Scientific Bulletin
of the Politehnica University of Timisoara, Romania

TRANSACTIONS on ENGINEERING AND MANAGEMENT

Volume 5, Number 1, 2019

Greening the Urban Transportation. A Debate on the Solutions of the Flying Car

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Abstract – Facing climate change challenges, many local governments worldwide became active deploying Green Urban Transport Policies (GUTP). By doing so, their central objective is to curb CO2 emissions and manage the latent tension between accessibility, mobility and quality of life. However, in some cases, those policies indirectly foster the localized development of cleantech innovations. In this paper we analyze the urban Europe state on cities, towns and suburbs based on the available data from the Report of 2016. Then there will be presented a study for the introducing of the flying car as an innovative solution from the electric one to green the cities' transportation.

Keywords: Green transportation, innovation; urban transport policy, airmobile, flying car

I. INTRODUCTION TO GREEN URBAN TRANSPORT POLICIES AND CLEANTECH INNOVATIONS

During the last decade, a "green turn" took place in the policy agendas of many cities worldwide (Betsill and Bulkeley, 2007). Cities realized that climate change can seriously endanger their very own sustainability and development prospects. Among manifold efforts, important initiatives have been focusing on decoupling transport from urban development (Bertolini et al, 2008), i.e. on reducing carbon emissions caused by urban mobility without endangering but improving urban accessibility, quality of life and growth (Carvalho et al., 2012).

Examples are the introduction of several green urban transport policies (GUTP) like the imposition of tight standards on buses' emissions, free parking and lower local taxes for "green" cars, procurement of cleaner bus fleets, but also direct support to the use and diffusion of renewable and cleaner fuels. GUTP are usually part of what in EU-jargon are known as Sustainable Urban Transport Plans (European Council, 2006), i.e. specific measures taken by local authorities to promote low CO2 emission and energy-efficient vehicles in order to reduce greenhouse gas emissions (Carvalho et al., 2012).

Pioneer cities in Northern Europe have been deploying related policies for already some years now. Moreover, as recently observed by Mingardo et al (2009), whether in an intended or unintended fashion, some of those policies seem to be linked with the development, also at the local and regional level, of several so-called cleantech innovations (Cooke, 2008), e.g. new vehicle engines, improved ways of producing and using low carbon fuels, new materials and engineering systems (Carvalho et al., 2012). It is not the first-time urban transport policies are used to accomplish policy objectives in other realms, like job creation, investment attraction and social inclusion (Blauwens et al, 2006). However, the relation between GUTP and the localized development of Page 3 of 39 cleantech innovations is still an unexplored and intriguing field, for several reasons.

In this context, the present paper there will be analyzed the urban Europe state on cities, towns and suburbs based on the available data from the Report of 2016. Then there will be presented a study for the introducing of the flying car as an innovative solution from the electric one to green the cities' transportation.

II. AN OVERVIEW OF SOME STATISTICS ON URBAN EUROPE

Throughout history, cities have been at the centre of change, from the spread of Greek and Roman civilizations, through the Italian renaissance period, to the industrial revolution in the United Kingdom (Kotzeva and Brandmüller, 2016). Over time, Europe has slowly transformed itself away from being a largely rural, agricultural community and according to the

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United Nations (as provided by the data of the United Nations which are based on national definitions which may undermine comparability in some cases; note these definitions are somewhat different to those employed elsewhere in this publication, based on a harmonized data collection exercise conducted by the EU), more than half of the European population was living in an urban area by 1950; this was also the case in North America and Oceania (Figure 1).

By contrast, more than 80% of those living in Africa and Asia in 1950 inhabited rural areas. While the pace of urbanization in these two continents subsequently accelerated, in 2015 most of their populations, Africa (59.6%) and Asia (51.8%), continued to live in rural areas. Almost three quarters of the European population lived in an urban area in 2015, while even higher shares were recorded in Latin America and the Caribbean (79.8%) and North America (81.6%). These different levels of urbanization show that, at a global level, it was only during the last decade that the total number of people living in urban areas overtook those living in rural areas (Kotzeva and Brandmüller, 2016).

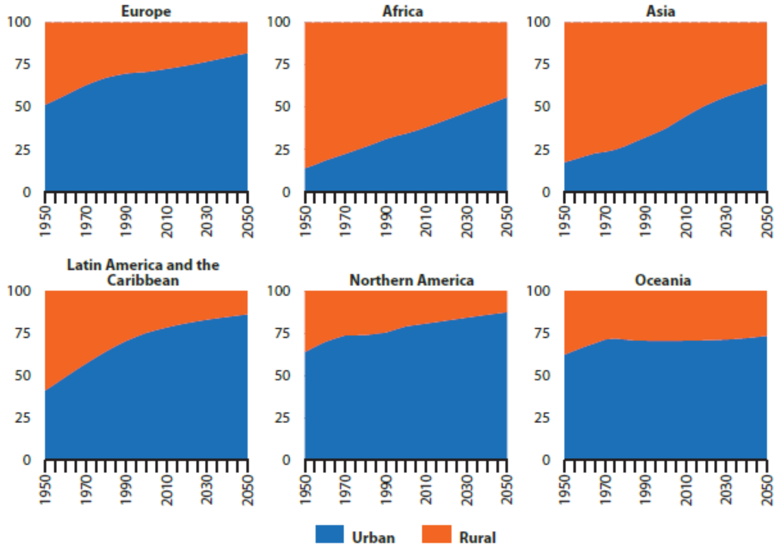


Fig. 1 Share of urban and rural populations, 1950–2050 (% of total population)

Source: World urbanization prospects — United Nations, Department of Economic and Social Affairs, Population Division (2014)

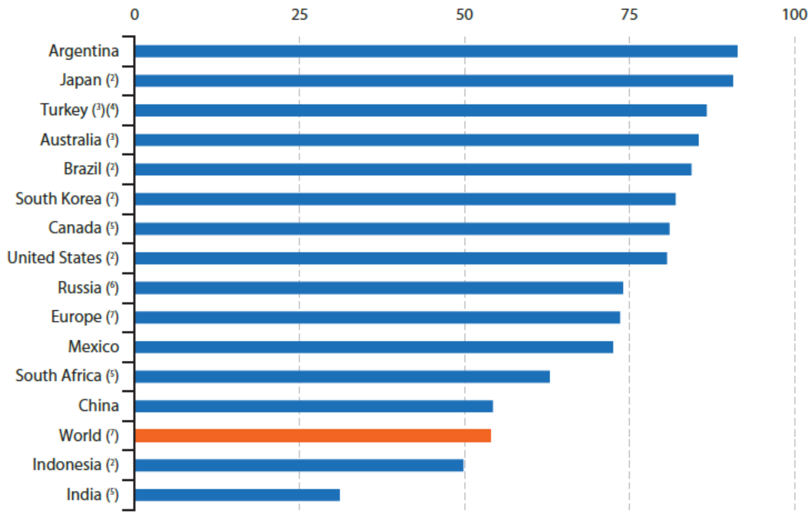
According to the United Nations (World urbanization prospects (2014)), approximately two thirds of the world's population will be living in an urban area by 2050. This rapid pace of change is projected to be driven primarily by changes in Africa and Asia, as the focus of global urbanization patterns continues to shift towards developing and emerging economies. The pace of change in Europe will likely be slower, with the share of the population living in urban areas projected to rise to just over 80% by 2050 (Kotzeva and Brandmüller, 2016).

Aside from the considerable differences in shares of urban populations across continents, there are also widespread differences between countries. Figure 2 provides information on the share of the urban population in 2014, which peaked (among those countries shown) in Argentina and Japan (2010 data) at over 90 %. Just over half (54.3%) the population of China was living in an urban area in 2014, while the urban population in India (2011 data) accounted for less than one third (31.1%) of the total number of inhabitants. For a more detailed analysis of global changes in the degree of urbanization (based on the development of a new global population grid), please refer to The State of European Cities report, recently released by the Directorate-General for Regional and Urban Policy (Kotzeva and Brandmüller, 2016).

As mention by (Kotzeva and Brandmüller, 2016), the spatial distribution of cities varies considerably: Europe is generally characterized by a high number of relatively small cities and towns that are distributed in a polycentric fashion; this reflects, to some degree, its historical past which has led to a fragmented pattern of around 50 countries being spread over the continent. By contrast, in some parts of Asia and North America, a relatively high proportion of the urban population is concentrated in a small number of very large cities.

The United Nations defines a megacity as having in excess of 10 million inhabitants. According to this criterion, there are only two megacities within the European Union (EU), those of Paris and London. Figure 3 presents a list of the top 30 global agglomerations in 2015, with all but one of these (the Peruvian capital of Lima with 9.9 million inhabitants) being classified as a megacity. Of the 29 megacities in 2015, Tokyo (Japan) was the world's largest city, its agglomeration numbered 38.0 million inhabitants. It was followed by Delhi (India) with 25.7 million, Shanghai (China) with 23.7 million, Mexico City (Mexico), Mumbai (India) and São Paulo (Brazil) each with around 21 million, and Beijing (China) and Osaka (Japan) each with just over 20 million inhabitants. The populations of Paris and London were, in global terms, relatively small, as each had less than 11 million inhabitants; in other words, they were less than one third the size of Tokyo. There were two other European cities in the ranking, the Turkish city of Istanbul (14.2 million inhabitants) and the Russian capital of Moscow (12.2 million inhabitants) (Kotzeva and Brandmüller, 2016).

Urban areas in the EU are often characterized by high concentrations of economic activity, employment and wealth with the daily flow of commuters into many of Europe's largest cities suggesting that opportunities abound in these hubs of innovation, distribution and consumption. However, cities in the EU are also characterized by a range of social inequalities, and it is commonplace to find people who enjoy a comfortable life living in close proximity to others who may face considerable challenges, for example, in relation to housing, poverty or crime — herein lies the 'urban paradox'. These polarized opportunities/challenges are often in stark contrast, as patterns of inequality in cities are generally more widespread than those observed for countries (Kotzeva and Brandmüller, 2016).



(1) United Nations data are based on national definitions; as such there may be a discrepancy with respect to the Eurostat data used elsewhere in this publication.

(2) 2010. (5) 2011.
(3) 2013. (6) 2012.
(4) Estimate. (7) 2015.

Fig. 2 Share of urban population, 2014 (% of total population)

Source: Demographic yearbook of the United Nations, Department of Economic and Social Affairs, Population Division (2014)

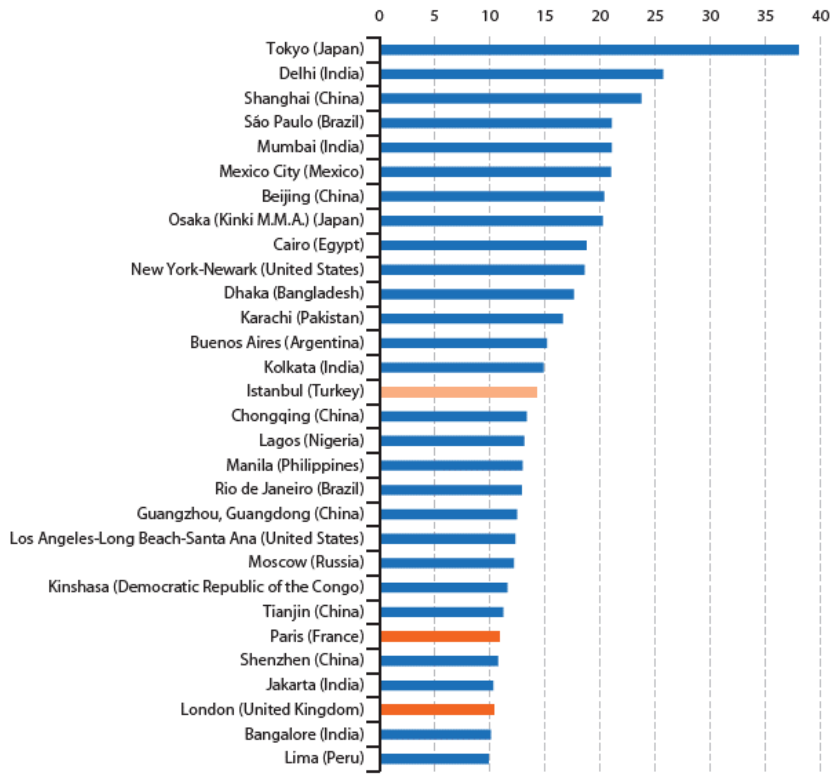


Fig. 3 Top 30 global urban agglomerations, 2015 (millions) (Projections of United Nations data are based on national definitions; as such there may be a discrepancy with respect to the Eurostat data used elsewhere in this publication.

Source: World urbanization prospects — United Nations, Department of Economic and Social Affairs, Population Division (2014)

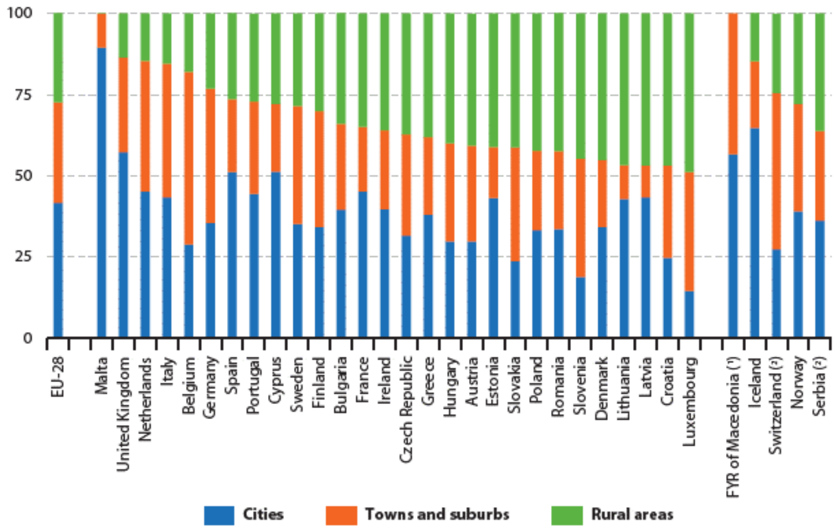


Fig. 4 Distribution of population, by degree of urbanization, 2014 (% of total population)
Source: Eurostat (online data code: ilc_lvho01)

There are considerable differences in the size and spatial distribution of urban developments across the EU Member States: for example, the Netherlands is characterized by a high level of population density and a high share of urban land use, whereas in most of the Nordic Member States and the interior of the Iberian Peninsula much lower levels of urban land use are commonplace. Each of the EU Member States has a distinctive history of territorial developments: for example, centrally planned economies and the lack of a market for land/property resulted in compact urban developments across most eastern and Baltic Member States. Since the middle of the last century, most of Europe has been characterized by spreading cities and increased population numbers, with people choosing to move out of inner cities to suburban and peri-urban areas (hybrid areas of fragmented urban and rural characteristics); this has resulted in the divide between urban and rural areas becoming increasingly blurred (Kotzeva and Brandmüller, 2016).

Capital cities have the potential to play a crucial role in urban developments within the EU; they are often hubs for competitiveness and employment and may be drivers of innovation and growth, as well as centres for education, science, social, cultural and ethnic diversity. A comparison of European cities' economic performance indicates that the major cities, and, the metropolitan regions of EU capital cities, generally outperform the rest. In some EU Member States, capital cities exert a form of "capital magnetism", through a monocentric pattern of urban development which attracts investment/resources, so these are concentrated in the capital. Whether such disparities have a positive or negative effect on the national economy is open to debate, as capital cities that dominate their national economies may create high levels of income and wealth that radiate to surrounding regions and pull other cities/regions up (Kotzeva and Brandmüller, 2016).

Smart cities may be defined as those which seek to address public issues via ICT-based solutions involving multi-stakeholder partnerships. Smart cities have the potential to improve the quality of life: they are innovative, making traditional networks and services more efficient through social innovation and the use of digital technologies, creating more inclusive, sustainable and connected cities for the potential benefit of their inhabitants, public administrations and businesses. Smart cities are generally characterized by very high concentrations of people having completed a higher education, while statistics on innovation activity confirm that they also record a high propensity to patent (Kotzeva and Brandmüller, 2016).

While urbanization has the potential to raise wealth, it often does so accompany by pollution or other forms of environmental damage. Indeed, global patterns of urbanization have created some of the biggest environmental challenges facing the planet. However, it is increasingly recognized that compact cities are resource-efficient ways for people to live and for businesses to exist, as proximity and the pooling of resources provides potential efficiency gains.

"Green cities" combine higher levels of efficiency, with innovative capacity and reduced environmental impact, addressing issues like congestion through the implementation of, among others, road charges and integrated public transport systems. This 'greening' of cities has the potential to reduce pollution and the harm that may be done to an individual's health, for example, by reducing traffic, promoting the use of cleaner or renewable fuels, encouraging cyclists/pedestrians, or introducing more green spaces (Kotzeva and Brandmüller, 2016).

In keeping with many aspects of urban development, tourism is a paradox, insofar as an increasing number of tourists in some towns and cities have resulted in congestion/saturation which may damage the atmosphere and local culture that made them attractive in the first place; Venezia (Italy) and Barcelona (Spain) are two of the most documented examples. Furthermore, while tourism has the potential to generate income which may be used to redevelop/regenerate urban areas, an influx of tourists can potentially lower the quality of life for local inhabitants, for example, through: higher levels of pollution and congestion; new retail formats replacing traditional commerce; increased prices; or increased noise (Kotzeva and Brandmüller, 2016).

Aside from attracting (potential) business investment, cities also need to attract individuals: this can be done through the quality of what they can offer in terms of education, jobs, social experiences, culture, sports and leisure facilities, environment, or urban safety. The results presented by (Kotzeva and Brandmüller, 2016) suggest that a high proportion of Europe's ageing population lives in relatively small towns and cities (with a preference to live on the coast), whereas younger people are more likely to live in the suburbs within proximity of capital or other large cities.

Employment rates among women were somewhat higher in cities than they were in towns and suburbs or rural areas. Indeed, female participation tended to influence overall employment rates far more than male rates and explained, for example, why relatively low employment rates were recorded in many (particularly rural) parts of southern Europe. Otherwise, one of the recurring themes in relation to urban labor markets is commuting, which results from increased levels of mobility. Lengthy commutes to work may be associated with increased congestion, as well as environmental and economic costs (for individuals, local authorities and enterprises). The share of people who use public transport to get to work is generally much higher in the EU's largest cities, while in provincial cities, towns and suburbs the use of private motor vehicles tends to be the principal mode of transport for traveling to work (Kotzeva and Brandmüller, 2016).

Some city-dwellers live in urban neighborhoods that are characterized by overcrowding and/or poor-quality housing, a lack of social housing and low levels of home ownership. Such issues may lead, among others, to lower life chances, health inequalities, increased risks of poverty and environmental risks. In absolute terms, the smallest dwellings in cities of the EU were located in the Baltic Member States and Romania (an average of less than 60 m² per dwelling) while the largest were located in Cyprus, Belgium, Luxembourg and Portugal (an average of more than 100 m² per dwelling); those city-dwellers enjoying the largest amounts of living space were usually living in provincial (rather than capital) cities. Indeed, it was commonplace to find that the capital city had the highest share of flats and the lowest share of houses in its total number of dwellings, likely due, among others, to the cost of land, a lack of space for new property developments, a range of alternative land uses competing for space (business and commercial property), and a high level of demand from those wishing to live in the capital city. The highest shares of one-person households among EU cities were recorded in four capitals located in western and northern Europe (Berlin, Helsinki, Amsterdam and Copenhagen) with almost half (49.0%) of all households in Berlin composed of single persons (Kotzeva and Brandmüller, 2016).

III. THE ANALYSIS OF THE EXISTING SOLUTIONS OF FLYING CARS

A. Electric energy used for greening transportation

As recently debated in by Gilbert and Perl (2018) their assessment of numerous alternatives to oil as a transport fuel concludes that, as oil depletion progresses, only electricity could reasonably power acceptable levels of land transport. Authors sustained that oil products will be increasingly devoted to fueling marine transport and aviation.

Furthermore, electricity is an advantageous energy source for land transport in every respect except one: it cannot be stored on board vehicles in acceptable quantities. This disadvantage can be overcome by delivering electricity to vehicles while in motion. Grid-connected electric vehicles have provided transport for at least as long as vehicles powered by internal combustion engines. As electric trains, streetcars, and trolleybuses, they provide most public transit in most of the world's major cities. Moreover, Gilbert and Perl (2018) anticipate substantial expansion in the use of this kind of vehicle, with development and some deployment of unfamiliar systems including trolley trucks and personal grid-connected vehicles.

Electric vehicles offer the important advantage of independence from how their fuel is produced. Electricity generation can transition among a variety of sources, from coal generation to solar thermal generation, without changes in the transport system. Electric traction is well suited to the necessary transition from non-renewable to renewable energy (Gilbert and Perl, 2018). Increased use of electricity could bring greater reliance on coal generation. We demonstrate that such reliance can be avoided through ready reduction in electricity consumption for other purposes and development of numerous opportunities for renewable generation (Gilbert and Perl, 2018).

According to the research of (Gilbert and Perl, 2018), the key feature of the transport redesign proposed for China and USA (important actors and countries for green transportation issues) is massive expansion of electrically powered land transport. Movement of people in the USA, for example, would be 30% electrically powered in 2025 compared with well under 1% today. Oil products would still fuel most motorized transport in the USA and China in 2025, but the transition to electric traction would be well under way and would continue for decades beyond 2025.

From these brief considerations, the transportation sector faces the challenge of meeting growing demand for convenient passenger mobility while reducing congestion, improving safety, and mitigating emissions. Automated driving and electrification are disruptive technologies that may contribute to these goals, but they are limited by congestion on existing roadways and land-use constraints. Electric vertical takeoff and landing aircraft (also known as, Vertical Take-Off Landing, VTOL) could overcome these limitations by enabling urban and regional aerial travel services (Kasliwal et al., 2019). In addition, they could be the solution for a sustainable transport in urban areas of tomorrow.

B. An inventory of flying cars

The Gyrocopter PAL-V One (Figure 4) was developed by a Dutch company founded in 2007. It is a three-wheel VTOL (Vertical Take-Off Landing) gyrocopter with two seats, a fuel engine of 160 kW equivalent with 217 HP. This is the first model designed and produced for the PAL-V. The maximum weight for take-off is 910 kg and the price of approximately 499.000€.

Pal-V Liberty Sport (Figure 5) is the second model generation designed and developed from PAL-V. It flies up to 3500 m altitude, and it has 400 km flight autonomy with a fuel consumption of 26 l/h. The fuel tank is 100 l and it used gasoline E95, E98 or E10. For driving this model, you need a flight license achieved after 40 hours training. The price is approximately 299.000€.

Fig. 4 Gyrocopter PAL-V One (Perez, 2014)


Fig. 5 Pal-V Liberty Sport (CarAndBike Team, 2018)


Fig. 6 AeroMobil 3.0 (Aeromobil, 2014)


Fig. 7 AeroMobil 4.0 (Aeromobil, 2018)

The AeroMobil VTOL 3.0 (Figure 6) has been developed by a private start-up founded in 2010 in Bratislava, Slovakia. This was the first model for testing, it has crushed during the flight tests, but the company continues with the next models. This is a STOL (Short Take-Off and Landing) vehicle and in back there are 25 years of development. Next model AeroMobil VTOL 4.0 (Figure 7) is available for order and buying but the price starts from 1.000.000 Euro. It has a safety system with parachute, airbags and the last carbon fiber type structure. It has a take-off weight of 960 kg, fuel engine of 224 kW (304 HP) and an autonomy driving option. Three minutes is the necessary time for switch the car in flight mode. The release design will be available in 2020. AeroMobil 5.0 (Figure 8) it is the first e-VTOL, full electric and vertical take-off and landing. Starting at 1.5 million Euro the model it is the last concept and the goal was to not see the difference between a normal car on the street and this flying car. It has four seats with two strength electric engines, the release is in 2025.

Terrafugia (Figure 9) has been created by five MIT graduate students that establish a company with the same name in 2006. They won the contest MIT 100 k Entrepreneurship 2006. It is an electric hybrid flying car, STOL variant with a price starting with 279.000$. Autonomy flight of 400 km and it requires a license flight of 40 hour of training. This is concept in the development phase, estimation release over 8 years with two electric engine of 600 HP, one back fuel engine of 300 HP and autonomy of 800 km. Cruise speed of 322 km/h.

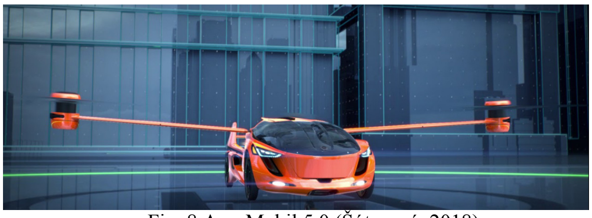


Fig. 8 AeroMobil 5.0 (Šútorová, 2018)


Fig. 9 Terrafugia Transition (Duncan, 2012)


Fig. 10 Terrafugia TF-X (Hirschberg, 2018)

Fig. 11 TF-2 Lift + Push (Lavars, 2018)

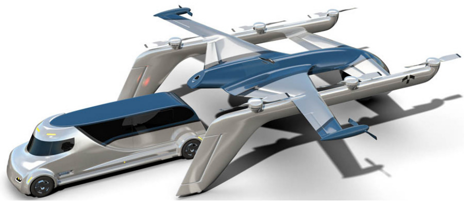


Fig. 12 TF-2 Lift + Push and Truck (Lavars, 2018)

Fig. 13 Volocopter 2X (Suton, 2019)

The next Terrafugia concept (Figure 10) it is a two parts system. The flying part it is call Lift + Push and it is the cabin flight with four seats for passengers. Always there is a driving person.

The model TF-2 Lift + Push flight cabin is separated when take-off by a truck which takes it and switch with a new cabin with four passengers ready to fly. The ticket's journey is around 380 - 420$ (Figure 11 and Figure 12).

Volocopter air taxi has been developed by a German group ready to launch an air taxi fleet in 2020 in Dubai, Singapore and Berlin. The Volocopter transport two passengers (160 kg) and it has 18 electric rotors for flying (Figure 13).

Black-fly (Figure 14) is an electric model built by the Opener, Ontario in Canada. It is flying with one passenger at a speed of 100 km/h for 30 minutes.

Fig. 14 Black-Fly (Alger, 2018)

Fig. 15 Lilium (Withers, 2019)

Fig. 16 Verde-Go PAT200 (Warwick, 2017)

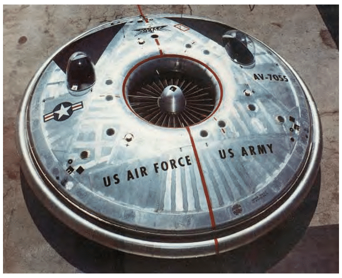


Fig. 17 Avrocar VZ-9 (Fedrigo et al., 2015)

Fig. 18 Bell Nexus (Zart, 2019)

Fig. 19 City Airbus (Cohen, 2017)

Lilium is an electric concept for urban transportation with an autonomy of 300 km in 60 minutes (Figure 15). First flight was made in 2019 and it is planning to come into use in 2025.

Verde-Go Aero PAT200 (Figure 16) is an electric-hybrid VTOL for commercial and urban transport. Cruise speed is 240 km/h with an autonomy between 30 and 60 km and a weight lift of 227 kg.

Avrocar VZ-9 (Figure 17) was a secret military project developed by the USA and Canada between 1952 – 1961. The Romanian engineer and scientist Henry Coanda contributed with the flying principle for this saucer. The diameter is 5.5 m, the thickness is 1.1 m and the weight of 1944 kg.

Bell Nexus (Figure 18) was developed by Bell who presents his concept at CES Las Vegas this year and with his flying car will complete the taxi fleet developed by Uber in 2020 for cities like Dubai, Dallas, LA, Tokyo, Rio de Janeiro, Melborne and Paris.

Citi Airbus, depicted in Figure 19, uses 8 rotors, four battery with a nominal voltage of 800 V, and four pair of propellers.

C. Conclusions about the existing solutions of the flying car

The transportation sector faces the challenge of meeting growing demand for convenient passenger mobility while reducing congestion, improving safety, and mitigating emissions. Automated driving and electrification are disruptive technologies that may contribute to these goals, but they are limited by congestion on existing roadways and land-use constraints. Electric vertical takeoff and landing aircrafts (VTOLs) could overcome these limitations by enabling urban and regional aerial travel services. VTOLs with tiltrotor, duct, and wing designs, such as the GL-10 prototype designed by NASA (Barnstorff, 2017), combine the convenience of local takeoff and landing like a helicopter with the efficient aerodynamic flight of an airplane. Although smaller and larger designs are possible, several companies are considering craft that can carry four to five occupants (Datta, 2018). Initially, these VTOLs would likely be piloted taxi services, but with advances in aviation regulation and sensor and processor technology, could transition toward future automated control (Amazon Web Services, 2018).

Electrification is a propulsion strategy for improving the sustainability of both aerial and ground-based transportation modes, owing to the superior efficiency of electric powertrains compared with combustion engines. One critical efficiency enabler for flying cars is distributed electric propulsion (DEP), which uses physically smaller, electrically driven propulsors (Kim et al., 2018). These propulsors can be used with greater flexibility to leverage the benefits of aero-propulsive coupling and improve performance compared with more traditional designs. This enables aerodynamically optimized designs, such as articulating propellers and high aspect-ratio blown wings, which allow efficient VTOL energy performance and significant noise reduction. DEP could facilitate VTOL success in the urban aerial taxi space, where conventional helicopters or vertical-lift aircraft have struggled.

In principle, VTOLs can travel the shortest distance between two points, and their relatively modest sizes would enable near point-to-point service. Conversely, road networks are much less direct and consequently have an associated circuity factor, defined as the ratio of the shortest network route to the Euclidian distance between two points (Ballou et al., 2002). This benefit of VTOL aerial systems could favor energy and travel-time performance, particularly in locations with congested and circuitous routing. High VTOL cruise speeds could reduce travel time further. Significant time savings and associated productivity gains could be a key factor in consumer adoption of VTOL transportation. Details regarding the role of flying cars in sustainable mobility have been shown by the work of Kasliwal et al. (2019). Furthermore, the flying cars can be parked conveniently than other conventional aircraft and it does not need much space to take off and land. They can meet the demands of fast travel between two cities with a typical car journey of about 3-5 hours, which can bring great convenience to the users.

IV. CONCLUSIONS AND FINAL REMARKS

The urban areas overcrowding problems have been considered challenges for the automotive industry. Traffic congestion, pollution, crashes, and delays are still a major problem in many large metropolitan areas. Multiple ideas have been suggested to overcome these problems, ranging from safety systems that would lead to a reduction in severe injuries to road infrastructure that could help cope with traffic congestions. The incorporation of advanced and intelligent technologies in transportation systems could certainly lead to significantly better transportation systems and enhance transportation services. Hopefully, new technologies could contribute to the transport challenges we are facing today. While several technologies might look unrealistic, other are developed or used (e.g., autonomous vehicles, privately owned flying cars) (Ben–Haim et al., 2018).

According to popular visions, flying cars will revolutionize personal transportation, providing solutions to various problems, e.g., traffic congestions, redundant infrastructure development or environmental damage (Rajashekara et al., 2016). However, despite technological feasibility, it is highly unlikely that this technology will be introduced to the market soon due to high safety risks, perceived low market potential, and legal aspects (Seidel et al., 2005; Rajashekara et al., 2016; Ben–Haim et al., 2018).

Flying car is a future today but it will become a usual car in the next 20 years considering the moving problems of the crowd cities (urban agglomerations). So, based on the references and the consulting companies' studies, electric cars will be a usual car over 5 to 10 year, in order to satisfy everyone's, need to get to their destination quickly.

The fly experience it is also a pleasure when you know it's safe. It is a challenge to design a flying car but also a huge success when you succeed. The technical solution analyzed in this study research demonstrate that the idea could is feasible and is perfectly achievable. Even if, for the moment, there are only demonstrative models built-up we estimate that in next 20 years the use of flying cars it will be a reality. However, the realization of this flying machine is also dependent on the development of other technologies and still has large number of challenges to overcome. For example, in order to improve its endurance, a battery with higher energy density is needed. It is hoped that such a concept can provide further motivation for aircraft designers today and in the future.

The study has recognized (based on the literature review and the information available on companies and professional organizations web pages) that flying cars can green the cities and this is not so distant future. Despite these aspects, there are many questions that need to be addressed to assess the viability of VTOLs including cost, noise, and societal and consumer acceptance. Our analysis has targeted the environmental sustainability of VTOLs compared with ground-based passenger cars because few studies of VTOLs' potential climate change implications are present in the literature (Ullman, 2017; Uber, 2017). Future researches will quantify the use-phase sustainability of these mobility systems, using two key metrics: primary energy use in units of megajoules [MJ] and GHG emissions in units of kilograms of carbon dioxide equivalents [kg-CO2e] on a 100-year global warming potential basis (similar indicators were used by (Chester and Horvath, 2012)).

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