). High low speed performance and high effectiveness at cruising speed</td>
<td>New Technically Advanced Small Aircraft (TASA)</td>
</tr>
<tr>
<td></td>
<td>Poor ride quality (Levels of vertical and lateral accelerations as a airplane response to atmospheric turbulence)</td>
<td>Improved response to atmosphere turbulence (better ride quality)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lift-drag ratio at cruising speed: 7-12</td>
<td>Lift-drag ratio at cruising speed: 10-15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max lift coefficient: 1.8 - 2.2</td>
<td>Max lift coefficient: 2.5 - 3</td>
<td></td>
</tr>
</tbody>
</table>
| Flight Control | Mechanical or hydro - mechanical | Fly-by-wire control systems (to be certified to JO-178 H adopted by FAA) [with hydraulic or electric actuator] and Full Authority Digital Engine Control (FADEC)
Pilot fly via computer | New Technically Advanced Small Aircraft (TASA) with fly-by-wire flight control system
New concept of flight control surfaces to make control difficulty level comparable to driving a car |
| Propulsion | Gasoline Piston engines, SFC: ~0.2 l/KM h
Related weight: 0.8 kg / KM
Price: 65k. $ for 200 KM
Propeller: Effectiveness: 0.70-0.80
Turbine engines
(800k $ for 1000 daN of thrust) | Compact diesel piston engines running on jet fuel (Jet-A) and bio-fuel, having low fuel consumption (~0.2 l/KM.h) and low mass to power ratio (~ 0.8 kg/KM), low vibration and noise levels, meeting ecological requirements.
Propeller: Effectiveness: 0.80-0.90
FADEC
Small turbofan jet engines with thrust 2:50 – 800 daN, max to thrust ratio about 0.12 kg/daN and specific fuel consumption below 0.5 kg/daN.h meeting noise and emissions requirements.
FADEC | Piston engine price comparable to car engine price
Jet engine price reduced by an order of magnitude
Introducing hybrid propulsion system - of eCATS (Environmentally Compatible Air Transportation System) project |
| Avionics | In older aircraft dozens of instruments, gauges and switches to monitor
Communication, navigation and flight control based mainly on radio and radar
In the last year new avionics systems was introduced. See: avionics reference list 2 | Communication, navigation and flight control based mainly on satellite systems (Galileo); Multi function autopilot (performing flight management and instructor role) linked with fly-by-wire system
Intuitive flight desk design. Easy to operate color flight parameters and multifunction displays (monitors) and Head Up Display allowing color visualization
Voice threat warning systems (prohibitive proximity to other aircraft or ground objects, deviating from planned flight path)
See table 1 EPATS avionics equipment list | New avionics to ensure compliance with SESAR project and:
- missions capabilities, autoland system |
<table>
<thead>
<tr>
<th>Systems</th>
<th>Ice protection systems</th>
<th>Equipped</th>
<th>More effective ice protection system</th>
<th>New Technically Advanced Small Aircraft (TASA)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lavatory system</td>
<td>Not equipped</td>
<td>Equipped for aircraft with more than 6 seatings</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emergency systems</td>
<td>Not equipped</td>
<td>Automatic emergency flight Back system³</td>
<td></td>
</tr>
<tr>
<td></td>
<td>On-Board Diagnostics System</td>
<td>Not equipped</td>
<td>On-Board Diagnostic System linked with Flight Operation Quality Assurance Center (FOQA)³</td>
<td></td>
</tr>
<tr>
<td>Performance Requirements See EPATS Aircraft Missions and Requirements</td>
<td>See Table 2 Reference aircraft</td>
<td>See: Scheme 1 EPATS aircraft categories, operations and missions Table 3 EPATS aircraft missions requirements Fig. 1 EPATS Payload Range Capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comfort</td>
<td>Unsatisfied level of cabin interior noise and vibration, restricted cabin size and poor ride comfort particularly for pistons. Levels of vertical and lateral accelerations as a airplane response to atmospheric turbulence is considered as severe for piston, moderate for turboprop and slight for jet.</td>
<td>Cabin size and furnishings in new technically advanced 4-6 seating aircraft similar to car. Interior noise and vibration reduced to appropriate level (say 25 dB). Implementation of Anti Noise Control (reduction). Improved Ride Control Index and implementation of ride control system (coupled with fly by wire control)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Security and Safety</td>
<td>The corporate jet accident rate of 0.08 accidents per 100,000 departures compares favourably with the scheduled airline rate of 0.112 for hull loss and/or fatal accidents per 100,000 departures of jet aircraft over 60,000 lbs and 0.241 for non-scheduled and all other operations of jet aircraft over 60,000 lbs</td>
<td>Accident rate of EPATS aircraft comparable with scheduled aircraft, due to: - fully automated control system (Digital Fly-by-wire, FADEC, autopilot) - Automatic emergency Flight Back system - On-Board Diagnostic System and FOQA - Crashworthiness features - Automated ATM and digital CNS - More effective ice protection system - More restrictive GS 2.5</td>
<td>New Technically Advanced Small Aircraft (TASA)</td>
<td></td>
</tr>
<tr>
<td>AIRPORTS</td>
<td>Maintenance</td>
<td>Maintenance man-hours required per flight hour: 0.5 - 2 TBO: 2000 - 3000</td>
<td>Performance of overhaul, repair, inspection, replacement, modification as well as Flight Operation Quality Assurance (FOQA) and Maintenance Resource Management (MRM) are standardized and centralized</td>
<td>Maintenance man-hours required per flight hour: 0.25 - 1 TBO: &gt; 5000</td>
</tr>
<tr>
<td>---</td>
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<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>To maintain and improve airworthiness</td>
<td></td>
<td>The increase of airports number is not envisaged. Only successive modernization is assumed. For EPATS operation 3 groups of landing facilities are predicted:</td>
<td>Successive adaptation to EPATS requirements in each NUTS 3 region are planned</td>
</tr>
<tr>
<td></td>
<td>There is about 2200 landing facilities from which only 43 main airports handle 85% of the European air traffic. The remaining, in which 1336 paved and 737 IFR, are weakly utilized.</td>
<td></td>
<td>- Typical controlled regional airport in every NUTS 2 region with aircraft fleet suitable to regional passenger traffic and with technical and operational maintenance service. - SATS airport with low passenger flow, no carrier base, 1 airstrip with artificial surface at least 1000 m long, no lights, no control tower, providing minimum service. - Airfield for emergency landing, meeting specific requirements. Most of abovementioned airports will emerge from acro club and others airfields as a results of regional community and authorities initiative.</td>
<td></td>
</tr>
<tr>
<td>ATM</td>
<td>ATM – ATC</td>
<td>Radio-electronic equipment (radio communication, radar approach systems and ILS), lights on airstrips and taxi ways, VOR/DME stations</td>
<td>New Air Traffic Control system designed for SATS, which will operate below air space operated by air lines (below 7000 m) and separated from airliner traffic. Main features of new ATC system for SATS are:</td>
<td>Fully operational European air traffic management and control system SATS, based on &quot;Open Sky&quot; and &quot;Free Flight&quot; rules. Ability to land on airfields with no lights, control tower in nearly all weather conditions. SESAR project implemented. ATM-ATC manages 52 mln flights a year</td>
</tr>
<tr>
<td>ATM-ATC manages 9 mln flights a year</td>
<td></td>
<td>- Air traffic control enroute and in airports' MTA are separated. - Aircraft position in flight is determined by satellite system and information on air traffic is delivered to pilot through system of transponders and pilot is warned if approaching 15 km radius visually on monitor and acoustically. - In the area of large airport control and management of air traffic is transferred to airport control according to specific procedures. In SATS airport area pilots control flight path according to specifically elaborated procedures adapted to newly implemented communication, navigation and air traffic control technologies. Full information on traffic situation in air and on the ground will be displayed on monitor.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
About 2500 aircraft, from which 1190 are commercial aircraft (mainly turbine) operated by 166 air-taxi companies employing 25,980 people. The remaining are: Corporate and Owner operated. The operators of air-taxi are major corporations and other business (60%), Governments (20%) and others wealthiest clients.

Air-taxi companies offer on demand flight from point to point and operate from about 200 airports.

The relationship Customers providers goes through brokers by phone and internet.

With the appearance of VLJ’s a new type of Next Generation Air-Taxi Company is born (see Air-Taxi Association ATXA, www.atxa.com) and a new neutral booking engine on Connect IT Technology are being created. New using VLJ’s Air-Taxi Company are coming on market.

In the first phase of development EPATS will be based on existing advanced airplanes. The fleet structure will be adapted to the passengers flow and their value of time from cheaper piston to expensive jet. In every NUTS 2 (267) region bases of EPATS commercial Operators offering transport service suitable to needs and wealth structures of population will arise. They will operate in the framework of Public Interactive Transportation System supported by local community and authorities.

The EPATS commercial operations (which meet FAR 135 standards) provide services: On demand and air-taxi services by aircraft and by seat, subscription flights and scheduled flight on connection with low (below 30 passengers by day) but periodically stable passenger flow,

The system will operate from and to all European airports that meet a set of standards defined by EPATS Association – expected to be 1100 at the end of first phase.

The number of personal aircraft operating in the European small aircraft transportation system is expected to reach 3200 units and the number of flights 2.4 million.

Community economic development alliances, which include the airport authority, municipalities, chambers of commerce, and others organizations as well as air-taxi company and small aircraft Carriers in the implementation of EPATS magnet program will lead, step by step, to Regional EPATS Association emerging and finally to EPATS Association, which will collect Operators and Contributors and manage Interactive Transportation System Network.

A new type of "customer adaptive" business model.

Advanced System Technology for Real-time Operations (known as ANTR) automates and manages every aspect of the company’s operations, end to end. This includes customer reservations, billing and membership management, flight records and training, flight planning and scheduling, pilot electronic flight bag (EFB), DayPort field information, and maintenance control.

New technically advanced aircraft will emerge and create new business advantages.

As a results of systematic and exhaustive interregional mobility surveys, data about passengers flow will be more trustworthy and structure fleet planning more reliable. This permits to invest more in the aircraft fleet deployment.

Demand prognosis shows the potential of market for 90,000 EPATS aircraft, from which 55% piston’s, 20% turboprop and 25% jet.

These aircraft will operate from airport of each NUTS 3 (1150) sub region and link them with each others.

The EPATS Interactive Transportation Network will be linked with SESAR System Wide Information Management (SWIM).
<table>
<thead>
<tr>
<th>PILOT TRAINING</th>
<th>EPATS</th>
<th>2.5 mln passengers</th>
<th>4 mln passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 mlb passenger.kilometers</td>
<td>3 mlb passengers kilometers</td>
<td>43 million flights per year</td>
</tr>
<tr>
<td></td>
<td>2150 aircraft in which:</td>
<td>3200 aircraft in which:</td>
<td>Demand prognosis shows the potential of market for:</td>
</tr>
<tr>
<td></td>
<td>1100 pistons</td>
<td>1600 pistons</td>
<td>90 000 EPATS aircraft,,</td>
</tr>
<tr>
<td></td>
<td>300 turboprops</td>
<td>450 turboprops</td>
<td>50 000 pistons</td>
</tr>
<tr>
<td></td>
<td>750 jets</td>
<td>1300 jets</td>
<td>16 000 turboprops</td>
</tr>
<tr>
<td></td>
<td>660 aircraft in which:</td>
<td></td>
<td>24 000 jets</td>
</tr>
<tr>
<td></td>
<td>430* pistons</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>151 turboprops</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>71**jets</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Few pilot schools owning flight simulators and several tens of centers authorized to give flight training.
- Traditional training methods.
- Low level of computers usage.
- Acquiring pilot license cost is thousand Euros and with IFR authorization cost is many times higher.
- Adapting training programs to new piloting and navigation technologies and new Air Traffic Management and Control procedures.
- Lowering pilot training costs by wide usage of simulators, personal computers and internet. Implementing wide aviation education of the society.
- Complete change of training methods. After acquiring the license, instructor is replaced with autopilot, which signals all mistakes and corrects pilot's actions. Training is available to wide range of population and acquiring pilot license becomes similar to getting a driving license.
- Population with pilot license is many times bigger.

EPATS AIRCRAFT MISSIONS SPECIFICATION
7. CONCLUSIONS

The EPATS requirements derives from utility and expense of air service, and these ultimately must be judged on the basis of its cost, safety, and convenience relative to other forms of travel, factoring in the potential savings in time, lodging, and ground transportation and the additional business opportunities that such direct service can provide.

Like in a car transport, to ensure broad access to personalized air transport, the range of aircraft types must be accommodated to the market demand and include both piston and turbine aircraft.

There is a need for further work on requirements. It is particularly important to carry out extensive surveys. Agree and adopt common requirements on small passenger planes determines the implementation of a joint UE development program.

It is crucial to initiate or support currently done research on traffic flows even stronger, not only from EPATS point of view, but also due to rational planning of the EU transport development reasons. The continuous research should include all EU regions and sub regions. Lack of this perspective is a significant flaw in strategic spatial planning and an obstacle for transport initiatives, including Small Aircraft Transportation System.

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INTELLIGENT PERSONALIZED AIR TRANSPORTATION SYSTEM (IPATS)

Alfred Baron
Institute of Aviation

Executive summary

The goal of IPATS is to personalize Air Transportation System and fill the communication gap, which exists on interregional national and European destinations with underdeveloped transport network, located in a distance longer than 300 km, and where implementation of others modes of fast transport (high-speed rail, traditional airlines) is irrational due to too low flow density travel and where road transport is too disadvantageous in individual, social as well as ecological dimension. Furthermore the objective of such system is to avoid the ever increasing congestion on European roads and to offer an alternative for current transport system. Achieving this objective involves the need to integrate Information & Communication sub-system which enables interaction between Users (passengers) and Providers through internet and mobile networks. This paper describes this new idea, its operational concept, system, which must be developed and assumptions for future investigation.

1. INTRODUCTION

The results of EPATS study (European Personal Air Transportation System) [1,2] show, that there is a real opportunity to shift a substantial part of long distance passengers trips by personal car to small aircraft transportation system and that the potential demand for EPATS aircraft in 2020th could reach 100 000 units. Condition for the achievement of such values is to approach the cost of travel by small aircraft and car. Analysis shows that it is possible through better use of aircraft, and this goal can be achieved by using new information and communication technologies to improve the flow of information between provider and customer.

The major goal of IPATS is to use this opportunity to realize the potential demand and to fill communication gap, which exists on interregional national and European destinations with underdeveloped transport network, located in a distance longer than 300 km, and where implementation of others modes of fast transport (high-speed rail, traditional airlines) is irrational due to too low flow density travel and where road transport is too disadvantageous in individual, social as well as ecological dimension.

A key aspect of IPATS is the application of net-centric model for transferring information of all types and for improving transportation management process. See Figure 1.

The effect of implementation of network-centric management (NCM) will be the possibility of creating various business models and an easy access to the IPATS transportation services for a wide audience. This will reduce transportation costs through the possibility of: adaptation of aircraft type to the passengers needs, plane-sharing and co-owner, increase of annual flight hours, better utilization of seats, decreasing of empty flights, optimization of itinerary etc.
At the most global level, the objective of the IPATS is to reduce economic disparities substantially that exists locally, regionally and nationally in EU.

The IPATS concept of operations utilizes small aircraft for public, corporate, business and personal transportation, for point-to-point direct travel between smaller regional, auxiliary and general aviation airports and between hubs and small airports. The IPATS would operate within the Single European Airspace System (SEAS) infrastructure, specifically among about 2000 public-use landing facilities. While scheduled air carriers serve just about 400 of these facilities, from which only 43 hubs handle 85% of the European air traffic and operates at the limits of their capacity.

The general concept of IPATS is to add to the System Wide Information Management (SWIM) currently deployed Air Traffic Control and Management a comprehensive information and communication system which would manage the complex passengers transportation services process, improve customer – provider link and interaction and would enable efficient use of aircraft fleet and consequently the price of service available and inexpensive charter flying.

The idea of inexpensive charter flying got energized because of the activities of NASA scientist Bruce Holmes, who was the driving force behind the conceptual Small Aircraft Transportation System, or SATS. NASA’s research effort was aimed at all facets of technology that would be required to move travelers between small airports outside the airline hub-and-spoke system, thereby relieving the congested hubs and, in the process, reviving general aviation and providing access to a wider public. The effort was aimed at new airframe and engine designs, a new-generation, advanced navigation and airspace management system. Too, it encouraged a revolutionary cockpit environment that replaced the standard instrument panel with advanced digital graphic displays, thereby enabling a single pilot to manage a jet aircraft in any weather. The advent of very light jets, which followed when Williams International and Pratt & Whitney Canada began development of ultra-small turbofans, was expected to allow operators to provide better, faster service. Unfortunately the SATS research and development does not include studies on complex relationships and linkages between market demand and supply and their impact on technologies and implementation schedule.

Modern European society’s need to travel is constantly growing. The extension of the European Union to 27 members will further intensify this development. However, current transport modes have limitations and are already suffering from congestion in some places: highways and most large airports are congested or could quickly reach their maximum capacity. Conversely, other airports, especially in Eastern Europe, are generally unused. Moreover, society is evolving: passengers are becoming more demanding in terms of time and cost, but their behaviour is also changing: individualisation is gradually becoming the byword, meaning that people want to have a choice. Future mobility therefore cannot be entirely satisfied by current transport systems, such as hubs, railways or highways.

A new transport mode [2] is thus needed.

2. SMALL AIR TRANSPORTATION SYSTEM – STATE OF THE ART

The basic factor having a restraining effect on SATS development is the price of transportation services, which exceed by many times costs of personal car usage.

Provided that price of 1 vehicle-kilometer (taxi) is ca. 0.5 €, the price of flight on 4-5 seats airplane will be from 1 to 10 € per vehicle-kilometer, depending what type of aircraft will be used and what business model will be operated.

However, if the comparison will be limited to operational costs referring to one vehicle kilometer, by assumption of car mileage of 20 000 kilometer yearly and aircraft annual flight hours of 800 flight-hours, then operational costs of the 1 vehicle km done by car will stay on the similar level of 0.5 € and the operational costs of airplane will get closer to cars’ costs and will amount from 0.5 to 2 € per kilometer.
Reasons of high costs of small aircraft transportation services underlie mainly in a way of their usage (business model) and in the operational personal costs. In particular these are:

- Level of small aircrafts annual flight hours: air taxis, corporate, business and private, calculated as a ratio of real annual flight hours to the recommended annual flight hours (it is assumed to be 1800 flight hours yearly); this ratio is really small and is between 5% for private aircrafts to 40% for air taxis.

- Large share of empty flight resulting from a need of redeployment of aircraft from the quarter base to the airport, from which the journey starts and vice versa. For currently located air taxis’ companies in Poland, this share amounts more than 50% of aircraft’s annual flight hours. See: SATS Report R3.1 “Charges for usage of public long-distance public mode of transportation – current state and trends” The similar situation can be noticed in other EU countries. It results from the fact, that few air taxis’ companies have their bases on the large airports and in order to serve the connections between other airports, they need to reach them.

- Large costs of technical maintenance of airplanes results from the small fleet and a lot of different types of aircrafts,

- Small level of load factor, what cause adequate increase of service prices.

- Large share of administration and marketing agency costs,

- Large costs of crew salaries caused by the necessity of employ 2 pilot, as it is required by the regulations.

Development of small aircrafts’ transportation is conditioned by lowering generalized costs of journey to the level similar to the costs of traveling by car.

A realization of this postulate is possible via:

- Applying of Business Model, which ensure removing of reasons for high air services costs, mentioned above in the point from a to e.

- Implementing Net-centric management and services ordering system

- Solving safety problem, connected with need of implementation of single pilot crew on all airplanes with 4-19 seats, which are designed for commercial passenger transportation. Moreover, introduction of changes in regulations CS23 and JAR-OPS 1 (elimination of reason “f”).

It is worth to mention, that lowering production cost and aircraft’s price will have influence on the reduction of transportation services costs only to some not large extent. The price of aircrafts will have a meaning mainly by during investment decisions. The share of price in the general transportation costs, expressed by the depreciation of the investment, is relatively small and if the usage is as recommended, it will amount only few percentages of general costs. Only if the annual flight hours is low, this share will increase and will constitute considerable amount of costs.

The costs of usage of private personal aircraft will always be higher than costs of personal car’s usage, even if prices of their purchase will be similar. It results mainly from the fact, that both mode of transportation are used in different way. For example, if resulting from people mobility, vehicle-kilometers will amount 20 000 km (therein a share of long-distance journeys will be 4 000 km), then all fixed costs (amortization, insurance, garage) will be related to the full mileage. If on long routes an owner substitutes a car with an airplane, then the benchmark for calculating costs of 1 vehicle-kilometer for the airplane will be 4 000 km and for the car 16 000 km. Hence, fixed costs related to the vehicle-kilometer will be repeatedly higher than for a car. Potential vehicle-kilometers (technically and economically justified) of a personal car comes to
20,000 carriage kilometers yearly, whereas a personal aircraft will be between 150,000 and 500,000, depending on the type of the aircraft (assuming rational aircraft flight hours of 800 hours yearly).

From comparison of above-mentioned figures, it can be seen that from economic point of view, owning a private personal aircraft is not cost-effective and may be only motivated by prestigious and hobby reasons or can be reasonable in cases, when time value of the owner is very high and costs of transportation are less important.

This situation may change in the future, when a hybrid vehicle will be developed, which will be used not only as ground but also as air transportation or will take off and land vertically or on a short distance, still keeping the features of aircraft in the flight (like speed and energy effectiveness). At the same time costs of its development and usage will not be much different from the costs of car. The topic of the R&D of such vehicles is European projects “Out of the box” and “PPlane”.

**State-of-the-art assessment**

Above mentioned circumstances cause, that more often (particularly in USA) small aircrafts, even the cheapest ones, are bought and used jointly, what produces not only decrease of investment’s contribution of particular buyers but also significant reduction of owners’ usage costs. By current level of traveling on long-distance journeys, in order to use fully the transportation capacities of small aircrafts, joint purchase and usage should be done by bigger group of people (several to few dozen people, depending on the intensity of traveling). By such groups of people, it is clear; that even the best flight share management, is not able to fulfill all requests of the owners in 100 %. Taking into consideration random demand on flights and a need of achieving maximum probability of satisfying co-owners’ necessity of traveling, there are two ways of solving this problem: decrease the amount of airplane’s co-owners, what leads to the increase of costs or rise the number of jointly bought and used planes by respectively larger group of people. Second solution is more profitable but it demands more complicated organization and management model. It requires also an answer for the question – by which amount of aircrafts, of a proper type and with suitable amount of co-owners, the probability of flight’s realization by each of them in demanded time period will be sufficiently high and will come for example to 0.95. Development of such models will be one of the objectives of business model elaboration.

Implementation of public small aircrafts transportation on interregional routes with small traffic density, require different business model and aircrafts characteristics that will allow to eliminate the reasons for high transportation costs, mentioned above in sub-points “a” to “e” and in consequence it will ensure profitability of system functioning.

It is assumed that characteristics of small aircrafts will change evolutionary as the results of new technologies and realized researches and appropriate changes in the regulations. In the first phase of IPATS implementation, existing on the market up-to-date business piston, turboprop and jet aircrafts will be used. However, they need to fulfill operational requirements of current JAR-OPS 1 regulations. Gradually, the aircrafts will be modernized, mainly in the field of further improvement of economic, ecological and safety parameters. One of such parameters concerning economic will be allowing for single crew on all aircrafts with max. 19 seats, provided that an autopilot will enable self-steering and automatic landing.

Main areas of upgrading will be related to avionics, propulsion system, CNS system (implementation of results of works done within the framework of program SESAR) and steering and positioning. Simultaneously, but little bit shifted in the phase, new design of aircrafts will be introduced on the marked. They will be more economic and adapted to the larger number of users, based on the new materials and technologies. It is predicted, that in Europe the biggest development and implementation of these aircrafts will be in years 2020-2030, as a result of research works and the pressure of the users market of developing IPATS.
3. **IPATS OBJECTIVES AND CHALLENGES**

There are two important challenges of transport defined in the framework of European Research Area and undertaken by IPATS:

- First – to give travelers a free choice of transport mode according to their need, and limited by their time value
- Second – to follow “European energy strategy for transport” in order to improve energy efficiency of all modes of transport

Furthermore the goal of IPATS is to personalize Air Transportation System and fill the communication gap, which exists on interregional national and European destinations with underdeveloped transport network, located in a distance longer than 300 km, and where implementation of others modes of fast transport (high-speed rail, traditional airlines) is irrational due to too low flow density travel and where road transport is too disadvantageous in individual, social as well as ecological dimension.

Another important goal is extending daily range (daily accessibility indicator) for intensive activity jobs, where people go to another place, do their business for a few hours, and return home. For most of people, the daily radius of action equals c.a. 200 km and is limited by the capabilities of a car travel. Only for limited number of connections, generally between European capitals, thanks to high frequency of high-speed rail and airlines, this radius may reach a length of 1000 km. If traveling by small piston aircraft the radius may be extended to 1200 km, but usage of a very light jet enables passengers to reach all regions of Europe within one day trip. The goal is to enable origin-destination travel at about four times the speed of car at the same costs. Personal speed is a vital factor in the advancement of transportation capabilities, and ultimately the advancement of societies.

At the most global level, the objective of the IPATS is to reduce economic disparities substantially that exists locally, regionally and nationally in Europe. Such economic disparities result from the inequitable distribution of accessibility in constrained nodal and network based infrastructure. The European highway and hub & spoke are clear examples of such constrained infrastructures. The on-demand, point-to-point access capabilities of IPATS reduce these constraints.

One of the most important issues arising during new transportation system design process is securing network activity above the critical level of economic efficiency.

The solution requires a thorough knowledge on current and forecasted passenger mobility distribution and intensity. This knowledge is usually scarce or hard to find in the low flow areas, e.g. between remote regions. It is one of the reasons why air, as well as surface modes transport network develop in these areas, where flow is intensive and well recognized.

This effects with transport networks development in already well developed areas and leaving behind, in fact, the larger share of population. This discrepancy can be reduced by adjustment of transportation service to individual population demand.

Preliminary analysis shows that it becomes possible by introducing small aircraft air transportation services supported by information system and ordering network, that enables interoperability and aircraft pooling at low density interregional passenger flow. On one hand, the system satisfies instant access to high speed transport, on the other; it enables optimal aircraft utilization and higher load factor, by timely and directional transport demand pooling and adjusting to it aircraft type, each time. Introduction of such a system will most probably revolutionize behavior of travelers and modal split.

Aircraft design analysis requires clear aircraft mission requirements and estimates of the number of vehicles to be produced in the program’s life cycle. Mission requirements are traditionally setup by the aircraft design team in consultation with the customer (typically airlines for commercial vehicle development). The determination of the potential market for the vehicle to be designed is more challenging to define.
4. THE IDEA

The term Intelligent Personalized Air Transportation System refers to efforts to add to and in an effort to manage factors that typically are at odds with each other, such as costs and travel time, load factor and demand, tariffs and revenues, demand and supply to improve effectiveness and affordability.

A key aspect of IPATS is the application of net-centric model for transferring information of all types which allows for improving transportation management process, various business models and an easy access to the IPATS transportation services for a wide audience.

The concept relies on Personalized Air Transportation System utilizing small aircraft (jet, turboprop, pistons) starting from airports, that are the most close to home. These aircraft, operating in nearly all weather conditions, could serve any kind of location, but their main point of interest would be serving inaccessible areas and interregional low density passenger flows.

IPATS will help to meet the ever more mobile and demanding society needs by increasing passenger choice. This system recommends an alternative to private car mode. It is also a means to make a stronger aeronautical Europe by developing technologies needed for this kind of aircraft and by strengthening General Aviation. Lastly, EPATS should increase the operational capacity and the efficiency of air transport systems. The IPATS concept is mainly based on:

- Using existing information & communication technologies, and a broad public access to the Internet and mobile networks.
- Using the already existing local and regional airports network (more than 2000), especially located on the periphery of European main transportation infrastructure, in the areas with low level of accessibility indicator
- Using new technologies concerning aerodynamics, materials, propulsion, communication, navigation and control based on satellite systems
- Adjusting aircraft fleet, operational structures and transportation management to local demand and interregional passengers flow,
- Creating friendly legal and economic conditions, promoting unification, standardization and integration of maintenance network

Introducing SESAR’s “lifecycle of Business Trajectory in which Trajectories will be expressed in all four (4D) dimensions” provides full information on where the aircraft are (air or on the ground), what their flight plans are (long Term, Mid/Short Term, Execution, Post flight) and what their routes are and number of passengers on board. In SESAR’s ATM system, all aviation system components cooperate and possesses a full 4-d information about others. There are also no technical barriers to include an intelligent customer–provider information & communication sub-system, which task would be optimal use of IPATS system and optimal mode choice for customer.

Implementation of such sub-system will bring several significant advantages:

- Knowledge diffusion concerning small aircraft transport possibilities
- Increase of share of people participating in air transport sector
- Cheaper flights: fly one-way, pay for one-way only, similar to urban taxi cubs
- Increase of the transport system energy and economy efficiency through better fleet allocation with multiplied annual volume and high load factors,
- Better use of airspace
- Facilitation in air traffic management and its monitoring
- Increase of regional accessibility levels
- A general outlook of IPATS system is shown on figure 1.
Fig. 0. Multimodal potential accessibility
(by European Spatial Planning and Observatory Network, Project 1.2.1, http://www.espon.eu)
5. OPERATIONAL CONCEPT

One of the main features of IPATS system conception is taking advantage of the internet network, introducing interactive air transport service ordering and tailoring it to planning and execution of business trajectory network described in D3 SESAR Chapter 2 The ATM Target Concept [13].

The Intelligent Transportation System will employ a Net-Centric method i.e. participating as a part of a continuously-evolving, complex community of people, devices, information and services interconnected by a communication network to achieve optimal benefit of resources and better synchronization of events and their consequences.

System functioning scheme is shown on the chart below (Fig. 1.).

The Information & Communication sub-system enables interaction between Users (passengers) and Providers (TMC) through internet and mobile networks.

This system connects a customer directly to the Regional Station of Transportation Management Center TMC, which is the Provider and plans IPATS system service.

Through the network a customer orders air transport from his origin to destination providing name of the airport of departure and arrival, date and time of departure and arrival, number of passengers, baggage, comfort class and other data relating to the order.

TMC, gathers and analyses all orders, associates passengers and itineraries and adjusts to them the optimal aircraft type (the least costs type), which may realize the order. The customer is informed about aircraft type, date and hour of flight departure and arrival, pick up time (when door-to-airport transport provided) and service price.

Depending on the number of orders for a given itinerary, given day and hour, and passengers requirements the TMC offers adjusted services and appropriate aircraft. It could be a small, 4-seat aircraft with one passenger on board as well as a 19-seat airplane fully occupied.
A flight may be ordered in various advance time. Earlier order allows more passengers going the same direction at the same time and, therefore, the ticket price could be lowered by using a larger aircraft (keeping load factor close to 100%). The system allows, also, for ordering on a very short time notice if the customer is counting on empty seats in larger aircraft flying the same Business Trajectory.

The system gains new capabilities and leads to higher productivity, higher accessibility and satisfaction of passengers. It enables adjusting connections, schedule time and aircraft type to personal needs, and makes possible to accommodate fleet to regional demand and better aircraft utilization, both in terms of flight hours yearly and load factor. In consequence the system contributes to more effective air traffic and fuel consumption and transportation costs per pas.km reduction.

The functions of IPATS Transportation Management Center includes:
- managing data-link with Regional Stations,
- monitoring passenger traffic,
- collecting and recording data,
- managing data in real time,
- collecting statistics about EPATS-ITN performance,
- others to be defined

6. ASUMPTIONS AND NEEDS OF STUDIES AND RESEARCH

Creating such a system assumes:
- A fleet large enough and a wide range of aircraft types satisfying various customer needs (from cheaper pistons to expensive jets)
- Creating European Central Data Base of IPATS aircraft including technical-operational data and transport service prices
- Creating Central Data Base of IPATS airports (which will be also utilized on board for safety purpose in emergency case – see SOFIA Program)
- Full information on current status of every aircraft in the system (from extended SWIM features): where it is, what is its flight plan, how many passengers it has according to the plan and further information required for constant flight plan update
- Creating Customer – Service provider interfaces, optimization models and software allowing for optimal choice of air connection for certain group of passengers, certain route and certain time through dialog between Customer and Service provider’s Server.
- Designing and creating IPATS Management System combined with SESAR’s Wide Information Management
- Designing internet network connecting Central European Server IPATS with all other components of the system and SWIM server (Results from DELIS project could be used [14])

6.1 Full information on passenger flow density of interregional travels should be a support for system realization. The support is expressed by number of passengers travelling in a year, month and day, from region “i” to region “j” with purpose “p”, using mode “m”, of income (wealth) category “v” (Nij,p,m,v(y,m,d)). Such information has to be provided for rational estimation of aircraft fleet structure. It is why we stress the significance of mobility surveys and analysis for appropriate transport mode development and particularly IPATS. To obtain such information, new methods of interregional traffic surveys should be employed, for example utilized in the Intelligent Ground Transportation System which use of Floating car data.

6.2 Small aircrafts missions and requirements. Three type of missions could be expected: 1) 1-19 passengers, short hops point-to-point, range 300-900 km, 2) 1-19 passengers, point-to-point and possible stop, range 500-1200km, 3) 1-9 passengers, multiple stops in one day or one long run, range 1000-2500 km. There is a question, what kind of airplanes will realize planned
missions and how they will change during time. For many fundamental questions regarding design solutions of future small aircrafts designed for passengers’ transportation, there is no straightforward and unanimous answer. To the questions belong inter alia: Do piston and turboprop propulsion still have chance for development? Should single engine airplanes be allowed for passenger transport? Can an automatic pilot substitute a co-pilot? Should crash landing systems be implemented? Should size and equipment in the cockpit be standardized? Should design regulations be the same as for passenger airplanes? etc. To these questions also inquiries regarding avionics, automation, diagnostics, technology etc. have to be added.

The answers on these questions can be obtained through appropriate studies and research. Forecasting of IPATS aircrafts design characteristics should be defined on the basis of inquiry survey. In such way, also previous results of R&D carried out by countries and EU programs, should be taken into consideration. Moreover, expected effects of future scientific and research activities of these institutions also should taken into consideration. It is important to have in mind that in the closest view, the most likely is a prognosis based on real research and technological achievements. However, in the further view credibility of the prognosis is dependent on the state of advancement of research works and on circumstances allowing for positive results. Hence, it is important during taking prognostic opinions to ask, on what basis the opinion is given.

The objectives of elaboration of technical requirements should be:
- Identification of features, which should characterize small aircrafts designed for passenger transportation, which will be designed, certified, and put into production in years 2010-2020 and widely exploited during next several dozen years.
- Introducing a category of small aircrafts designed for passengers’ transportation in regulations CS-23 (substituting a category of local transportation aircrafts – commuter, which includes two engines turboprop aircrafts with max. 19 seats by Small Airplane Passenger Transportation (SAPT) Category, which contain propeller and jet aircrafts with max. 19 seats), taking into consideration the implementation of new aircrafts types and new technologies.
- Providing recommendations for European GA industry, regarding the trend of development of small aircrafts and establishing a basis for designing, certification and implementation and at the same time creating synergy conditions, which allow for faster development of this category of airplanes.

Current regulations CS-23 (Certification Specification) regarding GA aircrafts include package of airworthiness codes and acceptable means of compliance as well as guidance material to be used in the certification process. The code is applicable for the following categories of airplanes: Normal, Operational, Acrobatic and Local Transportation (earlier commuters), limited to two-engine turboprop aircrafts with less than 19 seats.

None of these aircrafts’ types, fulfill today’s passenger aircraft requirements, with the exception of, in some way commuters, which includes only two-engine turboprop aircrafts. To the Normal category airplanes belong today’s tourist aircrafts and propeller business and taxi aircrafts. However, this category does not include jet aircrafts and it does not meet actual airplanes requirements, designed for passenger transportation. In many cases, they are not coherent with them, e.g. for local transportation aircraft the passenger weight of 86 kg (190 pounds) is assumed, whereas for the airplane of Normal category it is 77 kg (170 pounds). In the second part of CS-23 “Acceptable means of compliance” given methods concern mainly propeller aircrafts with low speed. There is no place in it for researches of subsonic and transonic jet aircrafts.

Forecasting of development of Air Traffic Management and Control Systems of air traffic will be based on results of SESAR project.
6.3 Business model should be developed and shows the benefits, which result from IPATS implementation.

IPATS system includes numerous different subsystem elements which are working in close cooperation and each of them opens a new market and a new business. These are: airports network, Aircraft Operators, ATM-ATC System, Logistics Organizations, Customers – Providers Services network, Aircraft Service & Maintenance, GA Manufacturers. The Business Model represents various aspects of business, including its purpose, services, strategies, infrastructure, organizational structures, trading practices and operational processes and policies. It contains different components like value proposition, value network, revenues generation, etc. It deals with innovative products which diffuse into the society and economy.

The business model is based on the developed business and marketing strategies, utilization of the values chain of activities and on the innovation diffusion process. IPATS is a very complex and large system depending on the development of technologies, economy, synergy and other transportation system.

Process of creating Regional Small Aircraft Transport System is a long-term, innovative, diffusion process. It will be generated under favorable conditions, if local community is aware of its real capabilities, wherever opinion that flying small aircraft is expensive and reserved for VIPs and very wealthy people. Still too many people associates aviation with something not common and not very safe. Very few are aware though, that modern aircraft consume less fuel per passenger kilometer, provide less expensive travel and better safety than cars. Therefore, it is very important to widely disseminate knowledge of modern small aircraft’s real capabilities and possibilities of their development.

Most favorable conditions for Small Aircraft Transport System development are present in regions without fast communication connections, with airfields and functioning General Aviation at the same time, where aviation communities are strong. Such regions are common in every EU member state. In Poland such regions are, i.e. regions of Rzeszów, Mielec, Bielsko, Opole, Lublin, Koszalin, and Mazury and so on. In these regions there are reasons to start Small Aircraft Transportation.

It is anticipated, that carrier organizations and IPATS aircraft fleet home-bases, providing transport services for people will be set up in every region. Such base would consist of various types of aircraft adapted to population’s income and needs: piston, turboprop and jets, with 4 to 19 seats. Initially modern aircraft, available currently on the market will be used, and as system develops, according to anticipated plans, these airplanes will be replaced with new types, designed with 21st century capabilities and needs on mind. It is predicted that such gradual replacement of aircraft fleet might start in the twenties. At that time small aircraft transportation will be available for medium class population.

A new organizational model of Regional SATS and alliance structure is needed. It should consist of semiautonomous business units that are responsible for their own profitability. Such company must balance the autonomy of the business units with the need to coordinate some of their activities. Companies enter alliances to effectively meet the needs of cooperation and personal transportation coordination. Such alliance is also needed to assure aircraft maintenance and Flight Operation Quality Assurance (FOQA).

The Business Model should include:

6.3.1 Comparative analysis of transportation parameters and their influence on the environment of land vehicles and aircrafts

It is assumed that implementation of new personal transportation system cannot worsen its influence on the surroundings in comparison with other existing means of transportation.
Means of transportation have impact on the environment via:
- Pollutants emission, mainly greenhouse gases, CO2 resulting from burning hydrocarbon fuels (in this paper it will be reduced to the amount of CO2 emission).
- Decreasing of energy non-renewable resources (oil, coal, gas).
- Decreasing of raw material resources (iron ore, copper ore, clay, wood etc.).
- Environmental pollution with usage wastes (tires, oils, acids, metals, materials, etc.).
- Occupation of grounds used for roads, highway, railways, airports and their pollution.
- Generation of noise.
- Generation of accidents.

Taking into consideration, that the main task of SATS is to substitute personal cars with small aircrafts on long journeys (300-1500 km), as a main fulfillment conditions of balanced transportation development rule, it has been assumed that in comparison with car transportation SATS should be:
- More ecological and energy-saving.
- Safer.
- Similarly available (for most people time of reaching the airport by car should not exceed 30 minutes and general costs of journey should not be higher).

It is assumed, that indicators of these aims’ accomplishments will be:
- Reduction of fuel usage and emission of CO2, other gases and particulate matter per passenger kilometer. Decreasing general journey costs, inter alia external transportation costs per one passenger kilometer.
- Increasing mean of transportation effectiveness in full development cycle (mass of used materials and grounds per passenger-kilometer).
- Decreasing of accidents ratio in count for one passenger kilometer.

The analysis goal is to show, that using current technology level and in current conditions of usage, these indicators are more favorable for SATS than for personal car transportation. It is assumed, that the development of both means of transportation towards improvement of these parameters will be occurring in the similar tempo and the differences between them will stay on the same level.

6.3.2 IPATS infrastructure, system functioning and added values

The goal of the IPATS system is to fill the communication gap, which exists on interregional, national and European destinations with underdeveloped transport network, located in a distance longer than 300 km, and where implementation of others modes of fast transport (high-speed rail, traditional airlines) is irrational due to too low flow density travel and where road transport is too disadvantageous in individual, social as well as ecological dimension.

The objective is to enable origin-destination travel between all European regions at speeds considerably higher than car speed at equivalent costs. Personal speed is a vital factor in the advancement of transportation capabilities, and, ultimately, the advancement of societies.

This task will describe actual state of infrastructure of the airports in the EU with particular consideration of small and unused airports and condition of airspace management and ATM. Furthermore, there will be introduced proposals of airports’ networks development, where IPATS aircrafts will operate and perspectives of development of common European sky and ATM systems, which result from works on SESAR project and take into account implementations of new IPATS system.

An idea of system operation will be based on net-centric architecture, using internet network, GSM network and satellite communication and navigation. A project of this system will be developed in the framework of WP4. On European scale, system operation will be established on connections of operational and marketing tasks of particular regional sub-systems, which will be modeled in task T3.3. In task T3.2 all functions, realized by system will be described and
it will be specified by what means was it done. Furthermore, all data, needed in system
management (Data Basis of Network Server), will be indicated, as well as source of information
of them.

6.3.3 Value proposition

In chain of activities of individual IPATS elements carrying added value there are: industrial
companies, research centers, airports and service base, ATM-ATC, carriers, technical service and
maintenance stations, flying schools.

Final values of this chain of actions are: value of products and services, employment, time
saved during travels, added values resulting from increased access of people from remote areas
to material and cultural goods, equalization of chances of region’s economic development,
decreasing excessive personal car transport development, which is getting more detrimental to
environment, (terrain for building roads and highways, fuel consumption, exhaust gas and noise
pollution, accidents), relieving air travel congestion in large airports areas and decreasing effects
of traffic congestion.

6.3.4 Business Model of regional IPATS system – example

It is anticipated, that in every region with airfield and proper conditions activities will be
performed to create a local small aircraft transportation system. Such activities should be
initiated by local authorities, economic organizations, owners and administration of airports,
small carriers, aviation organizations, etc.

It is assumed, that in the development of Business Model of regional IPATS system – example,
there will take part representatives of local authorities and businesses of specified regions.
A model should be based on real premises of considered regions and it will include:
- Data regarding passenger traffic, generated from influence area of investigated regional
airport to other regions of the country and Europe, particularly passenger car traffic.
- Discussion of strategic plans, concerning plans on passenger transportation network
development and idea of implementation IPATS in other country’s regions.
- Description of detailed business and transportation models and forecast of IPATS aircrafts
demand in next three 5-years periods.
- Concept of creation of regional aircraft fleet and financing them.
- Analysis of adaptation costs of local airport to the requirements of IPATS.
- Analysis of opportunities for providing technical and personnel conditions, which will allow
for creating aircrafts’ fleet and its management on the local airport and as well for ensuring
operation of Regional IPATS Logistic Center.
- Project of Regional IPATS Implementation Plan.
- Analysis of costs and opportunities for the investment project, connected with the
implementation of IPATS.

7. NET-CENTRIC MANAGEMENT SYSTEM

The core of network-centric system is a suitably programmed Central Server (look: Figure 2),
where the information on transportation process parameters (aircraft positions, weight, planned
routes, status of seats reservation and service order, etc.) is gathered in real time and it will be
the basis for the information optimization by specialized programs.

Information about aircraft positions are passed on through GPS, whereas the data about other
flight parameters (passengers number, flight time, amount of take-offs and landings, pilots work
time, etc.) are passed on through board devices, which register chosen parameters and send
them on-line to the Central Server, using for that special transmission channels, e.g. GPRS
(General Packet Radio Service) in the GSM network.
In the future phases of development, a function of aircraft positioning and other flight management and control functions will be done by complex information management system – SWIM – System Wide Information Management, which is planned to be implemented in the framework of European Program SESAR in year 2020.

A package of choosing the optimal mode of transportation can be found on the server and it gives customer an opportunity to choose among different options of ground and air transportation. Criteria of optimization in this package will be minimizing generalized travel costs, planned for the client. It contains costs of transportation, accommodation (hotels, traveling allowances and other expenses connected with a journey) and time value of passenger, lost in the journey (estimated by the customer).

Package managing seats reservation will allow to associate the reservations of the customers with the same or similar itinerary and link their execution in one flight, by plane, which will be the best chosen to the number of passengers and planned route. Thanks to current information about all planned and realized flight routes within the framework of IPATS network, reservation may be also linked with operational plans of other flights with the same routes taking passenger en route.

Program of optimal usage of private and co-owned aircrafts is a tool allowing to rational usage of private aircrafts, designed for personal transportation and giving fundamentals for economic calculations, needed by creating the most favorable models of co-ownership and usage of aircrafts bought by larger number of buyers.

Access to the Data Base or application programs, concentrated in the Central Server is obtained in the web browser, in any place all over the world, through special software (after entering login, password and generated security code).

Participant of the SATS transportation process after logging into the system will receive on the web site an access to different structures attached to him/her. Participants may have various amounts of access accounts with different entitlements. This system provides a possibility of connecting all participants of transportation process.

Access to the data and application programs, designed for the customers of SATS services and for the general public is available from any web browser, without the need to log in.
8. CONCLUSIONS

From a technical point of view, increasing the accessibility of high-speed mode of transport and replacing long distance car trips by more efficient and safer small aircraft is fully achievable. Prerequisite for achieving this is to align their costs.

Aside the characteristics of the airplane, the most significant impact on air transport costs are: the annual flight hours, load factor, fleet and continuous airworthiness management. Of key importance for these factors are:
- Adaptation of the aircraft fleet structure to the passenger flows, which must be the subject of separate studies
- The creation of flexible business models corresponding to social needs
- Coordination of activities of entities involved in the transport process
- Integrating maintenance and Continuous Airworthiness Management Organization

The introduction of net-centric management system and interactive customer-provider information & communication system

The development of these activities needs the EC cooperation and support and a series of public and private partnership

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AIR TRANSPORT EFFICIENCY AND ITS MEASURES

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Executive summary

There are various definitions of efficiency of transport and different methods of measurement. This makes it difficult to measure and carry out benchmarking assessment of different modes. This paper presents proposals for measuring the efficiency of transport systems, taking as criteria: travel time, energy consumption, material use, impact on environment, affordability and accessibility. Based on these criteria, a benchmarking analysis of road and air transport was carried out. A new proposal for general definition of efficiency of transport is presented.

1. INTRODUCTION

In ACARE Strategic Research Agenda Efficient Air Transport is defined as “the movement of aircraft, of all types, and their passengers, through European airports and sky, in a timely and economic manner, without undue constraints on their preferred flight trajectories (aircraft), journeys (passengers) or departure and arrival times” and the main Vision 2020 Goals are: three times more aircraft movements, punctuality (delays less than 15 min), time spent in airports – no more than 15 min, five-fold reduction in the average accidents rate [1]. This definition of efficiency is limited to the Air Traffic Management level.

At the air travel industry level efficiency is addressed to capital productivity and is measured in two ways [3]:
- The simplest measure is the average aggregate load factor of the airline. This can be taken to measure the approximate capital productivity of the airline. Aggregate load factor are defined as the percentage share of seats occupied per year in total aircraft seat capacity on route served by the carrier.
- A more adequate method is to evaluate efficiency by analyzing and comparing the outputs of the decision unit to its inputs. Each output and each input is assigned a weight and the ratio of weighted outputs to weighted inputs yields a global measure of efficiency in given environmental conditions. Outputs include total passengers transported and total passenger-kilometers. Inputs include total personnel, capacity, fuel and average stage length.

At the route level, standard measures of efficiency are load factors and fares. Load factors express the efficiency in the use of aircrafts on each route. The load factor depends on the structure of the fleet (average size and age of planes), on the economies of scale, passenger flow density, stage length, and on policy and market influences shaping the efficiency of carriers. The efficiency in the use of airline capital increase with average aircraft size and the size of market [3]. That explains the reasons behind the Hub & Spoke system and large airliners development at the expense of direct point-to-point connections and low passengers flows small aircraft service.
From the point of view of vehicle efficiency, the fundamental efficiency indicator of any vehicle are its velocity, payload and energy consumption. These indicators are used to define generic vehicular efficiency that applies to all vehicles.

At the level of European Union and respective Member States, the air transport efficiency evaluation cannot be limited to the level of Air Traffic Management or airline economic efficiency only. The evaluation has to take under consideration social aims, which are targeted by air transport and which were formulated in numerous documents concerning European Union transport policy. They especially concern: securing coherent and sustainable transport development, slowing the dynamics of car transport development down in favor of more environmental friendly modes, extending daily radius of population activity.

The natural measures of transport efficiency in this context at the country level are:
- Origin-Destination time of travel (as a result of mode speed, network availability and traffic management system)
- Energy (fuel) consumption at the level of system (required for 1 passenger-kilometer in given conditions)
- Material use (per 1 passenger-kilometer)
- Externalities – impact on environment (in terms of 1 passenger-kilometer)
- Affordability and Accessibility

As an example of a benchmarking assessment of the effectiveness of passenger transport we compare the road and air transport, particularly passenger cars and small airplanes operating in the European Personal Air Transportation System (EPATS) [14]

2. TIME EFFICIENCY

The travelling public has available a wide choice of modes of transport including car, bus, train, ship and aircraft. By far the most significant advantage of air travel is the time saved by the fast cruising speed. Professor Bouladon of the Geneva Institute aptly described this in his analysis of transport gaps in 1967. The total trip time shown in Fig. 1.7 is a combination of delay caused by the infrequency of the service, the speed of travel and the wasted time due to the interconnection of services.

![Figure 1. Transport gaps (Source Bouladon)](image)

Of the three “gaps” identified, the short- and long-haul ones are directly targeted by the air transport. Reducing each of the component times contributing to the overall trip time presents opportunities for both operational and technical improvements in new air transport and
continues to challenge aircraft designers, airline managers and airport operators. For short stages it is no longer acceptable to have long reporting times prior to boarding. The goal of EPATS Project is shortening reporting time and to fulfill the Short–haul gap.

As we all know, for shorter journeys and where a suitable public transport system is not available the private car is the natural choice of travel. For journeys less than 300 km the car is the dominant mode of transport.

We consider a time effective mode of transport, appropriate for certain groups of population if time of travel is the shortest among other modes. We call time saved by one traveler in terms of O-D travel realization a unitary time efficiency of transport system “m” for “i to j” itinerary in comparison to other available transport systems. Travel time consists of unproductive transport time (including node access, waiting for transport and compulsory rest during travel) and efficient time used for business trip objectives. For this analysis, we assume, typical business trips start during morning hours and trip objectives realization lasts 6 hours, because trip objectives and their time of realization may vary.

Global time efficiency of a new transport system implementation from “i to j” itinerary is measured by aggregating time savings of all passengers traveling using those itineraries per a unit of time (assumed 1 year). Thus, the efficiency depends on which itinerary the system is introduced to and what the flow of passengers is.

The transport time between all regional (16 NUTS-2) capitals using all available modes (except for coach) of transportation and hypothetical EPATS aircraft were analyzed to estimate time efficiency of the EPATS in Poland.

The time data came from train and air transport schedule and the Michelin internet website (http://www.viamichelin.com) for car travel. Data concerning number of business trips in Poland were taken from Polish Institute of Tourism (http://www.intur.com.pl/). The least time consuming mode was found for every itinerary (examples: Figure 2).

![Figure 2. Least time modes on itineraries originating from Rzeszów](image)
Calculations show that in 2007, for most business travel in Poland, the shortest time were achieved by using a car. See Figure 3. The implementation of EPATS radically changes the proportions. EPATS is the least time consuming mode in most of the cases. See Figure 4. EPATS possible time savings as a % of average minimum time business trip using modes available in 2007 is shown on Figure 5.

The global time efficiency of EPATS system in Poland is 30 million hours per year with an average of 10 hours on one business trip and number of business trips of 3 million per year.
3. ENERGY EFFICIENCY

The words “energy efficiency” are in common use qualitatively, but are difficult to define or even to conceptualize. An engineer may define energy efficiency in a very restrictive equipment sense, whereas an environmentalist may have a more broad view of energy efficiency. Increases in energy efficiency take place when either energy inputs are reduced for a given level of service or there are increased or enhanced services for a given amount of energy inputs. Energy use in the transportation sector is primarily for passenger travel and freight movements and is measured as Specific Fuel Consumption (SFC). The energy input is fuel consumption the given service is passenger transportation from origin to destination in given time and conditions.

In aviation, we can distinguish the following units of fuel consumption: hourly consumption, consumption per kilometer or passenger-kilometer and per unit of effective power, calculated as a product of number of transported passengers and speed. Fuel consumption and these units values depend on conditions and reference levels, for which they were chosen.

We can list the following levels of reference:
- aircraft technical level, at which various conditions of fuel consumption can be distinguished, especially: flight speed and level condition, longest range condition or during standard mission (according to the requirements), etc. These values are determined by calculations and analysis and are included in the set of aircraft characteristics, given in aircraft manual.
- air subsystem level which includes aircraft of a given airline, airports, air network and air

Figure 5. Average time saved during one business trip from one region of Poland to all of the rest after EPATS implementation.
traffic management, where average fuel consumption is determined on real routes and in real conditions taken under consideration including e.g.: waiting, route change, aircraft load, network geometry, etc.

- air transport system level which includes all airlines and all airports, air network and air traffic management system. Fuel consumption at this level is statistically determined and includes aircraft fleet as well as surface facilities and surface transport
- transport system level which includes consumption of fuel used for airport access and egress operations and airport fuel and material logistics

The example of fuel consumption at air transport system and its comparison to car transport system is given below on the graph Figure 6:

![Figure 6. Specific fuel consumption comparison on global level: Car - Aircraft](source: Annual Energy Outlook 2006 with Projection to 2030)

![Figure 7. ATR 42 Specific fuel consumption at different conditions](source: Flight Manual and Survey results)
Fundamental differences among the mentioned reference levels can be seen on the example of ATR-42, used by Polish Airlines on regional routes (see figure 7). The statistical specific fuel consumption per unit of this aircraft in real conditions, on distances of 300 km is about 7 liters of kerosene per 100 passenger-kilometers, while this value at block speed in standard conditions is about 3 liters per 100 pkm, that is two times less. It proves that the aircraft technical characteristics are far different from these, reached in the system. It is important not only in terms of fuel consumption, but also speed.

Main factors of specific fuel consumption [l/100 pas.km] increase in air transport system are: empty seats, waiting for start and landing, route extension due to network characteristics, route change due to traffic, etc. The more complete use of airspace and airport, the higher the loses. Increasing number of communication airports and making air traffic management more efficient leads to significant decrease in fuel consumption in air transport. The similar effect is generated by fitting network to directions of O-D(Origin-Destination) travel, simultaneously adjusting aircraft size to passenger flow density.

![Figure 8. Specific fuel consumption comparison](image)

Comparison of unit fuel consumption, in standard conditions, of car and aircraft of different size and with different propulsion via route distances were shown at the graph Figure 8.

When car statistical load factor is on average 1,2 persons per vehicle, its SFC on one passenger is on average 6,6 liters/100 km, what is, in comparison to 4-seat aircraft, higher by 50%. It is important to note, that the comparison of fuel consumption per unit of transport (passenger x kilometer) of two vehicles of very different speeds is not aligned to the definition of energy efficiency and lead to confusion. According to the definition of energy efficiency of transport mode, the energy put in the transport realization should be referred to the energy required for
In this transport realization, i.e. to 1 pas.km/hour or pas.speed. In reality, even when load factor is 1, the energy efficiency of car is much lower than aircraft. At an average speed of 80km/h, the SFC per 1 pas.km/hour is 0.025l/pas.km/h, when for aircraft at an average speed of 300 km/h it is, respectively, 0.01 litres/pas.km/h.

There are two, important reasons for that. Car power need is higher at higher speeds, than the need of the aircraft (higher resistance), energy loses for idle gear and for breaking and accelerating are important in total need of power of car. Figures 9 and 10 clearly show it.

![Figure 9. Car and four seats aircraft energy needs via speed](image)

![Figure 10. Energy split of car and aircraft](image)

Transport energy efficiency differences of car and aircraft will deepen in favor of aircraft. Assuming a similar development of car and plane propulsion towards more energy saving and ecological solutions, the differences will deepen due to changes in energy demand. Energy loses of car transport caused by road traffic, car mobility resistance and load factor will not be significantly changed and the congestion growth trend will remain disadvantageous. It is opposite in the air transport. There are still large reserves in energy demand at aircraft technical level (aerodynamics perfect ness increase, better material and technology use, lower weight),
as well as at the system level (better use of airport network, new air traffic management systems implementation). It is estimated that a unitary need for energy in EPATS system may be decreased in comparison to the present state in aviation by about 30%. It is worth mentioning, that the trend in air transport, focusing on hub-and-spoke system, good to serve large flow of passengers, by large aircraft does not favor energy saving, what is proved by the large disparities between unitary fuel consumption at the level of aircraft and the system. In air transport, transport system energy efficiency should be treated with a great care. It significantly impacts on liquid fuels reserves depletion, air pollution and transport costs. Air network efficiency and air traffic management system, although hard to examine, apart from delay indicator should be measured by energy loses indicators.

Since 1970 the specific fuel consumption of the European passenger fleet has already been cut by 70%. It is intended that this trend should continue. There are a lot of opportunities of reducing further specific fuel consumption - i.e. the amount of fuel necessary to transport one passenger over a certain distance in a given time. Further reductions in the specific fuel consumption of aircraft can be achieved not only through advanced engines, improving aircraft aerodynamics, introducing lighter materials, replacing heavy system components with lighter ones, but also by improving ATM – ATC technology, using direct link between nearest local airports and operating the most accommodated capacity of aircraft fleet.

Energy consumption statistics for modern civil aircraft show that air travel is not only a fast but also a fuel-efficient form of transport. The specific fuel consumption of some airliners at cruising speed is now below 3.5 litres of kerosene per 100 passenger-kilometre.

On average, for a long-distance journey, a mean class car with average consumption 8 litres per 100 km and average occupancy 1.3 persons per car will have a specific fuel consumption of 6.15 litres per 100 passenger-km. According to these figures, long-distance car travel requires a higher specific fuel quantity of 25% more than a propeller aircraft. Only if a minimum of three people is traveling in one car, do they consume less fuel per capita than in an aircraft. Even then, the time, cost and accessibility factors in reaching many destinations are points in favour of air travel.

At one time extraction costs and availability of aviation fuel had little impact on the evolution of the air transportation industry. Today, fuel conservation in aviation is one of the most critical concerns to air transportation.

By the early 1970s it had become increasingly evident that the era of plentiful, inexpensive petroleum-based fuel was ending. The fuel cost was becoming more significant in air transport economies. The forecast of jet fuel prices on the current dollars scale are expected to follow the trends of the previous years, indicating a four percent increase per year over 12 years. In order to achieve improved system efficiency a key requirement is an improved capability to accommodate fuel efficient aircraft operations.

The ideal aircraft would be economical to buy, maintain, have a high cruising speed, short take-off and landing distance, long range (adequate to demand), and be fuel efficient. It’s highly unlikely for an aircraft to have all of these characteristics but it is possible to retain the most important for the market. The goal in aircraft design is to achieve a rational balance between vehicle performance in combination with affordability.

4. MATERIALS EFFECTIVENESS

We understand material efficiency of a transport mode at the vehicle level as the mass of material used, needed to transport passengers – we assume, that it is relation of useful vehicle weight to total weight (take-off weight). At the level of transport system, we assume, that the weight of material, needed to transport 1 passenger-kilometer in full life cycle is measured in kg/pas.km. Material efficiency was calculated basing on statistical data of aircraft MTOW from 1300 to 28 000 kg and for an average personal car of 1700 kg.
Calculation assumptions:
- Life cycle of aircraft: 20 years, of car: 10 years
- Flight hours yearly of 9-seat aircraft for air-taxi and charter: 600 h, for more than 10-seat aircraft: 1800 h yearly
- Speeds were taken from characteristics
- Load factor of car: 0.3, of aircraft: 0.65
- Average car yearly volume of kilometers: 10 000 km.

Weight and materials effectiveness of car and aircraft are shown in figure 11 and 12.

Effectiveness = vehicle weight / (life cycle x yearly flight hours x travel speed x number of seats x load factor)
The differences in material efficiency among smaller and larger aircraft comes from different assumptions of yearly flight hours, what is supported by their purpose – small aircraft are mainly used as air-taxis, larger – for regular flights. Average, absolute values are: 0,14 for small and 0,025 kg per 1000 passenger-kilometers for larger. The differences are slight and in comparison to the one of car can be omitted (car: 10 kg per 1000 pas.km, that is 2 ranks higher).

If we total the material use with land consumed by roads, highways, parking places and other materials used for motorization infrastructure, then we clearly see, how great benefits is brought by passenger air transport, if we consider land use.

5. IMPACT ON ENVIRONMENT BY COSTS EXTERNALITIES MEASUREMENTS

The impact of air transportation on environment is carry out through costs externalities evaluation. The following data source were used to elaborate external costs of transportation presented in table 1 and figure 13:
1.”The Social Costs of Intercity Passenger Transportation: A Review and Comparison of Air and Highway” by David M. Levinson [10]
4. Values assumed for the aeroplanes are based on the comparative analyses, taking mainly into account the difference in: fatalities rate and crash externalities, traffic congestion, street parking, local air pollution, roadway costs and traffic services. [13]

The table 1 and figure 13 show evidently that the external costs of air transport are much lower than road transport, including external costs for environmental damage

![Car-Aircraft externalities costs comparison](image)

According to OECD document “Towards Sustainable Transportation” the externalities of transportation vehicle amount to:
**Car – 1,25 USD/km, Train – 0,25 USD/km, Aircraft – 0,45/km**

These figures and others, which can be found in the literature, show that there is a large dispersion of statistical data on the impact of transport on the environment, although most data indicate that the most harmful impact has road transport.
6. AFFORDABILITY AND ACCESSIBILITY

To high speed mode of transport in interregional trips (400 - 2000 km) (inter eu-25 and national), we consider that the mode of transport is:

- **accessible** if the access time to transportation system node is less than 1 hour and
- **affordable** if the generalized cost of travel does not exceed the generalized cost of travel by car.

For these assumptions we evaluate the affordability and accessibility (the share of people) of current high speed mode of transport and EPATS 2020

![Figure 14. Affordability and accessibility of current high speed mode of transport in EU-25](image)
Figure 15. Affordability and accessibility to EPATS 2020

For air transport accessibility can be also presented as the average distance to the nearest airport from where the flight is possible. The figure below shows the distance to different class of airport for a given percent of population.

Figure 16. Distance to airports in Europe. Source: EPATS Project

7. CONCLUSIONS

Main natural determinants of personal transportation system efficiency are:
- Traveling time as an effect of a mode speed, infrastructure, traffic management system and accessibility
- Energy used (fuel) on the realization of one passenger kilometer at given speed
- Resources used for the mode of transport and infrastructure production on one passenger kilometer
- Impacts on ecology
The global determinant including all other factors expressed in monetary form is the
generalized cost of transport of one passenger-kilometer.

The results of transport efficiency analysis allow the following conclusions:
- Levels of measurement influence efficiency evaluation significantly.
- The shorter distances and larger aircraft, the wider differences.
- Despite the fact, that larger aircraft have better weight ratio and energy consumption
characteristics, it is small aircraft, which provide higher efficiency in particular situations.
- Mode efficiency should be measured at the national/European economy level considering
social efficiency.
- Air transport is safer, environmentally friendlier and more energy and resource efficient than
car.
- The greatest disadvantage of contemporary modes of high-speed transport (scheduled air,
hi-speed train) are infrastructure development limitations, low nodes accessibility causing
unbalanced regional development as a side effect.
- On the system level Air Transport Efficiency should be define as energy consumption or costs
needed to shift one passenger (or kg) on representative (average) origin to destination Great
Circle Distance in time according to a fixed plan and complying specifications requirements,
including safety and environmental.

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and Highway by David M. Levinson
Conservation Strategies By Todd Litman Victoria Transport Policy Institute 6 May 2005
[13] Values assumed for the airplanes are based on the comparative analyses, taking mainly into
account the difference in: fatalities rate and crash externalities, traffic congestion, street
parking, local air pollution, roadway costs and traffic services.
[14] European Personal Air Transportation System Research Study. EU FP6 EPATS Project
THE EUROPEAN PERSONAL AIR TRANSPORTATION SYSTEM (EPATS) STUDY PROJECT: A SYSTEMATIC APPROACH BASED ON SMALL AIRCRAFT AND SMALL LOCAL AIRPORTS

Krzysztof Piwek, Andrzej Iwaniuk, Włodzimierz Gniewkowski
Institute of Aviation
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Executive summary

This paper describes the European Personal Air Transportation System (EPATS) STUDY project realized in the Sixth Framework Programme.

It consists of two parts:

First part includes basic information about the EPATS STUDY project: project objectives, list of partners, project structure and deliverables.

Second part contains results of the project. There are presented conclusions referring to the accessibility and suitability analysis of European airports, the EPATS demand forecasting, general requirements, environmental and safety aspects, business models and recommendations.

Results of the EPATS STUDY project show that it is possible to replace car trips on a distance longer than 300 km by personal air transport based on small aircraft and small local airports in Europe.

1. INTRODUCTION

The proposal of the European Personal Air Transportation System (EPATS) Study was prepared in response to call in the area of aeronautics Specific Support Actions (SSA), Priority 4: Aeronautics and Space - Integrating and Strengthening the European Research Area (Call identifier: FP6-2002-Aero-2) published by European Commission within the Sixth Framework Programme.

Considering the aeronautics research work programme [1] of the thematic priority "Aeronautics and Space", the EPATS proposal was oriented basically to two research areas: Research Area 1 Strengthening Competitiveness, Objective 3: To increase passenger choice with regard to travel costs, time to destination, onboard services and comfort.
Research Area 4 “Increasing the operational capacity and safety of the air transport system”. Objective 2. Increase system capacity. Objective 3. Improve system efficiency. Objective 4. Maximise airport operating capacity in all weather conditions to support increasing traffic.

The EPATS proposal was addressed to under mentioned call topics:
- Realising the European Research Area.
- Stimulating international cooperation.
- Developing a EU research strategy in the sector.
Considering The Vision For 2020 report [2] and The Strategic Research Agenda (SRA) [3] prepared by the Advisory Council for Aeronautics Research in Europe (ACARE) setting out the directions for European research in the next decades, the EPATS proposal fitted to the High Level Target Concepts for the work to 2020 especially to:

1. The Highly Customer Oriented Air Transport System.
2. The Highly Time Efficient Air Transport System.
3. The Highly Cost Efficient Air Transport System.

For example the first HLTCs is defined\(^1\): “The Highly Customer Oriented Air Transport System proposes a quantum leap in passenger choice and schedule flexibility. With a trend away from hub-oriented operations to more convenient point-to-point travel, increasing numbers of individuals on leisure and business travel fly in small to medium size aircraft ...”.
The EPATS proposal was accepted by European Commission and realized as Specific Support Action (SSA) project under contract no. ASA6-CT-2006-044549-EPATS.

2. EPATS STUDY PROJECT SYNOPSIS

The EPATS (European Personal Air Transportation System) focuses on the future Highly Customer Oriented and Time, and Cost Efficient Air Transport System. It fills a niche between Surface and Scheduled Air Transport. Future mobility cannot be satisfied only through investments in hub and spoke, or rail and highway systems. This future EPATS system will provide a wider use of small aircraft, served by small airports, to create access to more communities in less time.

The goal of the EPATS study was to demonstrate the needs and potential of small aircraft business development and to propose recommendations for the introduction of this new European Air Transportation System in the context of the European Research Areas.

The EPATS study was oriented toward the following issues:
- The potential new markets for personal aviation up to 2020.
- The potential impact of this new way of transport on the European ATM, and airport infrastructures, as well as the environmental, safety and security issues involved.
- The EPATS general specification and R&D Roadmap.

2.1 Project objectives

The objectives of the EPATS project were:

1. To identify the new market for personal aviation in Europe as the result of technology development and society needs. Characteristics of this travel mode are reduced door-to-door travel time by using small airports and small aircraft at low cost, operating in all weather conditions, serving also the suburban, rural and remote locations, and particularly the population that do not have access to high speed transportation networks.

2. To understand the impact of this potential market on the European ATM and airport infrastructures and to specify issues to be solved. The study addressed the need for special ATM system developments linked to the potential market demand in the context of the Single European Sky initiative. This work was fed into the SESAR (Single European Sky ATM Research) project.

3. To quantify the economic impact of implementing a new European personal air transport system in terms of transportation effectiveness and job creation.

4. To identify and assess mission’s requirements for possible new classes of aeroplanes based on advanced technologies, which will satisfy the society needs for flexible, fast, easy to use, efficient, low cost, near all weather, safe and environmentally friendly air travel.

\(^1\) Strategic Research Agenda [3] Volume 1 p. 34
5. To identify the step changes in European industry development of engines and avionics for small aircraft, and in technologies that need to be researched urgently in order to ensure a competitive position of the European aircraft industry, which is composed of many small and medium sized companies in this market segment.

6. To propose recommendations (in terms of the EPATS research and development roadmap) for the introduction of this new European Air Transportation System in the context of the European Research Areas and European partnership.

7. To disseminate the conclusions of the study amongst the European stakeholders, to increase interest in the potential new market, and to promote the revitalisation of the European General Aviation industry.

2.2 Detailed information

Contract number: ASA6-CT-2006-044549
Instrument: Specific Support Action
Call: FP6-2002-Aero-2
Starting date: 1 January 2007
Ending date: 30 June 2008
Duration: 18 month
Research domain: Thematic call in the area of Aeronautics Specific Support Actions
Website: http://epats.eu/
Coordinator: Krzysztof PIWEK, Institute of Aviation.
The studies were carried out by a Consortium supported by representative experts of the EPATS stakeholder community.
EPATS partners are listed below (No 1 – coordinator):

<table>
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<tr>
<th>Partner No.</th>
<th>Organisation name</th>
<th>Partner short name</th>
<th>Name of the Partner’s Project Manager</th>
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2.3 EPATS Project Structure
2.4 EPATS Project Results

The deliverables of these studies were reports containing a joint vision on the personal air transportation system in Europe of 2020 and proposals for developing this new small aircraft business at a European level.

The EPATS reports are listed below:

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All reports are accessible on EPATS Website or in Institute of Aviation archives. (Contact person - Krzysztof PIWEK, e-mail: , phone: (+48) 22 868 56 81, fax: (+48) 0 22 846 44 32)

3. EPATS STUDY RESULTS SYNTHESIS

The above-cited reports contain both results of particular matters in area of personal air transport based on small aircrafts and small local airports and summary included roadmap, requirements and conclusions.

However the fundamental question for EPATS Study was:

Is the personal air transport based on small aircraft and small local airports (EPATS) likely to have a future in Europe or not?
The answer this question is connected with the following questions:
1. What is the accessibility and suitability of European airports?
2. How much could be the potential transfer of traffic from road to the EPATS?
3. How to integrate EPATS traffic with future ATM projected by SESAR?
4. What will be impact on Airports?
5. What are the EPATS environmental and safety aspects?
6. How to define Missions Requirements for EPATS Aircraft?
7. What should be Roadmap and recommended R&T&D for next Frame Programs and Strategic Research Agendas?

The following chapters are described critical issues result from studies in EPATS Project and answers the above-mentioned questions.

3.1 What is the accessibility and suitability of European airports?

The accessibility and suitability analysis of European airports was conducted by Majka A., Brusow V., Klepacki Z. from Rzeszów University of Technology [6]. They researched airports and airfields in 34 European countries (27 countries that have joined the European Union and 7 other countries). There are about 1270 airports which have an ICAO code and 1300 landing fields (all together 2567) in 34 European countries (tab. 3.1).

Table 3.1. Number of airports and all landing fields in Europe. Source [6]

<table>
<thead>
<tr>
<th>No.</th>
<th>Country</th>
<th>Number of Airports</th>
<th>Number of Airfields</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Austria</td>
<td>9</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Belgium</td>
<td>18</td>
<td>56</td>
</tr>
<tr>
<td>3</td>
<td>Bosnia and Herzegovina</td>
<td>4</td>
<td>4*</td>
</tr>
<tr>
<td>4</td>
<td>Denmark</td>
<td>7</td>
<td>7*</td>
</tr>
<tr>
<td>5</td>
<td>Bulgaria</td>
<td>36</td>
<td>36*</td>
</tr>
<tr>
<td>6</td>
<td>Croatia</td>
<td>14</td>
<td>14*</td>
</tr>
<tr>
<td>7</td>
<td>Cyprus</td>
<td>3</td>
<td>3*</td>
</tr>
<tr>
<td>8</td>
<td>Czech Republic</td>
<td>18</td>
<td>18*</td>
</tr>
<tr>
<td>9</td>
<td>Denmark</td>
<td>52</td>
<td>52</td>
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<td>10</td>
<td>Estonia</td>
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</tr>
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<tr>
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<td>3*</td>
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<td>7</td>
<td>7*</td>
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<td>1</td>
<td>1*</td>
</tr>
<tr>
<td>22</td>
<td>Malta</td>
<td>1</td>
<td>1*</td>
</tr>
<tr>
<td>23</td>
<td>Kingdom of the Netherlands</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>24</td>
<td>Norway</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>25</td>
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<td>27</td>
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<td>22</td>
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</tr>
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<td>Slovakia</td>
<td>8</td>
<td>8*</td>
</tr>
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<td>29</td>
<td>Slovenia</td>
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<td>6*</td>
</tr>
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</tr>
<tr>
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<td>Ukraine</td>
<td>75</td>
<td>75*</td>
</tr>
<tr>
<td>34</td>
<td>United Kingdom</td>
<td>126</td>
<td>704</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>1268</td>
<td>2567</td>
</tr>
</tbody>
</table>

* No detailed data
The airports and landing field data was analysed statistical in view of location, runway characteristics (fig. 3.1), distances from the main 256 European cities to the nearest airport (fig. 3.2) and the population was quantified within particular radius of aerodromes (fig. 3.3).

Fig. 3.1: All European airports runways length histogram. Source [6]

Fig. 3.2: The distances from main European city to the nearest airports histogram. Source [6]
The final conclusions based on the analysis of current airport characteristics overview are[6]: Europe is a special area with unique features favouring the development of regional passenger air transportation system, since:
- it has about 1,270 airports and 1,300 landing fields, which means that for the most densely populated regions there is one airport per 2850 km² (one landing field per 1200 km²), and 390 000 inhabitants per one airport (170 000 inhabitants per one landing field),
- in the most densely populated regions, the nearest airport lies within a distance of less than 40 km for more than 95 % of population (within less than 20 km for 60 % of population),
- for most European cities, the nearest airport is located within 15 km (90 % of cities),
- there are many airports in the vicinity of the greatest European cities (not fewer than 10 airports within 50 km radius of each city) – passengers can freely choose the most suitable airport,
- a lot of European population (potential passengers) live close to airports – approximately 1 mln inhabitants within 40 km radius of aerodromes,
- most European airports have sufficient technical conditions for being utilized for normal operational purposes by GA aircraft (other landing fields should be modernized).

3.2 How much could be the potential transfer of traffic from road to the EPATS?

The problem of EPATS demand forecasting was analysed by the research team from M3Systems and Institute of Aviation in charge of Laplace I. [7, 8, 9, 10, 11].

They applied the generalized cost minimisation method, meaning that they compared the generalized cost for each mode of transport. The concept of generalized cost based on assumption that a traveller does not choose between 2 modes by comparing only prices; s/he also takes into consideration several qualitative factors such as transport time, frequency of the train or aircraft, comfort, or reason for travelling. These parameters are subjective: they are not perceived the same way from one passenger to another.

The concept of generalized cost assigns a monetary value for all these parameters [7]:

---

*Fig. 3.3: Cumulative distribution function of population within particular radius of aerodromes in Europe. Source [6]*
With \( C_g \) = Generalized Cost
\( C_{\text{travel}} \) = Travel Cost = monetary cost = Direct cost borne by the traveller
\( C_i \) = Non-monetary Cost

Because of the difficulty in evaluating aspects such as comfort, frequency, etc, they took into account only “time cost”, which depends on the time spent in travelling and on the value of time, i.e. the value that a passenger attributes to his time.

The following formula of generalized cost were used:

\[
C_g = C_{\text{travel}} (d) + V_t \times T_{\text{travel}} (d)
\]

With \( C_g \) = Generalized Cost
\( C_{\text{travel}} \) = Travel Cost = Out-of-pocket Cost
\( d \) = Travelled Distance
\( V_t \) = Value of time
\( T_{\text{travel}} \) = Travel time = time spent in travelling or waiting

The comparison of the generalized costs enables to compare modes and to choose the one that minimizes generalized cost for a given journey.

When a traveller with a value of time \( V_t \) compares two transport modes, mode i and mode j, he will choose the one having the smallest generalized cost, i.e.:

The traveller chooses the mode i if: \( C_{g_i} < C_{g_j} \)

Or if:

\[
C_{\text{travel}_i} + V_t \times T_{\text{travel}_i} < C_{\text{travel}_j} + V_t \times T_{\text{travel}_j}
\]

Or else if:

Introducing the notion of “Indifference time value” \( V_{t_j} \), such value of time that \( C_{g_j} = C_{g_i} \)

or

\[
V_{t_j} = \frac{C_{\text{travel}_j} - C_{\text{travel}_i}}{T_{\text{travel}_j} - T_{\text{travel}_i}}
\] (in € / h)

The traveller (with a value of time \( V_{t_j} \)) will choose the mode i if

\[
V_t > V_{t_j} \quad \text{when} \quad T_{\text{travel}_j} - T_{\text{travel}_i} > 0
\]
\[
V_t < V_{t_j} \quad \text{when} \quad T_{\text{travel}_j} - T_{\text{travel}_i} < 0
\]

In addition, the value of time can be expressed as a function of the distance since cost and time depends on the distance. The idea is therefore to construct indifference curves, or in other words to plot “indifference time value” versus “travelled distance”. These indifference curves enable to see clearly the preferred mode for a segment of the market, i.e. for a distance and a value of time given.

The second part of the method consists in linking the indifference curves to the expected results i.e. to the potential transfer of passenger-km. The Indifference Curve is a representation of “value of time” versus “distance”. Therefore it is needed to get a table providing passenger-km distribution versus value of time and travelled distance, for each transport mode (aircraft/car).
The combination of both previous elements (indifference curves between two modes and passenger-km distribution by value of time and distance) can be used to obtain a modal split. They can use a model split to compare EPATS with another transport mode, and determine a passenger’s preferred choice. They considered six EPATS aircraft types in the estimations:
- ACP-1 – Single-Engine Piston
- ACP-2 – Twin-Engine Piston
- ACT-1 – Single-Engine Turbo-prop
- ACT-2 – Twin-Engine Turboprop
- ACJ-1 – Twin-Engine Very Light Jet (<5000 kg)

They considered to perform estimations in the context of ASSESS scenarios that have been developed in order to evaluate the effects of the White Paper measures [26]. There are the Null, the Partial, the Full and the Extended scenarios.

Estimations of the number of flights as well as estimations of the EPATS fleet have been derived from the estimated number of transferred passengers to EPATS and from the category of EPATS aircraft that is considered on each connection. They attributed one category of aircraft per NUTS 2 connection using the following rule:
- Piston aircraft used for trip distances between 200 and 300 km
- Turboprop aircraft used for trip distances between 300 and 1000 km
- Jet aircraft for trips between 1000 and 2500 km.

The next articles of this edition described in detail the method of demand forecasting and results of estimation.

Here we cited main conclusions result from the analyse of the potential transfer of traffic from road to the EPATS [10] and modal split for interregional trips in Europe in 2020 [22]:
1. The total transfer of traffic from road and air transport modes to EPATS would reach 50 million flights in Europe in 2020.
2. In order to meet this demand it would necessary to have a fleet of around 110 000 personal aircrafts.
3. Estimated EPATS fleet: 66% of it would be Piston aircraft, 13% Turboprop aircraft and 21% Jet aircraft.

Fig. 3.4: Vision 2020 of modal split for interregional trips in Europe. Source [22]
3.3 How to integrate EPATS traffic with future ATM projected by SESAR?

The EPATS ATM general requirements was conducted by Brochard M. from EUROCONTROL [12].

At first he analysed current EPATS flights in Europe according to above specify classes of aircraft and based on one typical day in 2007. The Fig. 3.5 shows the geographical distribution of movements over one day. Small aircraft movements are non-homogenously distributed and the most crowded regions are matching with those of traditional traffic.

To conclude, EPATS flights accounts in average for 2661 flights a day (or 839 500 movements a year) in 2007 and it represents 8.1% of the total traffic in 2007. So, the impact of EPATS on ATM is limited in 2007.

The flight analysis for 2020 was based on the EPATS prediction model [9] and take into account two cases (Case A and Case B). This cases differ in limits of application for trip distance with respect to the jets (Case A – up to 800 km and Case B – up to 1000 km).

The fig. 3.6 shows one typical day of EPATS flights in 2020 for Case B. The most preferred area of EPATS doesn’t overlap with those of the traditional flights. EPATS keeps off the most crowded regions of the traditional flights. However, the biggest EPATS traffic takes place in Italy, Greece, Portugal, Spain, the Southern regions of France, England, the South-Eastern areas of Poland and the North-Western locations of Germany.
To consider cruising altitudes (see Fig. 3.7), piston and turboprop aircraft are estimated to take the lower regions of airspace, between FL 20 and FL 250 and jets are assessed to use FL 350.

The distribution shows that the impact of the EPATS flights on the cruising altitude of the traditional traffic is most concerned between the FL 100 and FL 190. Above FL 190 the interaction decreases to zero, expect the vicinity of the FL 250 and FL 350.
The final conclusions resulting from the analysis of the impact of the EPATS on ATM are the following [12]:

1. The predicted EPATS IFR (Instrumental Flight Rules) flights are found to grow from less than 1 million (as in 2007) to 2,944,105 or 2,860,539, respectively for the Case A and Case B projections. Knowing the targets of SESAR, it is clear that these personal IFR flights fit in the capacity targets defined by SESAR.

2. The EPATS VFR (Visual Flight Rules) segment is expected to grow from about 15 million flights a year (as in 2007) to 41.2 million for the Case A and 40 million with respect to the B prediction. The impact of the personal VFR flights on the ATM is an unknown problem, since these movements are not clearly addressed in the targets of the coming ATM. Nevertheless, this investigation showed that personal VFR movements flying at low altitude will meet the arrival / departure flows of the traditional traffic at the airport vicinities. Therefore, EPATS VFR will affect these regions, and call for advanced methods to cope with the two classes of traffic together (EPATS and traditional). If not feasible, the deviation or the separation of the flights will be needed.

3. With respect to the total EPATS traffic, this investigation showed the evidence for the fact that the geographical distribution of the envisioned EPATS flights is different from those of the rest of the airspace users. More particularly, the results indicate that generally personal movements keep off the most crowded regions of the traditional flights. However, EPATS will influence the rest of the airspace users in Italy; Greece; Portugal; Spain; the Southern regions of France, England; the South-Eastern areas of Poland and the North-Western locations of Germany. With respect to the impact of EPATS on the most preferred airports of the traditional flights, Athens, Rome, Madrid, Barcelona, Warsaw, London are found to be the most influenced, while the most congested locations such as Frankfurt, Amsterdam or Paris are indicated to be less concerned. The cruising altitude distribution showed that 60% of the personal movements take place in the airspace below FL 100, in which only 2% of the traditional flights are present.

4. Major findings of the analysis suggested that future decisions concerning the airspace organization should take into consideration that (in 2020) about 40 million personal flights would rely on the see-and-avoid concept, from which a significant percentage would take place below FL 100. Beside, a particular focus on the terminal area management is also proposed to cope with the EPATS and the traditional flights at the airport vicinities. Finally, it is also suggested to address the business model of EPATS in order to clarify whether the flights will take place by scheduling or by request, and how these will fit in the SESAR business trajectory process.

3.4 What will be impact on Airports?

The EPATS Airports General Requirements was analysed by van Schaik F. J., Hogenhuis R. H. and Waver R. from National Aerospace Laboratory, Netherlands [13]. The EPATS Study recommends and concludes on the following airport infrastructure topics [13, 22]:

**Airports:**

- It seems that Europe has enough small airports to accommodate 100,000 plus small aircraft.
- Some economic growth centres will be places to create or modernise small airports, especially in areas where other more traditional means of transport are absent. The local economy will be the driving factor because it will have direct benefit.
- Each region NUTS 2 and NUTS 3 airport will have good chances become the home base of EPATS operators. These airports need more facilities and probably Air Traffic Control to service safe flight operations during peak hours. Examples in the US demonstrate that air taxi operators could service their own airports with tower control.
- EPATS aircraft may fly under rules that are neither IFR nor VFR. Their avionics may allow self separation as if EPATS are flying VFR. Research is recommended to what traffic quantities Self separating EPATS flights can be maintained on non-towered airports.
Runways and Approach / Departure:

- One runway per airport could accommodate up to 400 movements a day, which is the average rate estimated for 100,000 small aircraft, 1000 European airfields of interest and equal numbers of home based aircraft and visiting aircraft. Noise and environment may restrict the airport to lower numbers, but from air traffic and safety reasons 400 movements per runway are certainly possible.

- Punctuality of air transport services will benefit from Autoland facilities, satellite based local area augmentation systems and extra beacons although the EPATS aircraft will probably operate rather independently from VOR, NDB and DME. Satellite based Autoland systems still need certification. Autoland systems should be available on pilot demand either by calling the local airport operator or by remote ATC operations. Autoland will need additional certification if the airfield is not controlled and if a fire brigade is not available on the spot. In conclusion research is recommended on cheap and safe Autoland facilities for EPATS aircraft.

- EPATS operations during night and low visibility need approach lighting and runway lighting, preferably systems that can be ignited on pilot demand either by local airport operators or remotely. Research is recommended on remote control of airports, including approach and runway lighting.

- Quiet airports are also places where wildlife likes to live. Safe EPATS operations require protection against wildlife and birds. It is inevitable to take care of this aspect. Local airport operators could be trained to inspect the runway short before landing. Research is recommended on animal friendly protection of runways and taxiway against bird and wildlife.

Taxiways and parking:

- The existing 2000 small European airports possess probably sufficient taxiways with sufficient quality.

- Extra parking and hangars may be needed to host the extra 100 of EPATS aircraft on average per airport. Airfields with one runway and subsequent taxiway and aprons will occupy a rectangle of land with about 1 km length and about 500 m width. This should be enough space to create extra parking stands for engined taxi in and taxi out parking of about 100 extra small aircraft.

- Taxiway guidance (markings, painting, lighting) should serve the EPATS pilots according to ICAO standards and up to a level that taxi operations can happen uncontrolled and punctually. Research on certification of moving map cockpit displays is recommended.

Air Traffic Control and flight preparations

- Airports with low traffic will not need control. In comparison much of the VFR general aviation happens on uncontrolled airfields and procedures guarantee safe operations there.

- It will save the cost of personnel if airports are controlled remotely. Applied research and development is needed for optimal ways of remote airport control.

- The availability of meteo data for flight preparation is of utmost importance. Present day European meteo data systems are already available but may need further development and certification to allow use for flight preparation.

Airport facilities:

- The runway(s), taxiways and aprons should be free of snow and ice for safe operations. Local airport operators (services) should take care of this aspect of airport accessibility and reliability. Research is recommended to predict local ice forming and snow several hours before landing. Research and development is needed how to protect runways and taxiways longer against snow and ice than present day methods.

- The EPATS aircraft should be free of snow and ice before take off. Methods could be developed
for simple removal of snow and ice on small aircraft. Off course indoor parking in heated hangars will solve the problem.
- Provision of electrical power would be needed, but if not available, EPATS aircraft could use their own battery power for starting up the engines.
- Various types of fuel should be available on small airports to prevent extra refuel stop overs. It might be futuristic but technology for in flight refuelling exist!
- Small repair and maintenance would benefit flight operational reliability.

**Passenger facilities:**
- Connectivity (car, public transport) is needed to fulfil the EPATS goal of spending as little time as possible in the transport system.
- The need for restaurants, waiting room, parking and shops will grow with the traffic.
- Simple but secure check in and customs procedures are needed; biometrics is a candidate.
- Better statistical data is needed to track the EPATS evolution and consequences for airports.

### 3.5 What are the EPATS environmental and safety aspects?

The most important environmental effects of EPATS were studied within the budgetary limits of the project. It gives also an indication of important subjects for further research. The discussion about the environment was divided into two subjects: noise and emissions.

Estimations were made on basis of the expected change in transport from car to Personal Aircraft: about 100 000 additional EPATS aircraft till 2020, resulting in about 93 extra movements per regional airport per working day and 24 000 extra flights on average per European regional airfield per year.

**Noise estimation**

Comparing different aircraft types is difficult because a lot of factors contribute to the noise production. For a good comparison all aircraft should have comparable weight (except for VLJ since these aircraft are designed to be lighter compared to other small jet aircraft), year of design (engines became quieter during the years), maximum range (the longer the range, the more fuel will be needed, which means that the weight of the aircraft increases) and number of passengers (to find the noise production per passenger).

The decision was made to base our estimations on public data for existing small aircraft close to what is expected to become EPATS aircraft.

![Table 3-2: Comparison of noise production of different aircraft types. Source [13]](image)
Table 3-2 shows these noise data for several aircraft, furthermore the maximum take-off weight (MTOW) in kilograms, year of introduction (year), maximum number of passengers (pas), range in kilometres and aircraft type (P = piston, TP = turboprop, J = jet and VLJ = very light jet) are given. The noise values (LA) are given for take-off (TO) and approach (APP); the noise values are estimations, given in dB(A). The two final columns show the take-off and approach noise levels, corrected for the number of passengers.

New aircraft with considerable weight reduction and new engines result in a reduction of the noise production. As could be expected aircraft with single piston engine have lower approach noise level. It can be concluded that using VLJ instead of regular light jets is desirable in order to reduce the noise impact. Furthermore the use of single and twin piston engines and turboprops gives better or comparable noise characteristics during the approach, while the VLJ produces less noise during the take-off. It should also be noted that use of EPATS aircraft replaces equivalent transport by car and that it reduces as such the noise produced by cars. The design of noise abatement routes and silent take off and approach procedures will reduce the noise impact.

**Emissions**

In order to make a good comparison between different types of aircraft, information about the type of engines and emission indices (amount of emitted pollutant per kilogram fuel used) for the different pollutants is needed. However, obtaining all emission indices for a set of different aircraft was outside the scope of this study. For this reason only a comparison of the specific fuel consumption (SFC) for existing look alike EPATS aircraft was made. The amount of fuel used is directly linked to the amount of CO2, H2O and SOX emissions.

The SFC in table 3-2 is given in kilograms of fuel used per passenger kilometre (kg/pas.km). Due to a lack of data the SFC values were calculated by dividing the maximum fuel weight (MFW) in kilograms by the maximum range of the aircraft times the number of available passenger seats.

Table 3-3: Comparison SFC of different aircraft types. Source [13]

The table shows that modern turboprop aircraft are much more fuel efficient than VLJs. Since turboprop aircraft have a much lower cruise speed than VLJs, they are best suited for travelling over relatively short distances. Due to higher cruising speed VLJs are better suited for transport over longer distances than aircraft with piston engines.

EPATS was also compared with the fuel consumption of cars supposed to be replaced by EPATS. It showed that the car is most fuel efficient but only if all cars are fully loaded. The load factor has a large impact on the amount of fuel used per passenger kilometre.

For this reason it is of great importance that the load factor of the aircraft in the EPATS concept is as high as possible.

Both the noise and the emission aspects of EPATS can be predicted better if more detailed and mature data become available for the EPATS aircraft of the future.
Safety and EPATS

An overview was made of safety aspects of EPATS in the areas of: aircraft manufacturing and certification, flight operations, training and qualification, airport and air traffic control, safety programs and safety oversight. The assumption was made that JAR-23 Airworthiness will be enhanced to obtain the same safety level as JAR-25.

3.6 How to define Missions Requirement for EPATS Aircraft?

The missions requirement for EPATS aircraft was conducted by Gnarowski W., Pokorski M., Zdrojewski W. from Institute of Aviation [14].
The characteristics of EPATS airplanes taking into account the forecast results CESAR and SESAR programs and American forecast.

In order to define mission requirements for further EPATS family aircrafts, wide variety of activities were performed. They could be divided into 4 steps.

1. Creation of aircraft data base. It includes over 120 constructions of normal and commuter categories (up to 19 passengers and up to 19 000 lb=8550 kg maximum take-off weight). Three types of propulsion systems are represented: pistons, turbo-props and jets. Nearly 50 parameters per aircraft have been collected.

2. The EPATS Aircraft Reference List has been created. It includes 15 constructions. The following criterion (with a few exceptions) have been taken under account for airplanes evaluation:
   - F fulfilling forecasted mission for EPATS fleet
   - F fulfilling requirements CS-23 with supplementary requirements
   - Designed or modernized after year 2000
   - Credible and confirmed specifications and performance
   - Traditional Value index including airplane Price (TVI-P)

The preliminary calculation for one selected distance 926 km (500 nm) and one utilization level (600 block hours) have been performed. Mission data based on publications.

3. Detailed analyses for 8 most promising airplane. These are:
   - Cirrus SR-22
   - Piaggio Avanti II
   - Piper Seneca V
   - BAE Jetstream 32
   - Epic Dynasty
   - Eclipse 500
   - Pilatus PC-12
   - Grob SPn.

In this step for particular airplanes either aerodynamics and propulsion characteristics have been reconstructed. Also flight mechanics model was created. Such a way is flexible and full of potential, however it is also more time consuming. 4 distances, 3 flight levels per distance and annual utilization levels from 200 to 2000 block hours have been analyzed.

4. EPATS aircraft requirements. Using data obtained during previous steps and taking under account outer sources such as CESAR, SESAR, American forecasts, a requirements proposal has been created. In fact it is not a full conceptual design. That is because EPATS program is too small to manage such an effort.
Results of comparison of future EPATS aircraft and reference 8 constructions shows in sequence: The Block Speed – Fig. 3.9 and Fig. 3.10, The Direct Operating Costs – Fig. 3.11 and Fig. 3.12, The Specific Fuel Consumptions – Fig. 3.13 and Fig. 3.14.
The speed of future jet and normally aspirated single-piston are the same as references. New large t-prop is a little quicker while turbocharged pressurized piston is significantly quicker which places it between pistons and turbo-props.

![Fig. 3.11 Direct Operating Cost – reference aircraft. Source [14]](image1)

![Fig. 3.12 Direct Operating Cost – future aircraft. Source [14]](image2)

The Direct Operating Costs of new airplanes are significantly lower than reference’s. Jets are the most expensive of all. The cheapest is large (19 pax.) turbo-prop.
The Specific Fuel Consumptions of new airplanes are significantly lower than reference’s. New aircraft are of course better – cheaper and more fuel efficient. The brief summary of comparison is shown in Table 3-4.

Table 3-4: EPATS aircraft comparison: reference vs. future. Source [14]
The analyses show that affordable personal transport is real. However, several actions must be taken to reach this goal:

1. Airplanes must be fitted to needs in terms of their
   - Size (range, comfort, speed)
   - Performance (airport accessibility, operating cost, fuel consumption)
   - Available airspace (flight performance)

2. Operating must be optimised (to reduce DOC):
   - High utilization intensity
   - Low Indirect Cost fraction

3. Technical and production improvements are needed
   - Lower design, production and operating costs (e.g., excepted CESAR results)
   - Avionics needed to fly into future airspace (SESAR requirements)

3.7 What should be Roadmap and recommended R&D for next Frame Programs and Strategic Research Agendas?

The EPATS Recommendations for Framework Program and Roadmap was elaborated by the all participants of the project in charge of Piwek, K. and Baron A. from Institute of Aviation [22].

The EPATS Study project can be the beginning of a long term, wide and multidisciplinary international transport program for Europe, which is only possible to accomplish with the support of the EU Commission, Member States and local authorities and, also, by cooperating with business and research entities among which, especially, aviation industry and its research and development branches.

It is crucial to solve the transport problems followed by the need of action and research in various sectors, particularly:

A. Space and population mobility management. It is especially important to possess deeper knowledge about unused transport infrastructure, namely airports and airfields, and about population mobility entailing flow intensity and structure among regions and cities (outlaying the main transport networks) national as well as European.

B. Environmental protection. Despite much of research in this area, still, there is a shortage of credible and detailed results of comparison analysis between cars and aircraft concerning the scale of negative impact on the environment and natural resources.

C. Air traffic control and management systems. New, appearing technologies need to be applied and adjusted to future needs of air traffic enlarged by the EPATS introduction. In particular, SESAR program realization is important.

D. Airport infrastructure. It is important to prepare a coherent classification and database of all European airports and airfields, which will be used for airspace management. Furthermore, a European strategic small and medium airports development and modernization program has to be formulated adapting airports to new ATM-ATC and CNS technologies and to the needs of regions.

E. Research and development of the EPATS aircraft. Main objectives will focus on further improvement of small aircraft characteristics simultaneously lowering costs of production and operating. All aviation domains require a wide research: from modelling and aerodynamics through production technologies and pilot training including. Efficient use of the results of the research is conditioned by their integration and application in particular aircraft design project, which then have to be tested in flight. Consequently, research programs should strictly pertain to aircraft development plans.

F. General aviation propulsion. Shortage in production and development of small aircraft engine for propeller driven as well as jet aircraft is a significant problem for the development of general aviation in Europe. The main questions regarding general aviation development in the EU, including the EPATS, is: should European aviation industry rely on its own
production, followed by initiatives in the sector, or accept import strategy from the USA? The European Commission should answer to this question of strategic nature (basing on analysis of engine industry), because it is corresponding to one of the most crucial challenges given to the European aviation: to become competitive at the World market, especially towards North America.

G. General aviation equipment. In the area of electronic equipment, the problem is similar to propulsion. Although the European market exists, most of the equipment is imported from the USA due to lower prices. Therefore cockpit production is very expensive in relation to other parts. Unification of equipment and cooperation with car industry could be a possible solution.

H. Aircraft production. One of the main objectives is to lower the costs of production (2-3 times in 20 year). It is only possible in the large serial production system extended by a deeper cooperation among aviation industry companies. It is assumed that the consolidation of European general aviation industry will advance, basing on the European Technology Platform, for which European Commission projects a new instrument entitled Joint Technology Initiative.

I. Transport services. For cities and region functioning the EAPTS serves a social role (i.e. high speed transport, when other modes are unavailable) as well as behavioural control role in the direction to reduce interregional and international car travel. The state should be interested in high speed, efficient, operating mode of transport reflecting the national needs. As a public good, air transport should be clearly legislated in the frame of regulations of the system. The most important elements of the system are regulations concerning the EPATS organizers, rules of operators access and rules of public financing. A base for organization of the EPATS in a region should be an adequate, local, long-term transport plan relying on previous mobility and travellers flow research and supported by cost-benefit analysis.

J. Regulation

**Major investigation elements of the EPATS R&D vision**

The small aircraft technology R&D which address the EPATS aircraft should explore all areas in which advanced technology application could provide improved passenger acceptance, increased safety, decreased operating costs and better environment. Although some improvements in future EPATS aircraft can be achieved merely by utilizing available technology it is clear, that to meet the EPATS objective new advances in technology have to be achieved. Some topics listed here underneath are realized as part of SESAR and CESAR Program.

**Infrastructure**

„Smart” airports with higher utility and safety in more weather conditions, along with free flight procedures for expanded AS capacity, and airport utility, including:

- Satellite navigation approaches to all landing areas, without requirements for control towers and radar, and fully digital flight, traffic, and destination information systems.
- Flight Information Services (FIS), broadcast by terrestrial or satellite systems.
- Traffic Information Services (TIS), including Automatic Dependent Surveillance, broadcast by aircraft, terrestrial, or satellite systems.
- Destination Information Services (DIS) for intermodal connectivity, and vehicle and operator/passenger services, via terrestrial or satellite systems.
- Near-all-weather operations at non-towered airports without radar coverage.
- 3,500 to 5,000 foot runways, with marking and lighting.
- Airports within a 15 minute drive of communities served.
- Safety services.
Aircraft

Aircraft technology objectives are planned to achieve advancements in affordability, safety, ease-of-use, airport utility, and includes the following:

- Simplified and intuitive flight controls, including decoupling.
- Envelope limiting (Active load control) and ride smoothing concepts.
- Active flow control for improved cruise & low speed performance. The objective is to use control surfaces of an a/c wing to adapt its configuration to the various phases of the flight mission for increased efficiency and to gust and manœuvres for reduced loads.
- Aircraft fineness ratio and lifting enhancement (higher cruising speed – lower stalling speed).
- Useful weight to takeoff weight enhancement. Multi layer/multi-function architectures should be used to decrease the negative impact on weight deriving from ancillary functions requested to the structure (lightning protection, electrical grounding, thermal insulation).
- Aircraft fineness ratio and lifting enhancement (higher cruising speed – lower stalling speed).
- Airframe modular design, highly integrated processes, one shot process for example, by manufacturing a one-piece fuselage section.
- New concept configuration (plan form) to accommodate other systems integration.
- Crashworthy airframes.
- Comfort improvement (ride quality, noise level, cabin space, convenience).
- Minimum maintenance labour.
- Automotive synergies in manufacturing, including automation in integrated composite structures.
- Per passenger cost operations competitive with automobiles on day trips of 300 miles or more.

Aircraft systems

- Highway in the Sky (HITS) graphical flight path operating systems, including graphical weather, navigation, traffic, terrain, and airspace depictions.
- Hazardous weather and ice-tolerant avoid and exit operating procedures.
- Advanced pilot vehicle interface systems, including artificial/synthetic vision for “electronic” visual meteorological conditions.
- Satellite-based communications, navigation, and surveillance for ubiquitous flight and destination information systems.
- On-board access to travel information for seamless air/ground and mass/personal transportation intermodal connectivity.
- Mission management and trajectory control.
- Improve safety, handling, and ride quality while reducing pilot workload and maintenance costs. Potential advanced-technology applications include fly-by-wire or fibre-optics controls, gust-load alleviation technologies, low-cost icing protection, and improved navigation and guidance equipment.
- One Network of “Sensors & Actuators” to Actively Manage the Airflow and Loads Across the Whole Flight Regime of the Product.
- Embedded health-monitoring systems that will allow the airplane to self-monitor and report maintenance requirements to ground-based computer systems.
Aircraft propulsions

- New engines, burning unleaded fuel, with single-lever power controls, intuitive diagnostics, and longer TBOs.
- Next generation propulsion systems, including non-hydrocarbon and hybrid concepts.
- Quiet non-hydrocarbon propulsion, low emissions combustion system & alternative fuel.
- New small turbine and compression-ignition engines. Acquisition price: Piston < 10 000 €, Turbine < 100 000 €.
- Advanced propellers.

Training

Simplified and affordable pilot training through advanced technologies, including:
- Unified instrument-private pilot training curriculum.
- On-board, embedded training capabilities.
- Training time and cost commensurate with Public School implementation of “Fliers education” along with Drivers education.
- Internet-based, and simulation-enhanced training systems.
- Pilots are able to maintain all necessary competencies and proficiencies for EPATS Highway in the Sky system flight operations, within constraints imposed by typical professional and personal time schedules.

The EPATS development phases

The EPATS development consists of 4 phases:
Phase I - Studies and analyses involve

Table 3-5: EPATS phases development timetable. Source [22]
4. CONCLUSIONS

To summarise this short description of the EPATS STUDY project we conclude:
1. Results of the EPATS STUDY project shows that it is possible to replace car trips on a distance longer than 300 km by personal air transport based on small aircraft and small local airports in Europe.
This statement is confirmed by the following arguments:
- High density Airport Network (about 1,270 airports and 1,300 landing fields).
- New ATM Technology based on SESAR Programme.
- Technically Advanced Aircraft as the result of realized (CESAR) and future European Programme.
- European Synergy Possibility in European Union.
- Increasing Mobility and Social Needs based on the forecast demand.
2. In order to provide competitiveness and meet the customer needs of the EPATS it is necessary to activate the international transport program for Europe. The program should ensure the European GA and ATM manufacturers world leadership in this line of products.
BIBLIOGRAPHY