Preliminary Analysis of Small Aircraft Traffic Characteristics and its Impact on European ATM Parameters – a Small Aircraft Prediction Model

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Abstract— The further globalization and mobility freedom indicate rapid increase in needs of personal used air transport systems (see NASA SATS program). Such new and further general aviation (GA) requires totally new, innovative ideas and the use of the newest technological achievements to ensure a new, inexpensive, and secure control system.

The goal of this paper is the development of a European small aircraft prediction model that could be applied for the analysis of the impact of small aircraft (SA) activity on the current ATM parameters. Therefore, this paper analysis the current European small aircraft’s traffic (using EUROCONTROL database) and different aspects (development of the economy, changes in market needs, application of new technologies, etc.) having influences on air transportation system in general and especially on the European ATM/ATC. It also deals with the possible model structures, model classes and finally gives a relatively simple model based on Markov chain that has been chosen for testing it in simulation. The simulation results show, that the developed model could be used in preliminary prediction of the European small aircraft activity and in the definition of required changes in regulation, management and service providers to ensure the further development of SA.

Index terms— general aviation, prediction methods, small aircraft, traffic characteristics

I. INTRODUCTION

Today’s air traffic volume is projected to be doubled by 2020 [1,2]. On the other hand, today there are approximately [3],[4] 300 000 private and small aircraft pilots in Europe who fly more than 60 000 small aircraft. As the technology is already available to establish a safe, economical and environment friendly new air transportation system based on personal air transportation purposes, their traveling habits might change. Maximum satisfaction of requirements could take over the lead, such as traveling on demand, point-to-point and in a more flexible way [6]. Additionally, from our perspective, small aircraft (SA) has to be designed to be affordable to anybody, without any special or extra knowledge and abilities (similarly to the NASA SATS project [2],[6]). As this future state could enhance people’s quality of life and ensures their freedom, aviation should use radically new, innovative ideas in order to break down the currently existing limits and constraints in air transportation.

With accordance to our investigation, this market - in new democratic countries and in new members of European Union (EU) - will develop rapidly, with a significant increase in terms of small aircraft. This development will continuously be very high over the next 20 years [5], even higher, than conventional air traffic as we can see it in the figure 1.1. However here microjet means an aircraft with a maximum take-off weight between 5000 and 10000 lbs (such as Honda Jet, Avocet, Safire, etc.), from our perspective it could also be understood as a small aircraft (coming from the practice of NASA SATS program [2],[6]), a personal aircraft (for personal air transportation purposes [4],[7]) an air taxi [8], or even a UAV.

In the face of this increase, the current system is already reaching its limits, thus most probably it will not be able to meet that future need of tomorrow’s capacity (in several domains such as environmental consideration, security, safety,
etc. [2]). Moreover, the saturated fact of today’s big airports could obligate personal aircraft flights to use regional airports, or other underutilized landing possibilities, which in most of the cases are not equipped with modern radio-location systems for controlling the air traffic. Thus, in the aim of decreasing such and other negative effects - caused by the increased number of small aircraft - current ATC/ATM, airport and airline operators might call for a change. Therefore we have to develop radically new concepts to be able to accomplish future tasks (such as pilot workload monitoring, simplified control [4], automatic control system, etc.), and to minimize the interaction between SA and the conventional air traffic. Hopefully, such change in air transportation of the future has a perfect timing [1], because we still have a little time to prepare ourselves for the work ahead of us, before air transportation will reach the record levels.

For a better understanding of the work to be accomplished in the domain of SA activity, initially we discovered the following related works. First of all, the NASA’s Small Aircraft Transportation System (SATS) [2], [6] that desire to expand the use of small airports and small aircraft for public transportation, through cockpit development and some advanced operational concepts in non-radar airspace at non-towered airports. Or the Personal Air Transportation System (PATS) [4], [7] project that is very similar to SATS, however here, investigations are done in the domain of aircraft maneuverability simplification via automation, without focusing on cockpit development. Another thought provoking idea is the SkyCar [13], a vehicle capable of vertical take-off and landing that looks like a cross between a sports car and a tiny jet aircraft. And finally the UK JETPOD [8], which is a European pre-designed study for advanced personal air transportation.

Generally, the purpose of these programs is to make small aircraft as easy and safe to operate as cars, with a cost the same as a mid-range car. However these have been very useful to name the currently available small aircraft, cockpit development benefits and requirements vis-à-vis pilot experiments, their limitation (expect the UK JETPOD) is the focus on the American market. As Europe consists of several countries, with different social and economical characteristics, the importance of our study is to adopt their results and predictions on the European market attributes. Additionally, expect the last few years of development in this field, small aircraft development has not been in focus for over 40 years, since the World War II. The companies producing these aircraft have partly changed their activity, or jointed to a bigger civil and military aircraft development. Due to this past, we do not have enough statistical data and experience for describing the future growth of small aircraft activity, especially for the European market.

In order to deal with this past and to ensure future needs described above, the impact of small aircraft on the European air transportation system has to be analyzed. Among several areas, our research deals with air traffic control, air traffic management domain. Therefore the analysis of the European ATM parameters, from a small aircraft point of view.

As the analysis of small aircraft activity is a pioneer task in Europe, the initial objective is to obtain relevant information and a wide knowledge on its development. In order to define its main characteristics and trends, we firstly should analyze the current air traffic situation, by taking into account the flights that are the most close to a small aircraft of our objective. This approach might restrict the area to be focused on and give us a first idea, how SA might interact with conventional air traffic in Europe.

Using the results of the traffic analysis, our objective is also to forecast/analyze the impact of small aircraft on different fields/parameters of the European ATM. That demands a SA prediction model, which could forecast any SA traffic load on the current system parameters. Using the model and by running a simulation, the definition of the bottleneck - among the ATM parameters that might call for further investigation - could be named.

Once these objectives have been accomplished, further investigations might focus on tasks, to minimize the impact of small aircraft on the air transportation system. This could be imagined by giving proposals, solutions for a particular domain, and shifting the ATM attributes towards a system that could give solutions for future requirements of small aircraft purposes.

II. CURRENT EUROPEAN SMALL AIRCRAFT RESEMBLING AIR TRAFFIC ANALYSIS

In Europe, the air traffic analyze with small aircraft in head is a pioneer task. Thus, our investigation only covers a nine-month period (in 2004) by taking into consideration one day from the weekends and weekdays, from EUROCONTROL’s CFMU database. Using our SA definition, this allowed us to analyze more than 50,000 European flights; to recognize the impact of seasons; and finally to define, whether business or leisure flights are more often to happen.

The result and the distribution of the number of flights for the whole examination period is shown in the figure 2.1. It could be concluded, that the number of flights that take place during the weekdays is nearly twice more important, that is for the weekends, even so the average number of flights for the whole period is 1429. This could mean that the distribution of flights represents more a business market segment, where the
flexibility of passengers is underlined.

In order to be able to place, and to assess how these flights are going to penetrate to the airspace, the evaluation of the flight level density is crucial. The study takes into consideration the cruising path that is visible in the figure 2.2. As we might observe, most of the flights take place around FL 100, and just a very few percent of them (18%) are flying at least up to FL 200. The reason for such a low altitude could be due to propulsion technology, and / or flight distance preference, which calls for further investigations. Firstly, we analyzed the current small aircraft propulsion technology preference. The figure 2.2. shows, that propellered technology is in majority with nearly 59% of the flights, which is followed by turboprop (29%) and jets (12%). We ended up with nearly the same result by analyzing the 15 mostly preferred small aircraft, where propellered technology preference becomes even more clear.

After the analysis of the flight altitude and propulsion technology preference, we already had an idea about short flight distances. To demonstrate it, we accomplish the flight distance analysis such as follows.

At the same time, as CFMU database does not contain flight distance data, we used GPS coordinates and great circle distance calculation to support the computations. Finally, the figure 2.3. shows that the most frequent flight distance belongs to 150 km, which is already 12% of the total small aircraft flights. Then 85% of them are not longer than 500 km, and just 3% (!) are more than 1000 km, which gives an average of 310 km. Thus we could conclude, that currently short flights at low altitudes are more often to happen, with the preference of a propellered small aircraft. To understand what could be behind such a distribution, and how that traffic could be look like, we represented one typical day of small aircraft flights in Europe, using COSAAC Software (see figure 2.4.). There, the flights are very different one from the other, and it would be difficult to define preferable routes, or city pairs as it might be possible for conventional air traffic. One exception is the traffic between England and some of its islands (such as Alderney, Jersey, Guernsey) where even scheduled flights could be found several times a day, which shifts them to the top of the most frequent city pairs list. As for city pairs, in total we found more than 12,000 for the whole examination period, where just half of them occurred at least once, and just 4,3% took place at least once in a week. Moreover, some of these city pairs have the same origin and destination, which could be due to flight plan errors, or even training flights.

Hence SAs are flying at low altitudes, for short distances, with a very low number of scheduled flights. Their distribution is very high, thus it would be difficult to identify preferable destinations, or city pairs, as it might be done for the conventional air traffic (see figure 2.4.).

III. LESSONS LEARNED FROM AIR TRAFFIC ANALYSIS

Even so cruising altitude distribution of small aircraft flights has been mentioned, their impact on the airspace density, and on other flights requires further investigations.

Here, both small aircraft and commercial flights have been examined in the same time, which allows us to assess the most
preferable altitudes for both cases, and to evaluate whether any kind of impact exists, or could exist between them. The figure 3.1 shows that nowadays the above mentioned flights are quite separated by more than 20,000 feet between their most crowded areas. But if we would like to trace an optimal limit between them – which means, that both impacts the other in a minimal way – that would be around FL 190. In that manner, 93% of the commercial flights will take place above that altitude, and they will be impacted by 18% of small aircraft flights.

Anyhow, even if that trend in small aircraft altitude preference remains the same, a raised number of flights could shift the previously mentioned 18% to higher values, which might seriously impact the commercial air traffic. Moreover the same problem should be faced, if any SA performance or flight distance value changes, which calls for further ATM studies (such as the assessment of the number of conflicts, sectorization constraints, etc.) in order to meet target objectives and make small aircraft transportation relevant.

An additional study to gain more accurate information on the current state of aviation could be the 3 dimensional altitude distribution within a given sector (including incoming and outgoing flights) at airport vicinity.

The figure 3.2 shows the complexity of traffic situation, which is no more a clearly separated cruising altitude distribution, but much more a mixture of small aircraft and commercial flights, with some descending, climbing and cruising airplanes at airport surroundings. From that point of view, commercial flights should face with serious problems, while they desire to pass through low level airspaces crowded with small aircraft, especially in case of an increased traffic volume. Certainly, many solutions could exist to solve this problem, while minimizing the impact of small aircraft. One of them lies in the idea to oblige small aircraft flights to make a deviation at airport vicinity, which might enable the rest of airspace users with the same service, as today.

From a small aircraft point of view, airport surrounding means the areas with commercial flights lower than FL 190, which as previously mentioned is the optimal altitude where the impact of both small aircraft and commercial flights is minimal. In the aim, to imagine how seriously such a procedure could limit the freedom of small aircraft users, we calculated the average distance (depending on aircraft performance and airport SIDs: Standard Instrumental Departure routes, STARs: Standard Terminal Arrival Routes [9]) that might be required for a commercial flight to reach FL 190. That gave us 130 km [9]. Finally, by tracing circles with this radius around big European airports we had the figure 3.3. Surprisingly, these circles are covering an exceptionally large geographic area, which can not be deviated without the serious impacts on small aircraft’s flight plan and contradictions with target objectives such as freedom.

Thus other solutions have to take into consideration, such as defining corridors within the airspace that might enable small aircraft to pass by crowded areas. Anyhow, a major conclusion is that a flexible or optimal usage of airspace capabilities that replies to dynamic traffic requirements could become important. Nevertheless that could create an increased pilot/controller workload and high requirements on cockpit instrumentation, which might call for an increased level of automation.

IV. INITIAL SMALL AIRCRAFT PREDICTION MODEL - A GENERAL OVERVIEW

The input data analysis clarified, that the initial problem with SA prediction modeling is, that the generally used solutions can not give a suitable result, since small aircraft transportation does not exist today in Europe, hence the relevant information which might be used is more than limited. This lack of input data, and the aim to have an advanced model that could reply to our specific requirements, forced us to come up with the (already discussed) air traffic analysis. Using its results and arguments on the number of small aircraft, flight level, and other characteristics, the elements and the initial data of a model started to be available. However, we already had something in mid about the key elements, their role and weight remained unclear. Thus, firstly we decided to investigate an initial prediction model that could finally answer the remained uncertainties, and which could serve as a good starting point to represent the relationships, and to understand their functionalities. Moreover, the right balance between the major factors should be found and applied, in order to eliminate unforeseen complexities and side effects (such as increased costs due to a high level of cockpit instruments), while trying to bring into play the most possible benefits. This balance also calls for an initial SA prediction model.
As preliminary analysis show [10],[11],[12] GDP, costs, population density, and other socioeconomic characteristics could seriously influence the demand of small aircraft, thus it should make a part of our investigation. Even so, our approach to initial prediction modeling is, that the GDP might totally describe the mobility of passengers, hence our input data – that we call here market attributes – mainly consists of GDP, and other SA relevant elements, like technological development and regulation. Naturally other fields could also be added; nevertheless even this simplified input data should fulfill our requirements: to obtain an initial prediction model. As for the rest of our input data, we do believe that the demand mainly depends on the availability of SA, which might be driven by the technological development. Anyhow, the effect of regulation has been added as well, since it might seriously influence the SA activity, in any future scenario (such as noise restriction at airport vicinities).

Then, as the figure 4.1. shows, that market attributes drives the characteristics of small aircraft (SA) and traditional air traffic as it comes for economical theories [11] [12]. Thus the small aircraft group (figure 6.1.: left, in the middle) consists of the number of aircraft (SA need) and its cost (assuming, that it could be defined by the technological development and regulation). Additionally, this same group contains a supplementary domain called flexibility of market requirements. This element takes into consideration the flexibility of the market to SA cost and to the fulfill of its requirements. Thus a low market flexibility would describe the possibility where SA need is highly dependent on its cost and the fulfill of market requirements, even thought any GDP and technological development increase. With other words, this means, that future SA users will not be able to accept higher costs, or a lower satisfaction of their requirements (such as the non-availability of SA for pilots with limited experience).

In order to have the total amount of traffic, which interaction on ATM might be analyzed, the traditional traffic characteristics has been added as well (figure 4.1.: right in the middle).

The final element of the model – interaction on ATM - is made up of some of the air traffic management domains from a SA point of view. These elements are mainly the outcome of the SA traffic, current ATM constraints and future perspectives analysis [10]. For instance as chapter V showed the difficulty of small aircraft flights at airport surroundings, some revolutionary solutions might require a new ASM, or an enhanced automation, therefore these two domains could make a part of our investigations. Following this logic, avionics – for example - means cockpit instruments and navigation tolls (such as TCAS, GPS, ADS-B, and others). Separation responsibility is defined by its importance, without taking into consideration whether pilots or controllers should deal with it. Similarly, the domain of "automation" means more its significance, without underlining, that it might range from automation of controllers’ routine tasks to autonomous operation, with advanced airborne system application (such as Airborne Separation Assurance Systems) and even free flight.

V. PREDICTION MODEL STRUCTURES

Generally, the transportation systems are the dynamic systems. The future of the dynamics systems can be defined with the following general models written in continuous/discrete form such as follows:

\[ x(t_0) = x_0 , \]  
\[ x(t) = f(x(t), u(t), p(\zeta)) + F(p(\zeta))n(t) , \]  
\[ y(t) = g(x(t), u(t), p(\zeta)) + G(p(\zeta))n, \]  

where \( x, u, p, n, y, \eta \) are the state, control (input or regulatory) and parameter (system structural and operational characteristics), state noise, observation (output), and measurement noise vectors, \( f \) and \( g \) are system state and observation functions, \( F \) and \( G \) are system matrices, \( t \) is time and \( \zeta \) is a random value.

However in general – and with accordance to control theory - \( u \) is a known vector, in our case it is defined by regulatory aspects, like changes in requirements generated by safety reasons, or changes in taxation systems, application of radically new technologies, etc. The system characteristics, \( p \) are depend on the development of SA, economical characteristics, and on the competitor aspects (such as growth of the high speed trains, road traffic problems, etc.). Hence, \( p \) is an unknown vector, which can be changed randomly and non-continuously that is described by a random value, \( \zeta \) depicting real position of the parameter vector, \( p \) in its possible space, \( \Omega_p \). As usually, the state noise vector is assumed to be zero-mean; and the measurement noise vector is assumed to be a sequence of independent Gaussian random variables with zero mean and identity covariance. Finally, the model (1) can be given in linearised form (as is the case of stability and control derivatives of an aircraft):
\[
x(t_0) = x_0, \\
x(t) = A\dot{x}(t) + B\dot{u}(t) + F\dot{n}(t), \quad (2) \\
y(t_0) = C\dot{x}(t) + D\dot{u}(t) + G\dot{n_i}. \\
\]

On the other hand, the model (1) represents the following stochastic (random) differential equations in system of equations (1a):

\[
\bullet \quad \dot{x} = f(x, t) + \sigma(x, t)\xi(t), \quad (3)
\]

which is called as diffusion process. The first, deterministic part at the right side of the equation describes the direction of the changes of the stochastic process passing through the \(x(t) = X\) at the moment \(t\), while the second part shows the scattering the random process, where, \(\xi(t)\) is the white noise.

In prediction and forecast technology several models based on the use of diffusion models were developed [14]. From one hand the innovation diffusion theory has applied the S models for getting information about the introducing of a new product/service into the market that aims to describe the market share changes [14].

On the other hand the model classes defined by (3) can apply to the description of the system dynamics rewriting the model (1b) into the following form of controlled diffusion process:

\[
\dot{x} = \Phi(x, t) + b(t) + \sigma(x, t)\xi(t), \quad (4)
\]

where \(\Phi\) is the deterministic vector function describing the rate of changes in state vector, as the products of the functions of the state and the time increment; \(b\) is the vector of control effects and finally \(\sigma\) is the transfer matrix giving the effects of the noise disturbance on the state vector.

Replacing the state (or phase) vector \(x\) by \(x = m_x + \Delta x\) the equations (4) can be statistically linearised in the area closed to \(x = m_x\):

\[
\dot{x} = \frac{d}{dt}(m_x + \Delta x) = F(m_x, t) + U(m_x, t)\Delta x + b(t) + \sigma(x, t)\xi(t) \quad (5)
\]

where \(U(m_x, t)\) is the sensitivity matrix, i.e. matrix of partial derivatives of vector function \(F(x, t)\) respectively to state vector \(x\) determined at \(x = m_x\).

In case of stationer white noise the equation (5) represents the well known linearised model of aircraft motion:

\[
m_x = F(m_x, t) + b(t). \quad (6)
\]

However, this class of models could be applied for the prediction of the small aircraft activity, the relevant preliminary information – in Europe - that might be required for model estimation, is more than limited. Moreover, according to our analysis, the prediction model can not be given in a generalized form, since the system should include the major effects influencing on SA growth, which defines a large and very complex system with internal coupling and discrete (step) changes - depending on the regulational aspects or the application of the new technological achievements.

Thus, the prediction model - in a general form - is the result of the superpositions of the general growth (exponential), periodical changes (in requirements) and the discrete changes (in characteristics of general growth). Hence, the model (1b) should be rewritten in the form of stochastic equations, such as follows:

\[
\dot{x} = f_x(x, u, t) \quad (7)
\]

In order to be able to use this model, the SA traffic characteristics should be analyzed at first, as it was already mentioned at the previous chapters.

VI. INITIAL SMALL AIRCRAFT PREDICTION MODEL - MATHEMATICAL DESCRIPTION

In order to set up a mathematical model – that replies to our complex interactions – we assume that the equation (7) hold the form, and where \(x\) is the vector of the dependent variables like:

\[
x = \begin{bmatrix} \text{SA}_\text{need} \\
\text{SA}_\text{mark} \_\text{req} \\
\text{SA}_\text{need} \\
\text{T}_\text{need} \\
\text{cos} \_t \\
\text{avionics} \\
\text{ASM} \\
\text{sep} \_\text{resp} \\
\text{automation} \end{bmatrix}
\]

\(u\) is the input vector,

\[
u^t = [\text{GDP} \_\text{regulation} \_\text{techn}_\text{development}]
\]

and \(t\) is the time.

The equation (7) is now a non-linear differential equation. With its linearization we receive (8) such as follows:

\[
\dot{x}(t) = A^* \cdot x(t) + B^* \cdot u(t) \quad (8)
\]

Where

\[
A^* = \begin{bmatrix} a_{11} & ... & a_{1n} \\
... & a_{g1} & ... \\
a_{n1} & ... & a_{nn} \end{bmatrix} \quad \text{and} \quad B^* = \begin{bmatrix} b_{11} & ... & b_{1m} \\
... & b_{ke} & ... \\
b_{n1} & ... & b_{nm} \end{bmatrix}
\]
with
\[ a_{ij} = \frac{\partial f_j(x,u,t)}{\partial x_j}, \text{ and } b_{ke} = \frac{\partial f_k(x,u,t)}{\partial u_e} \]

The equation (8) could be discretized such as follows:
If \( T \) is the discretization time, we could define:
\[ t = kT, \text{ where } k \in N \text{ is the time in years.} \]

Thus the equation (8) takes the following form:
\[ \frac{x[k+1] - x[k]}{T} = A^* \cdot x[k] + B^* \cdot u[k] \]  \tag{9}

knowing that \( \Delta t \Rightarrow T \).

With the rearrangement of (9), the prediction of the elements of the vector \( x \) could be done with the following equation:
\[ x[k + 1] = Ax[k] + Bu[k] \]  \tag{10}

Where, the matrix \( A \) describes the relationships between the elements of the vector \( x \), therefore \( a_{ij} \) (where \( i \neq j \)) are coefficients, that express the connection between \( a_{ij} \) and \( a_{ji} \) (such as the connection between automation and SA need). \( B \) similarly to \( A \) describes the relationships between the input elements (vector \( u \)).

The advantage of such an approach is that it could be used for any interaction modeling even with different small aircraft characteristics.

However, the challenge is to find the coefficients for both \( A \) and \( B \) matrixes. For our small aircraft purposes, they are partially based on statistics, and on estimations.

Finally, the outcome of the equation (10) could give us an initial prediction of each elements of the vector \( x \), that might help us to understand their role, and to foresee, what could be a relevant domain to focused on.

VII. SIMULATION

To have the prediction of the key elements (vector \( x \)), in this paper, only a example of a simulation is presented, where the input data is defined with five scenarios, that ranges from optimal (4: large number of SA) to catastrophic (5: limited number of SA) and some between such as follows: scenario 1 is defined by a moderate GDP, technological development growth with a non-flexible market (see chapter IV). Scenario 2 is the opposite of the previous, thus here, the market is flexible, and it can accept higher cost, and / or lower level of satisfaction of their requirements. Additionally, for both scenario 1 and 2, a regulation has been added, since it might be interesting to define, and to analyze its impact on the key elements. Note that in this model, the effect of regulation is considered as a decreasing factor on the “flexibility of market requirements”, and an increasing cause on “SA costs”. Finally, scenarios 3, 4 and 5 are the ones with a flexible market, and without regulation, where the difference between them lies in the definition of a low (4), moderate (3), and rapid (5) GDP, technological development growth. As a final point, note, that all the input data are based on assumptions.

By running a simulation with these scenarios, the model
gives the outcome of each key elements (vector x), however, this paper only presents three of them (SA need, fulfill of market requirements, and the role of automation), as it is presented in the figure 6.1.

By focusing on the "SA need" outcome, it predicts nearly six times (see figure 7.1.) more small aircraft (that is today) for the most optimal scenario (4). This number becomes a bit smaller with scenario 3 and 5, which is caused by the decreased GDP and technological development growth. Finally, scenario 1 and 2 are the situations, where the outcome is impacted by a regulation. Its effect is clearly visible on both curves, causing a wave part that lasts for several years. Logically, for scenario 1 it is easier to track, due to the non-flexible market situation, which is more sensitive to any "cost" or “flexibility of market requirements” change.

As for the effect of regulation, it could be also observed in the figures of "flexibility of market requirements" outcome (see figure 7.1.). Here again, only scenarios 1 and 2 are impacted, otherwise the curves are slightly different due to the variation in SA number.

As for the curve automation, it has to be underlined again, that this analyze does not aim to point out one of the automation capabilities, since it only represents its importance to achieve the future air transportation of small aircraft. Anyhow, in the figure 7.1., its increasing role might be observed, that could be even three times more important, that is today. This result might correspond to any future scenario, since automation capabilities should become a major factor in the future, where aviation should face with an increased number of small aircraft that might significantly impact the conventional air traffic (as it was already foreseen in the small aircraft resembling traffic analysis). Moreover, if these small aircraft are handled by pilots with limited experiments who would not be able – or just do not willing to – deal with high separation responsibilities and difficult procedures, automation might become even more important.

VIII. CONCLUSION

The increasing economy and air traffic volume might allow the future of small aircraft transportation. In that scenario, traveling habits will change. Maximum satisfaction of market requirements will take over the lead, which could enhance people’s quality of life and ensures their freedom.

Such a shift in air traffic attributes, and the increased number of flights could call for a change or demand enhancement is several areas of the current ATM, thus it has to be analyzed. The identification of the bottleneck among these ATM domains could be imagined by the results coming from a mathematical model that describes the impact of small aircraft on ATM.

In the face of this model calls for relevant information and the knowledge on small aircraft transportation attributes, in Europe, the availability of these data is extremely limited. This forced us to accomplish the initial objectives, namely the analysis of small aircraft flights. This partial result allowed us to place small aircraft flights in the airspace, and to use arguments on flight level, flight distance, propulsion technology preference, that is mainly impacts the conventional air traffic at airport surroundings.

With these clarified main characteristics, and the restricted area that should be focused on, the definition of the mathematical model became possible. The initial prediction model showed the complexity of the work ahead of us, and gave some preliminary results on the number of small aircraft, and the characteristic of some of the ATM fields that might be focused on.

Anyhow, the prediction model could enable the definition of the bottleneck among the ATM parameters, that might be focused for any further investigations, where new technologies and ideas - enabling such modifications in air transportation – could be applied to the entire system intelligently and in an integrated fashion, in the aim of having a new, effective, more safe and accessible way of transportation to any users.

IX. FUTURE WORKS

After the initial prediction model, and once the relationship between some of the most important elements of the European small aircraft transportation has been clarified, further investigations should focus on an advanced mathematical model that already replies to a complex system approach. A general system overview of such a small aircraft prediction modeling could be described such as follows: the ATM could be considered from a complex system modeling view at the macroscopic level, where the whole system is decomposed into the following three subsystems:

- Society Subsystem: that contains the society constraints and drives for growth including passengers and airlines,
- Technical Subsystem: that includes all technical infrastructures supporting the functioning of the ATM system,
- Human Subsystem that takes into consideration all human components of the whole system, from flow managers to supervisors, pilots and controllers.

From such a point of view, the impact of small aircraft on ATM could be modeled in terms of sets of components of different subsystems and sets of interactivities between them, to accomplish the mission of simultaneously maintaining safety and sustaining growth.

This model will also rely on a more advanced small aircraft demand model, using theories of macroeconomics in air transportation. This challenging task could be accomplished using similar activities that might be adapted to European small aircraft and market requirements.

Naturally, due to the lack of preliminary information and dependence on the applied scenarios, the model must be tested and enhanced in accuracy for further use.

Finally, once the model is already available, with the use of scenarios, we could provide simulation based recommendations and proposals for further Air Traffic Management research areas, from a small aircraft point of view.
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