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ISSN 2454-0471

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INAIR 2012

International Conference on Air Transport

20 – 21 September 2012
Žilina, Slovakia

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UNIVERSITY OF ŽILINA

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International Conference on Air Transport

20 – 21 September 2012

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MOVING CARGO BY AIR: IN A SAFE WAY

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Abstract *– This paper deals with description of recent development in the field of screening of air crago. It also describes technology for air cargo security.*

Key words – air crago security, air crago scanners.

INTRODUCTION

The air cargo system is a complex, multi-faceted network that handles a vast amount of freight, packages, and mail carried aboard passenger and all-cargo aircraft. The air cargo system is vulnerable to several security threats including potential plots to place explosives aboard aircraft; illegal shipments of hazardous materials; criminal activities such as smuggling and theft; and potential hijackings and sabotage by persons with access to aircraft. Several procedural and technology initiative to enhance air cargo security and deter terrorist and criminal threats have been put in place or are under consideration. Procedural initiatives include industry-wide consolidation of the "known shipper" program; increased cargo inspections; increased physical security of air cargo facilities; increased oversight of air cargo operations; security training for cargo workers; and stricter controls over access to cargo aircraft and air cargo operations areas. Technology being considered to improve air cargo security includes tamper-resistant and tamper-evident packaging and containers; explosive detection systems (EDS) and other cargo screening technologies; blast-resistant cargo containers and aircraft hardening; and biometric systems for worker identification and access control.

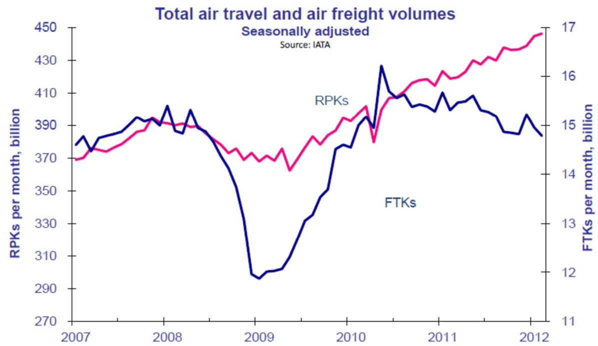

Figure 1 *Total air travel and freight volumes of IATA members (seasonally adjusted). Source: IATA*

AIR CARGO DEMAND

Freight volumes in February 2012 were considerably higher than a year ago. However, there were distortions to the results by the Arab Spring which happened a year ago, cargo delays from Chinese New Year in January, and Carnival in Brazil occurring a month earlier in 2012. After adjusting for the distortions, freight traffic declined through to September 2011, after which it stabilized, moving around a broadly flat trend through to February 2012 (Figure 1).

Figure 2 *Total air cargo growth by region. Source: IATA*

AIR CARGO SECURITY RISKS

Potential risks associated with air cargo security include introduction of explosive and incendiary devices in cargo placed aboard aircraft; shipment of undeclared or undetected hazardous materials aboard aircraft; cargo crime including theft and smuggling; and aircraft hijackings and sabotage by individuals with access to aircraft.

AIR CARGO SCREENING TECHNOLOGY

Various technologies are available for detecting explosives, incendiary devices, and the presence of various chemical and biological agents and nuclear weapons in cargo. Key technologies under consideration for screening air cargo for threat objects include x-ray screening, x-ray based explosive detection systems, chemical trace detection systems, and technologies based on neutron beams. In addition to these technological approaches, several experts and TSA officials have been advocating and pursuing an increased use of canine teams for screening cargo and mail. The main drawback to any of these screening techniques is that the screening process takes time and may significantly impact cargo delivery schedules. While the various technologies differ in their capabilities and performance, in general, more detailed screening analyses require more time and could affect cargo throughput. Another concern regarding these technologies is the cost associated with acquisition, operation, and maintenance of screening systems. X-Ray Screening. The most common systems currently available for largescale screening of cargo shipments utilize x-ray technology. These systems rely on well understood transmission and backscatter x-ray techniques to probe cargo containers. Many of these systems utilize low-dose x-ray sources that emit narrow x-ray beams thus virtually eliminating the need for shielding. These devices are compact and light weight, thus allowing them to be mounted on moving platforms that can scan over containers.68 X-ray devices are becoming more common at major ports of entry, border crossings, and airports overseas as post-September 11th security concerns are spurring increased development and deployment of these devices. The systems are being utilized to screen for drugs and other contraband as well as explosives in cargo shipments. One of the most significant operational challenges in using x-ray screening devices is the performance of the human operator. A variety of human factors considerations contribute to the operator's ability to detect threat objects when viewing x-ray images. These include the monotony of the task, fatigue, time pressure, the adequacy of training, and working conditions. These human factors are important to consider in fielding x-ray screening systems to ensure high detection rates of threat objects while minimizing false alarm rates that would unnecessarily slow the cargo inspection and handling process. Technologies such as threat image projection (TIP), that superimpose stored images of threat objects on x-ray scans can help keep operators alert and may be effective tools for training and performance monitoring. Additional technologies, such as computer algorithms for highlighting potential threat objects, may also be considered to aid human observers.[1]

Smiths Detection unveiled a new, dual-view x-ray inspection system designed to meet the growing global demands of screening large cargo, pallets and freight items on both passenger and cargo aircraft.

The compact HI-SCAN 145180-2is is capable of screening objects up to 57in x 71in (145cm x 180cm), meeting the maximum skid/pallet size allowed by the US Transportation Security Administration (TSA).[2]

Figure 3 *The compact HI-SCAN 145180-2is was publicly launched by Smiths on March 15, 2012. (Smiths Detection)*

Figure 4 *Rapiscan Eagle® A1000capable of screening of air cargo pallets and containers (Rapisscan)*

The Rapiscan Eagle A1000 delivers powerful, high throughput screening of single or mixed commodity air cargo pallets and containers. TSA Approved - on the Air Cargo Qualified Technology List of approved air cargo screening systems. A 1 MV X-ray imaging system - powerful enough to screen pallets and containers for air cargo. Multiple configurations – either scan with a conveyor system or with dollies towed by a tug. Large inspection tunnel – scans even large air cargo containers and pallets. Screen range of cargo types – easily inspects homogeneous and mixed cargo. The Rapiscan Eagle A1000 offers high penetration, best-in-class imaging, robust standard features and advanced options that

[1] Bart Elias, Air Cargo Security, Updated July 30, 2007, Specialist in Aviation Security, Safety, and Technology Resources, Science, and Industry Division

[2] Available online at: http://www.airportsinternational.com/2012/03/smiths-launches-air-cargo-scanner/ Smiths Launches Air Cargo Scanner, posted on March 20, 2012 by Tom Allett

make it the most powerful, user-friendly and efficient air cargo scanner available.[3]

The Linescan 229 is a cargo X-ray screening system with a tunnel opening of 1.8m (6') wide by 1.8m (6') high. The Linescan 229 is a 450Kv system that can accommodate large pallets, crates, and containers typical in air cargo. Using EG&G Astrophysics' patented E-Scan® technology, the Linescan 229 can be used to inspect cargo pallets for narcotics and contraband as well as manifest verification. It is ideal for use at ports of entry, warehouses, airports, customs facilities, and transportation operations. The Linescan 229 can inspect pallets and containers weighing up to 3600kg (7920 lbs.) without having to disassemble pallets or unpacking containers. The Linescan 229 also saves processing time and storage space by avoiding the 24 hour "Wait Time" required in case of a bomb threat. The Linescan 229 is assembled on site and can be easily integrated into an existing cargo handling system.[4]

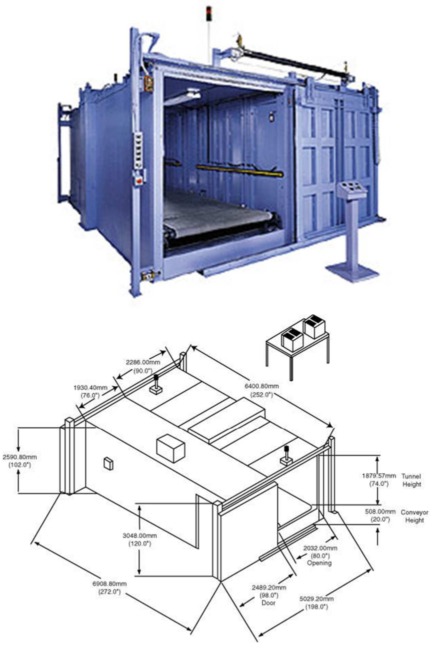

***Figure 5** The Linescan 229 cargo X-ray screening system with a tunnel*

CONCLUSIONS

Since September 11, 2001, a variety of air cargo security measures have been put in place or are under consideration. The purpose of these security measures is to mitigate: (1) the risks associated with placing cargo on passenger and all-cargo aircraft; and (2) the high level of access to aircraft during cargo operations. This report will examine the key security risks associated with air cargo operations and options for mitigating these risks. Appropriatie legislation over the past years has called for continued increases to the amounts of air cargo that is physically screened.

3 Availavble online at: http://www.rapiscansystems.com/en/products/bpi/productsrapiscan_eagle_a1000 accessed on Friday, April,13 2012

4 Availavble online at: http://global-security-solutions.com/LinescanCargoScanner.html accessed on Friday, April,13 2012

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[2] Airlines Financial Monitor March 2012, IATA

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SECURITY DECISION MAKING: SIMULATING REALITY

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Abstract *– high risk organizations, like airports, face continuing threats that require ongoing and time-sensitive security decisions. A time honored way to prepare security employees to deal with such decisions is through training. The ability to react quickly and effectively in a time of crisis correlates directly with the quality of training given to the employee. To improve the decision making process, we propose and develop a dynamic simulation model of security decision making, that mimics the reality of social behavior that is critical in the decision process.*

Today, nearly all compulsory training programs are based on rule compliance, i.e., learning security rules and procedures. However, recent evidence shows that over a third, to half of airport employees bend, break and/or discard the rules. This occurs particularly in non-routine situations where rules may either be absent or not applicable. Therefore, theoretical knowledge of security rules does not always guarantee preparedness of the security staff when facing a real critical situation.

To fill this gap, we have opted for a training methodology employing an evidence based simulation of various crisis situations. It takes into account formal and informal relationships that exist in airport organizations – between departments as well as among co-workers. As training progresses, a cumulative data base of stored experiences is generated and is used to create a realistic model of various parameters of the trainee and of airport organizational security processes including: cultural differences, local habits and rules particular to each airport.

This methodology exposes trainees to computer based simulations allowing security decision choices to evolve over time and be guided by a realistic security framework in which employees face both routine and non-routine situations. In addition, the simulation can run on a stand-alone computer which results in significant costs savings through flexible physical placement (home, office), the ability to divide tasks, continue anytime – time flexible schedules, and the creation of an individual model of each person during the lifetime of a trainee's employment.

Key words – airport, security decisions, behavioral model, simulation, training.

INTRODUCTION

The BEMOSA research team has been examining airports throughout Europe, focusing on key decision making groups such as security employees, service vendors and passengers. Each group is faced with particular types of security and safety challenges. It became obvious in the early stages of the project that our proposed model could provide a generic structure of the simulation, but data is always specific to each airport, given that the model takes into account the cultural affinities and diversity inherent in the organizational climate of a particular airport.

To focus on airport security decision making we therefore took a three pronged approach.

- To examine in detail and trace over an extended time period how security crisis decisions are made by key groups associated with land, air and maintenance activities of an airport,
- Use this information to develop a behavioral science predictive model through trend and simulation analysis and
- From this model, formulate fundamentals for a crisis management training program.

Advanced modeling and simulation is based on:

- Direct, multi-faceted observations of group behavior in airports;
- Developing a realistic model of social behavior during security threats in airports;
- The development and integration of advanced software simulations that help to capture and predict social behavior under stressful emergencies.

We have defined principal parameters of the trainee model as:

- Age
- Sex
- Years of experience
- Tendency to act as an adaptive person
- Person having inclination to social decision making
- Tendency to act as a bureaucratic person
- Situation handling capabilities
- Rules and regulation mastering
- Passenger care
- Cooperation with a superior
- Risk taking or time loosing
- Cooperation with colleagues

This set of parameters could be extended and also reduced according to the needs of a particular organization. The multidimensional model provides information about strong and weak points of the trainee and it is a source of valuable data for decisions about further training needs of a particular trainee. As an example, a table containing the database of trainee's model parameters can be seen on Fig. 1. Each row contains data of one particular trainee. Each column is dedicated to one parameter and contains an integer variable attributing a score for a given parameter. Columns A and C are in years, column B is represented by two values (0 (M) and 100 (F)) and the rest are in percent.

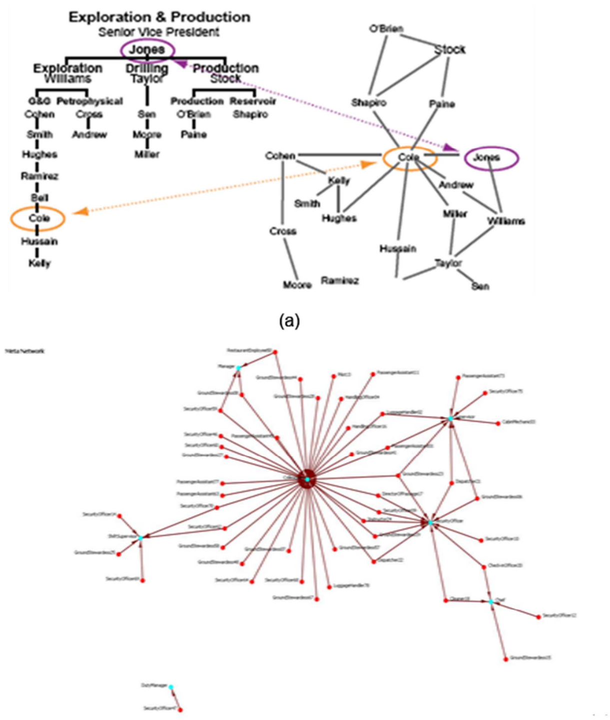
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Trainee No.	Age	Sex	Experience	Adaptive	Bureaucratic	Social DM	Situation handling	Regulation mastering	Passenger care	Boss cooperation	Risking or time loosing	Colleagues cooperation
2	1	22	0	5	30	70	0	76	96	93	62	62	52
3	2	25	100	3	45	15	40	86	65	82	51	55	91
4	3	53	100	4	0	90	10	69	77	59	95	70	89
5	4	32	0	2	32	26	42	95	72	74	73	56	92
6	5	46	0	3	56	19	25	76	64	53	89	50	84
7	6	56	100	1	43	23	34	83	73	57	67	51	84
8	7	54	100	5	76	0	24	58	81	71	55	68	72
9	8	22	100	4	35	21	44	67	58	90	81	57	63
10	9	27	0	6	41	10	49	86	58	98	98	51	75
11	10	28	0	5	0	20	80	78	93	98	62	55	54
12	11	31	0	3	65	10	25	97	54	76	67	59	54
13	12	23	0	5	47	20	33	59	61	68	52	63	94
14	13	43	100	7	69	5	26	82	64	83	53	68	63
15	14	58	100	5	87	10	3	71	55	81	68	54	59
16	15	54	100	6	43	45	12	83	68	56	96	58	88
17	16	53	100	4	65	8	27	71	54	94	75	62	62
18	17	21	0	10	15	80	5	93	61	98	95	53	76
19	18	24	100	5	80	10	10	83	65	63	71	82	63
20	19	34	0	3	67	5	28	61	80	72	56	63	76
21	20	54	100	4	56	10	34	59	73	50	71	62	51
22	21	36	100	5	60	20	20	83	74	70	57	66	78
23	22	59	0	3	76	24	0	71	64	77	59	54	94
24	23	61	0	4	45	33	22	93	53	95	85	57	87
25	24	45	100	2	73	25	2	73	64	53	75	51	78
26	25	43	0	6	86	10	4	71	71	62	72	87	80
27	26	53	0	5	54	21	25	82	72	60	61	57	84
28	27	44	0	4	24	43	33	84	85	88	67	65	92
29	28	21	100	7	35	10	55	92	72	57	68	57	70
30	29	36	0	4	10	70	20	72	89	59	96	64	73
31	30	37	0	5	0	84	16	92	80	93	81	65	74

Figure 1 – *Model database example*

The airport model consequently consists of potential trainees' models and a set of parameters that is adjusted for the purpose of the airport model.

ORGANIZATIONAL STRUCTURE, FORMAL AND INFORMAL RELATIONSHIPS

Every airport is a complex technical and human infrastructure. At the early stage of the project, a close examination of various airport organizations has been done. We have collected extensive data via diligent observation of an airport's traffic, gathering data via structured questionnaires and performing interviews. The results showed that in decision making processes, formal and informal relationships play an important role (Fig. 2). Group decision making has been intensively studied and it has provided a solid base for modeling the realities of how decisions in crisis situation are made. Obviously we could not create crisis situations and study them in real time. Lack of hard evidence has been overcome by simulations and related training that provided a wealth of knowledge about an organization's functioning and social chain decision making.



(b)

Figure 2 *– Social decision making general example (a) [1] and for one airport analyzed by BEMOSA Consortium (b) [2]*

An example of 3D graphical representation of a multidimensional airport model that can be used to discover formal and informal relationships can be seen on Fig. 3.

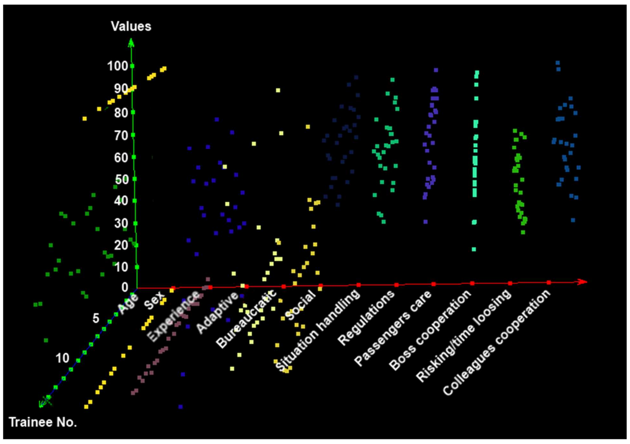


Figure 3 – *Graphical representation of informal and formal relationships at an airport*

SIMULATION

We have observed that, in time of crises, most security personnel reacted far from optimum behavior. We believe that one of the principal causes for such failures is lack of experience with critical situations. For this reason we have created various training scenarios in the form of a computer simulation accompanied with many good and bad possible solutions. Various solutions for problem solving are provided to a trainee in the form of a suggested course of action.

Each scenario represents a possible model of human interaction in the airport environment and simulates responses of participants. We have divided each scenario into so called “mini scenarios” that starts with previous decisions of the trainee and finishes with the current decision of a trainee. For example one of the scenarios deals with a dangerous looking spilled liquid. It could be a harmless soft drink or possibly a poisonous substance. Both possibilities are included in this particular training session. The “Mini scenario” starts with the security person encountering the puddle of dangerously looking liquid and finishes, with the decision of “trying to separate an area with a puddle away from passengers”. The following mini scenario starts with an action such as “calling a colleague for help” which finishes the test case.

Between beginning and end of the scenario many possible trainee actions could take place. For example: call police, try to solve the problem by themself, call a friend for a piece of advice, raise alarm etc. At the end of the session, the trainee is at liberty to write comments to indicate if he or she was not comfortable with the choices proposed by the computer simulation and indicate the preferable course of action that would be his or her strategy for problem solving. This approach provides excellent feedback that can be immediately utilized for more precise model building.

EFFECTIVE TRAINING

It is very important to understand the close connectivity and mutual interaction among dynamic model building, simulation and training programs, as this interaction is absolutely essential for effective training. This is the essence of BEMOSA research and development. It is also important to bear in mind that each airport is unique as shown in Fig. 4.

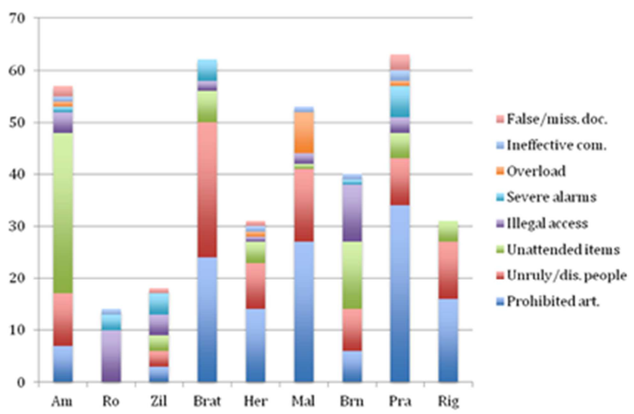


Figure 4 *– Representation of differences among the airports - Amsterdam, Rome, Zilina, Bratislava, Heraklion, Malta, Brno, Prague and Riga*

As discussed previously, each trainee has his or her unique model that allows for a unique tailor-made training program for each participant involved in the training. Access to the training program is also via a computer. This means that a trainee can go through the training any time during a shift, provided it does not interfere with his or her duties. (e.g., during the day when workload is low). This feature should be highly appreciated by airport managers because they do not need to reshuffle teams of employees because of their participation in a training program. The basic training structure and access to it is shown in Fig. 5.

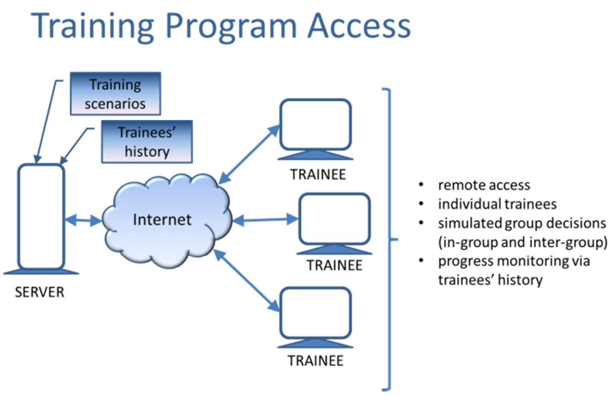


Figure 5 *- Tailor-made training*

Tailor-made training evolves in two stages as shown Fig. 6 and Fig. 8. The “First training session” enables collection of data via questionnaires and interviews in order to create the “Initial Trainee Profile”. Based on the first session, profiling of the trainee allows for a suitable scenario to be chosen. For example, according to the first screening, a trainee has tendency to take too much risk in his approach to problem solving. However, the questionnaires and interviews could provide only very rough profile of a person given that there is divergence between statements provided by people in questionnaires and real life. For this reason the following stage is very important. In the example described above, the next training session provides the trainee a scenario that requires a very careful approach to problem solving; otherwise it would lead to grave consequences. The simulation then gives the trainee feedback that mitigates his or her weaknesses in problem solving. Nothing in the scenario building is random. Scenarios are created very carefully and purposely in order to identify profiles of behaviour of the trainee as shown in Fig. 7.

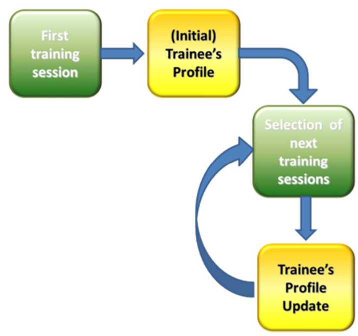


Figure 6 *- Initial stage in the training process*

In our example presented in Fig. 7, we have chosen three behavior profiles: adaptive, bureaucratic/procedures compliant and social decision making. In real life people are never a hundred percent for any given parmater. In our example, the trainee’s behavior profile is evaluated as follows: 60% adaptive, 30% bureaucratic, 10% social decision making. Based on that, the following training is tailor-made for that specific behavior profile; the trainee’s evolution is monitored and it is projected to his or her personal model.

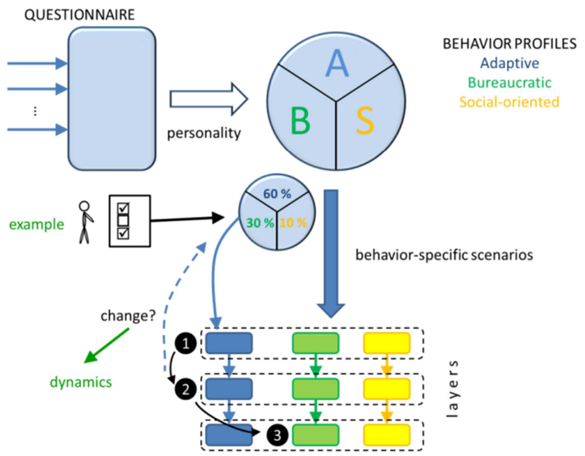


***Figure 7**- Scenario building*

The trainee communicates with the training program via the computer user interface. Scenarios are presented in the form of text, pictures and alternatively videos (Fig. 8). The "Mini scenario" could also be in a dynamic form as seen in Fig. 9. As an example, part of a "mini scenario" is simulation of a growing passenger queue resulting in significant delays, in combination with a dangerously looking object in a suitcase. Scenarios could also be presented in the form of a computer animation. Naturally, more realistic presentations of problem scenes will result in increased training efficacy.

In the "Next step selection" (Fig. 8), the options available for the trainee will be selected according to the trainee's behavior profile. For example, airport management responsible for security staff training wants to teach "adaptive" behavior that it is necessary to follow the procedures. In another training mode trainee is forced to solve a problem alone and when she or he call police for advice he or she will get "No response".

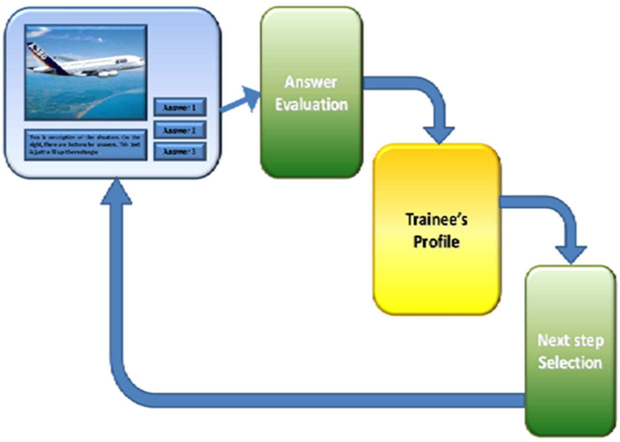


***Figure 8** - User interface and principal scheme of a training process*

Many different scenarios could be created primarily for training purposes, personality building and also for prevention of anticipated crisis situations. Several examples follow:

- Dangerously looking spilled liquid
- Screening
- Quarrel among passengers
- Unruly animal
- Attack of a passenger towards airport employee
- Unruly kids
- Non-public zone trespassing
- Stolen luggage
- Abandoned luggage

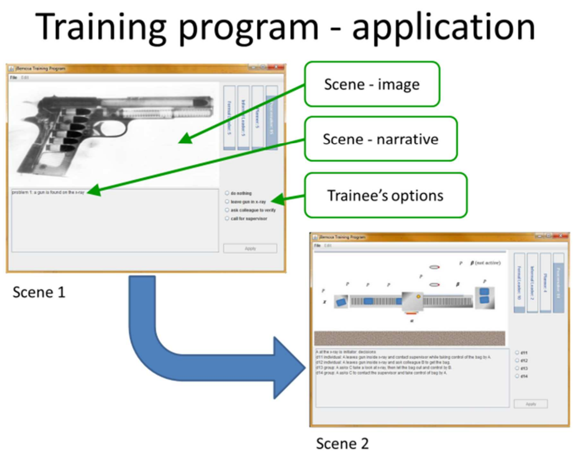


***Figure 9** - Dynamic scenario*

Evaluation

Each step of a scenario ("mini scenario") is evaluated and a trainee gets points to his/her profile (consisting of adaptive, bureaucratic, social decision making components). Calculation of points is rather sophisticated process. It is the result of an evaluation of many factors such as the tendency to act as an adaptive person, tendency to act as a person having inclination to social decision making, rules and regulation mastering, passenger care etc.

One of the major advantages of our methodology is the evaluation process that can be done by a group consisting of experts in the field of security, airport management (knowing the environment inside out), police, fire fighters etc. Evaluation is implemented to a computer simulation prior to an actual training session. This eliminates subjectivity and improves the quality of training.

Conclusion

We are certain that the significant elements for hazards elimination of hostile action in the air transport system have been built by the BEMOSA project. Importance of prevention measures is without question. Our system including modeling, simulation and training is inseparable and could contribute significantly to discover security gaps in an airport's organization. Additionally, security personnel could be well prepared for crisis situations with the help of our training methodology to avoid financial loss due to unnecessary delays, material damage, and possibly injuries and loss of lives. We have based the creation of our methodology on a vast amount of data collected in different airports of varying sizes, with different types of passenger, and different local cultures etc. This leads us to believe that the results of our development our applicable in airports across the globe.

We believe that BEMOSA project will contribute significantly to the overall European objective of eliminating hazards of hostile action in the air transport system.

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WORLD TRADE IN AIR TRANSPORT SERVICES: VALUES AND SELECTED COUNTRIES RANKING

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Abstract – *The paper provides an analysis of ten chosen countries in terms of market position on global trade in air transport services. The analysis shows trade position of these countries according to export, import, turnover, amount of balance and market share values.*

Key words – Air transport services. Export. Import. Turnover. World trade.

INTRODUCTION

Air transport facilitates access to markets, people, capital, resources and opportunities. Relationship between air transport and economic activity is comprehensive. Between 1970 and 2005, the total volume of passengers carried by world airlines increased 6.5 times from 310 million to 2 billion passengers. During the same period, world GDP tripled from 12 to 36 trillion USD (World Bank, 2008). Therefore aviation is an important component representative of global trade, world trade in air transport services included.

TRENDS IN WORLD TRADE IN AIR TRANSPORT SERVICES

Values of world trade in air transport services confirm a long-term positive dynamics in growth in spite of declines in particular years. Since 2006, the value of export and import of air transport services grew every year until 2008. In 2009 the value of export and import of air transport services decreased due to global economic crisis to similar levels as in 2006 and then again increased in 2010.

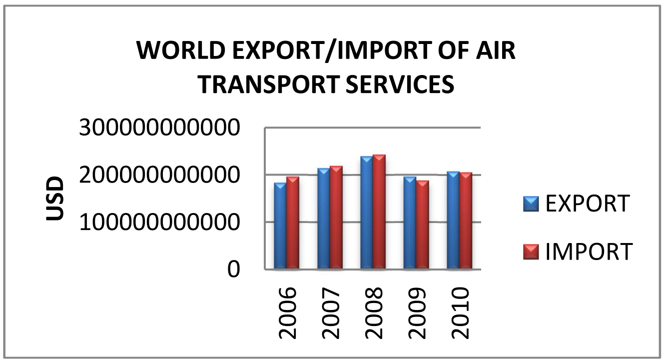

Figure 1 *– Trends in world exports and imports of air transport services (Source: Processed by author using data from International Trade Centre, 2011)*

Within 2006 - 2010, the average annual increase in export of air transport services was 1,09% and import of air transport services increased by 1,07% expressed through average composed growth annual rate. After a decline in value in 2009, the volume of exported services in air transport grew by 1,03% in 2010 and value of imported services grew by 1,04% respectively. In 2010 world imports of services amounted to 3,693 billion USD and the total import of air transport services represented 17,87% of total imported services in the world. In case of export, the total amount of exported services in the world amounted to 3,665 billion USD and the total exported air transport services represented 18,36% of total exported services in the world.

Table 1 – World exports and imports of air transport services 2006 - 2010

WORLD	2006	2007	2008	2009	2010
EXPORT (USD)	182721053000	214366642000	239241466000	195804234000	207738321000
IMPORT (USD)	195619088000	219236103000	242312235000	187904667000	205210380000

(Source: International Trade Centre, 2011)

EXPORT ANALYSIS OF SELECTED COUNTRIES

On the export side, the most important air transport services exporters are United States with the total value of exported air transport services 192 billion USD summing the values for 2006 to 2010 years, Germany with 107 billion USD and United Kingdom with 77 billion USD respectively. Average annual growth rate in the period 2006 and 2010 for the countries analyzed was achieving levels between 1,01% and 1,08%. Almost every country from selected countries recorded an increase in the value of exported air transport services in 2010 by about 1% in comparison with 2009 value on the other side, the decrease of exported air transport services values in 2009 was on average less than 1% in comparison with 2008.

IMPORT ANALYSIS OF SELECTED COUNTRIES

As can be seen in the Figure 3, the value of imported air transport services increased from 2006 to 2008 in all countries, just like the world´s value of import of air transport services. Also, the value then decreased in 2009 due to global economic crisis and increased again in 2010. The most important importers of air transport services among selected countries are United States, United Kingdom and Germany with average annual growth rate of imported air transport services in the period from 2006 to 2010 by about 1-2%. Almost every country from chosen countries recorded an increase in the value of imported air transport services in 2010 by about 1% comparing it with 2009 on the other hand, the decrease of values in 2009 was on average less than 1%.

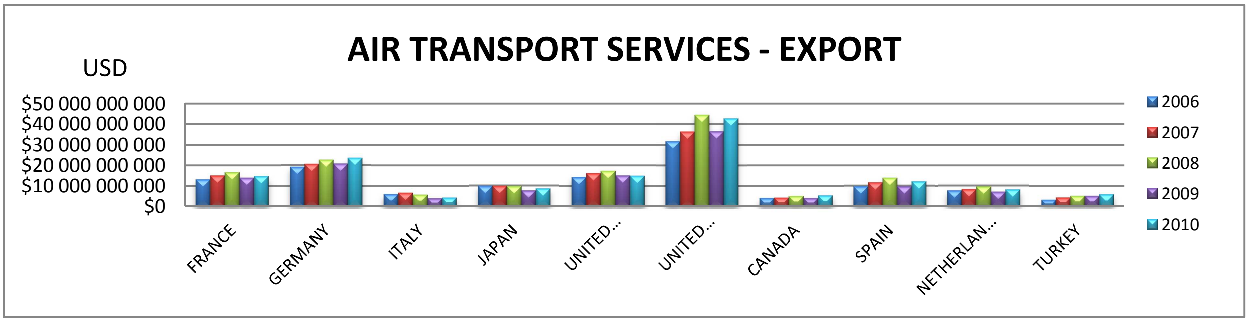

Figure 2 *– Export of air transport services by selected countries 2006-2010, (Source: Processed by author using data from International Trade Centre, 2011)*

Table 2 – Selected countries air transport services export 2006-2010

EXPORT (USD)	2006	2007	2008	2009	2010
FRANCE	13355228000	15160723000	16769327000	14094740000	14863041000
GERMANY	19330000000	20791000000	22834000000	20872000000	23762540000
ITALY	6188366000	6803643000	5852272000	4112563000	4351327000
JAPAN	9974290000	10079488000	9911087000	7876448000	8800420000
UNITED KINGDOM	14375628000	16193394000	17315488000	15084463000	15019687000
UNITED STATES	31735898000	36523552000	44559296000	36576924000	42889424000
CANADA	4286999000	4464203000	5184435000	4214854000	5500534000
SPAIN	9848948000	11747267000	13926100000	9882711000	12172741000
NETHERLANDS	7822330000	8465478000	9694218000	7238384000	8234832000
TURKEY	3389000000	4401000000	5197000000	5230000000	6027929000

(Source: International Trade Centre, 2011)

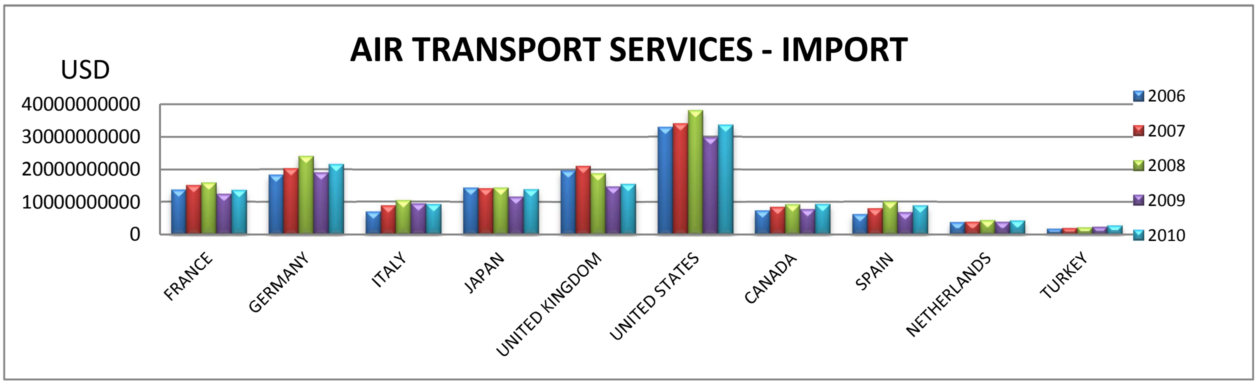

Figure 3 *– Import of air transport services by selected countries 2006-2010, (Source: Processed by author using data from International Trade Centre, 2011)*

Table 3 – Selected countries air transport services import 2006-2010

IMPORT (USD)	2006	2007	2008	2009	2010
FRANCE	13739100000	15074497000	15918263000	12477721000	13633417000
GERMANY	18349000000	20249000000	24070000000	18988000000	21566216000
ITALY	7046432000	8884016000	10456659000	9472204000	9322139000
JAPAN	14372437000	14216927000	14352887000	11660776000	13877892000
UNITED KINGDOM	19656370000	21119604000	18811828000	14788417000	15527413000
UNITED STATES	32939790000	34084972000	38066360000	29796808000	33697372000
CANADA	7391833000	8544828000	9236767000	7767474000	9412564000
SPAIN	6246072000	7983434000	10088256000	6793148000	8906139000
NETHERLANDS	3814131000	3879486000	4371626000	3868344000	4256095000
TURKEY	1792000000	1993000000	2185000000	2360000000	2837674000

(Source: International Trade Centre, 2011)

EXPORT SHARE IN WORLD TRADE IN AIR TRANSPORT SERVICES OF SELECTED COUNTRIES

The total amount of United States exported air transport services in the period from 2006 to 2010 was 34,71% of total world export of air transport services. The share of German export on the world trade was 20,32%, the share of United Kingdom and France was about 13% - 19%. Export values of other selected countries such as Spain, Netherlands, Italy, Japan, Canada and Turkey ranged between 2% and 13%.

IMPORT SHARE IN WORLD TRADE IN AIR TRANSPORT SERVICES OF SELECTED COUNTRIES

Table shows the share of air transport imports of selected countries on total amount of world imported air transport services. Between years 2006 and 2010 United States emerge with the average annual market share of 16,1% as a key player in the air transport services trade along with Germany 9,9% and United Kingdom with the average annual market share of 8,6%.

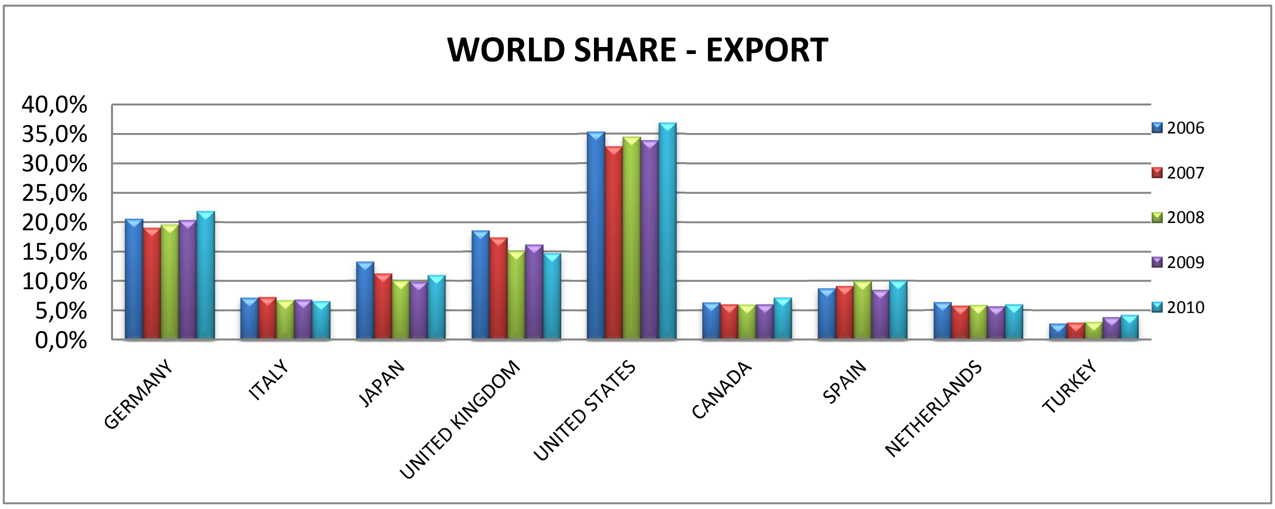

Figure 4 *– Export of air transport services - world shares of selected countries 2006-2010, (Source: Processed by author using data from International Trade Centre, 2011)*

Table 4 – Export of air transport services – world shares of selected countries 2006-2010

EXPORT SHARE (%)	2006	2007	2008	2009	2010
FRANCE	14,8%	14,1%	13,7%	13,6%	13,7%
GERMANY	20,6%	19,1%	19,6%	20,4%	21,9%
ITALY	7,2%	7,3%	6,8%	6,9%	6,6%
JAPAN	13,3%	11,3%	10,1%	9,9%	11,0%
UNITED KINGDOM	18,6%	17,4%	15,1%	16,2%	14,7%
UNITED STATES	35,4%	32,9%	34,5%	33,9%	36,9%
CANADA	6,4%	6,1%	6,0%	6,1%	7,2%
SPAIN	8,8%	9,2%	10,0%	8,5%	10,1%
NETHERLANDS	6,4%	5,8%	5,9%	5,7%	6,0%
TURKEY	2,8%	3,0%	3,1%	3,9%	4,3%

(Source: Processed by author using data from International Trade Centre, 2011)

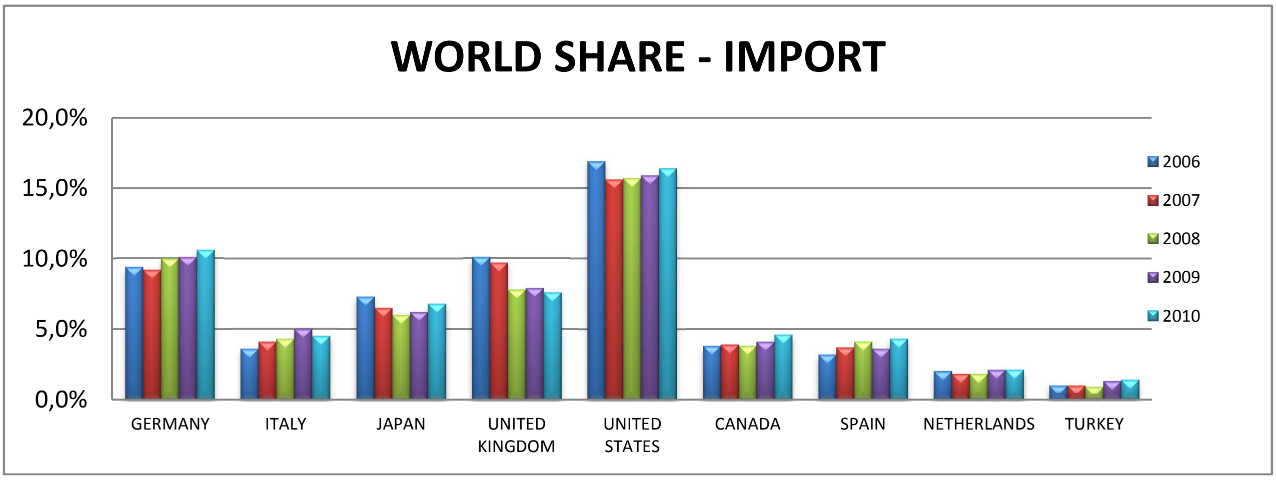

Figure 5 *– Import of air transport services - world shares of selected countries 2006-2010, (Source: Processed by author using data from International Trade Centre, 2011)*

Table 4 – Import of air transport services – world shares of selected countries 2006-2010, (Source: Processed by author using data from International Trade Centre, 2011)

IMPORT SHARE (%)	2006	2007	2008	2009	2010
FRANCE	7,0%	6,9%	6,6%	6,6%	6,6%
GERMANY	9,4%	9,2%	10,0%	10,1%	10,6%
ITALY	3,6%	4,1%	4,3%	5,0%	4,5%
JAPAN	7,3%	6,5%	6,0%	6,2%	6,8%
UNITED KINGDOM	10,1%	9,7%	7,8%	7,9%	7,6%
UNITED STATES	16,9%	15,6%	15,7%	15,9%	16,4%
CANADA	3,8%	3,9%	3,8%	4,1%	4,6%
SPAIN	3,2%	3,7%	4,1%	3,6%	4,3%
NETHERLANDS	2,0%	1,8%	1,8%	2,1%	2,1%
TURKEY	1,0%	1,0%	0,9%	1,3%	1,4%

(Source: Processed by author using data from International Trade Centre, 2011)

AMOUNT OF BALANCE ANALYSIS

Table 5 shows amount of balance in air transport services of selected countries. Since 2007 United States and France recorded positive trade balances. Countries such as Japan, Italy and Canada imported more air transport services as they exported in period from 2006 to 2010. Netherlands, Turkey and Spain exported more air transport services in period from 2006 to 2010 as they imported. Germany exported more air transport services than imported in mentioned period with the exception of 2008. The biggest surplus had achieved by United States between 2006 and 2010. On the other side, the biggest shortage, about -5,4 billion USD, had Italy in period from 2006 to 2010. In 2010 represented Japan´s value of shortage -5,1 billion USD which means, that Japan imported more air transport services than exported. United States confirmed its position of the biggest exporter of air transport services in 2010 with value of surplus about 9,2 billion USD.

Table 5 – Selected countries amount of balance 2006-2010

AMOUNT OF BALANCE (USD)	2006	2007	2008	2009	2010
FRANCE	-383872000	86226000	851064000	1617019000	1229624000
GERMANY	981000000	542000000	-1236000000	1884000000	2196324000
ITALY	-858066000	-2080373000	-4604387000	-5359641000	-4970812000
JAPAN	-4398147000	-4137439000	-4441800000	-3784328000	-5077472000
UNITED KINGDOM	-5280742000	-4926210000	-1496340000	296046000	-507726000
UNITED STATES	-1203892000	2438580000	6492936000	6780116000	9192052000
CANADA	-3104834000	-4080625000	-4052332000	-3552620000	-3912030000
SPAIN	3602876000	3763833000	3837844000	3089563000	3266602000
NETHERLANDS	4008199000	4585992000	5322592000	3370040000	3978737000
TURKEY	1597000000	2408000000	3012000000	2870000000	3190255000

(Source: Processed by author using data from International Trade Centre, 2011)

TURNOVER ANALYSIS

Since 2006 United States hold a leading position in air transport services trade with average annual turnover of 72,2 billion USD. The rest of Great Five including United Kingdom, Germany, France and Japan counted average annual turnover between values 23 and 42 billion USD in the years analyzed. In 2010 United States showed turnover´s value 76,6 billion USD.

Table 5 shows on year by year basis turnover dynamics of turnover between 2009 and 2010 using composed average growth rate. Spain achieved the biggest value of average annual turnover dynamics, slightly more than 26%. The countries with high turnover dynamics are also Canada with turnover dynamics more than 24%, Japan and Turkey with turnover dynamics more than 16%. The leader in air transport services trade United States had turnover dynamics about 15,4%, which represent the middle position within the group of mentioned countries. Low average annual turnover composed growth rate reported United Kingdom about 2,3%.

Table 5 – Turnover dynamics of selected countries between 2009 and 2010

TURNOVER DYNAMICS	2009-2010
SPAIN	26,40 %
CANADA	24,46 %
TURKEY	16,81 %
JAPAN	16,08 %
UNITED STATES	15,39 %
GERMANY	13,72 %
NETHERLANDS	12,46 %
FRANCE	7,24 %
UNITED KINGDOM	2,26 %
ITALY	0,65 %

(Source: Processed by author using data from International Trade Centre, 2011)

CONCLUSION

Our analysis shows that Great Five (United States, United Kingdom, Germany, France and Japan) represent cardinal countries in world trade in air services with regard to turnover robustness. United States holds its position of a leader in global trade in air transport services with the value of turnover about 76,6 billion USD in 2010 and being the biggest exporter and importer of air transport services since 2006 until now.

On the side of export of air transport services in 2010 changes have occurred in Great Five group as this group was entered by Spain excluding Japan out of the G5. However Japan had in 2010 the bigger value of turnover than Spain, Spain exported more air transport services than Japan in 2010. The Great Five in import of air transport services in 2010 was without changes comparing to Great Five in turnover of air transport services.

Amount of balance analysis shows that countries like Spain, Turkey and Netherlands had during the 2006 and 2010 period long-term positive amount of balance position on trade in air transport services. That means that these countries exported more air transport services every year during mentioned period. On the other hand, Japan and Italy had long-term negative amount of balance position on trade in air transport services, so they imported more air transport services as they exported during mentioned period.

The biggest annual increase in turnover from 2009 to 2010 recorded Spain with 26,4% and Canada with 24,5%. Group of countries with low annual increase, less than 10%, between 2009 and 2010 includes France, United Kingdom and Italy. The value of more than 10% and less than 20% of annual increase in turnover had in mentioned period Netherlands, United States, Japan, Turkey and Germany.

The position of export and import leader represents United States with the export share more than 35% in global air transport services trade in 2010. United States are also a leader in import of air transport services with the share more than 16% in global air transport services trade in 2010. Since 2009 has trade in air transport services growing tendency after a slight climb-down of global economic crisis. Average annual growth rate of world export and import of air transported services represented during the period 2006 and 2010 more than 1%. Effect of global economic crisis caused in 2009 decrease of about 1% of export and import of air transport services in chosen countries in comparison with 2008. Trade in air transport services accounted for about one fifth of global trade in services in 2010.

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ADVANCE AMPHIBIOUS OPTIMIZATION CONCEPT DESIGN BASED ON A FUTURISTIC 2050 VISION

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Abstract – *The purpose of this paper is to explore more radical, environmentally efficient, and innovative technologies for future aeronautical transport concepts on a 2050 vision. Aircraft design is affected in such a way, that a radical thinking is out of the question, showing no actual progress in this field of study. A new concept will be introduced, omitting any of the actual restrictions in which a radical thinking could be compromise. This will enable the creation of "out of the box" ideas in aircraft design, in this case the design of an advance amphibious design. The preliminary design development lead to the creation of an Advance Amphibian Aircraft (AAA) that exceeds its water capabilities by the use of a trimaran boat hull concept, and excels the air performance due to the high results generated by the Advance Amphibian Aircraft. A new design optimization process is introduced in order to adapt the trimaran concept into the landplane configuration.*

Keywords – Seaplanes, Amphibians, 2050 Visionary Aircraft Concepts, Trimaran, Optimization Design Method.

I. INTRODUCTION

The versatility of transportation vehicles in a futuristic idea will allow an increase in a wider perspective into looking greater designs. However, due to the economical constraints the world faces today, this "out of the box" thinking is restricted to the same problems, money and social acceptance. Now, according to the European Vision 2020 guidelines [1], these have become: more affordable, safer, cleaner and quieter. During the postwar era, the empirical guidelines during those days were: higher, further, and faster.

Some examples of this futuristic vision are the creation of flying cars, water hover vehicles, among others. However, there is a design of such vehicles that had existed for decades, amphibious aircraft. Current designs are obsolete and lack an advance approach. Updates to these vehicles have been stagnated since the new guidelines do not meet the requirements into creating advance designs. The market is unreliable, and investing in such vehicles will be risky, an even if it is created a cleaner, safer, and quieter amphibian this will not be affordable. For this instance, a new vision would be created focusing in the creation of advance aircraft designs.

This new vision will be called Future Air Transport Concept Technologies for 2050 in which the new guidelines will be: safer, quieter, cleaner and efficient. An efficient concept will adopt the early guidelines (higher, further, and faster), with no restrictions in material, capital or infrastructure for planning, designing, testing, and constructing. Let us recall this is just a radical way of thinking in order to expand the researcher's mind with no restrictions what so ever.

II. PRELIMINARY DESIGN DEVELOPMENT AND ANALYSIS

A. Introduction

In this 2050 Visionary Concept of an advance amphibious aircraft, the guidelines stated before will be taken into account in order to implement this idea into an amphibian design. However, not only the design characteristics will make a decisive change in the preliminary method, as well the computational optimization design method will take a new approach.

Some literature review approaches the design of a seaplane by first designing the floating device (i.e. the boat hull or floats) and then designing the aircraft components (wings, fuselage, empennage, etc.) [2], [3], [4]. The first steps for amphibian design is to create a boat hull or floats that will be stable, with satisfy aerodynamic and hydrodynamic properties, and will support water loads. The design of the aircraft segment depends on the properties of the hull or floats. This gives the amphibian aircraft designer a disadvantage in having an open mind on the manner on how to elaborate an advance amphibian aircraft design with an "out of the box" configuration. This approach limits the theoretical thinking into a method restricted by certain design parameters, on the contrary on what the 2050 visionary concept guidelines stand for. Nonetheless, the creativity to elaborate an advance amphibian design will push the limits into proposing a new design optimization method. This research paper will propose a new design seaplane method by designing each of the seaplane segments ("ship vessel" and "aircraft") in a separate manner, opposing the design method proposed by the old reports. This idea will adapt, instead, to design first the "aircraft" segment and then adapting the "boat" segment into the conceptual design. There are three main advantages of adapting this conceptual design method:

1. The “aircraft” segment can be design in a separate manner, using whatever optimization method the designer will like to choose. The “boat” optimization design method will be elaborated in such a manner that will adapt which ever aircraft configuration (Conventional, Blended Wing Body, Canard, V-Tail, etc) and will optimized the desire boat hull design parameters. Therefore,
2. The conversion of an existing landplane structure into a seaplane configuration will be elaborated into this design method.
3. Simplification of this method will expand the complexity of creating an advance amphibian “boat” segment by studying a more reliable hull design and running separate trial tests.

B. *Mathematical Design Development*

In the design of an aircraft vehicle, there are many proposed methods that are utilized to optimize the desire design. Raymer [5] uses a proposed design method mainly used in a Class I sizing process based largely on empirical methods. Many other design methods are involved and introduced depending on the aircraft configuration (canard, Blended Wing Body, Flying Wing). The aircraft will be design in a separate manner from the ship vessel, and when the two designs are elaborated, a new design method will be introduced in order to blend the aircraft and vessel into an amphibian configuration.

A sizing mathematical code developed in MATLAB was created in order to run specific theoretical calculations that will be necessary to size the optimum seaplane trimaran design. The sizing code is set up to work with a number of different aircraft configurations which would then add the desire floating device (boat hull, twin floats, wing tip tanks, trimaran, hydrofoils) to transform the landplane aircraft into an amphibious configuration. The following flowchart (Fig. 1) shows the proposed optimization design method.

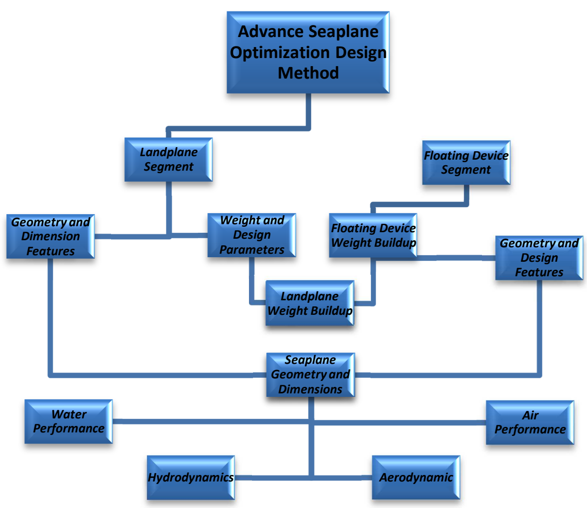

Fig. 1: MATLAB Mathematical Code Flow Chart

The code will work in two separate optimization methods. First it will calculate the landplane aircraft. Using the proposed design method it will first input fix parameters, (Aspect Ratio *AR*, Wing Loading *W/S*, and Thrust Available T_A) to attain the desire design. The code will run iteration loops until the initial guess Takeoff Gross Weight (TOGW) matches the calculated Gross Weight (GW) as shown from Fig. 2. This will give output values of the landplane that will be required to calculate the floating device. However, the designer may be eligible to use any computation device or code to elaborate the most optimum aircraft design.

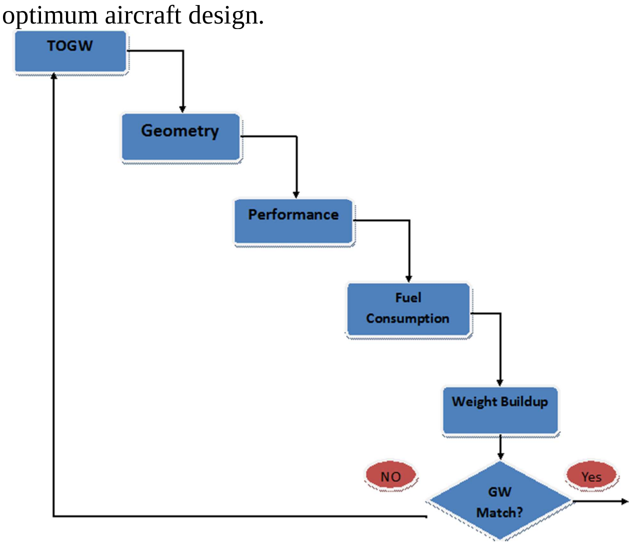

Fig. 2: Sizing Code Flowchart

With the aircraft sized, the output characteristics of the landplane will be input into the floating device segment of the code. Fig. 3 shows the input characteristics needed from the landplane necessary to calculate the floating device characteristics.

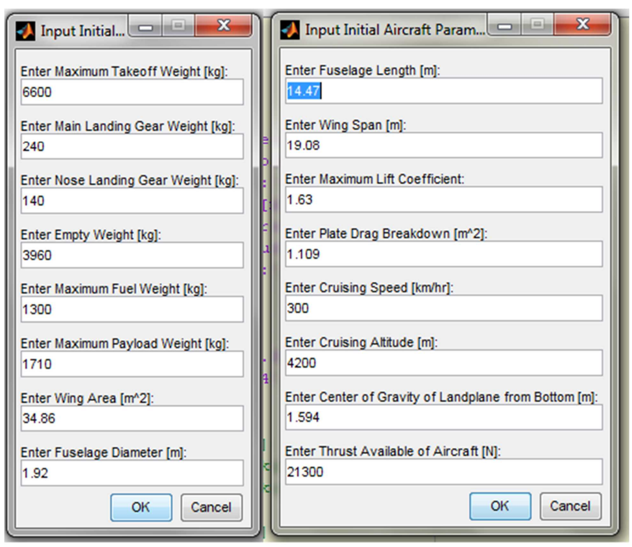

Fig. 3: Input Landplane Characteristics

The following individual component weights are sent to functions which will calculate other components of the seaplane. Geometry and performance characteristics are then output and with this data obtained, a picture showing the basic geometry is drawn.

C. Trimaran Geometry Calculations

The design method of an amphibious aircraft implemented will be using a wide variety of methods in order to compare and maximize the desire results. Yet, in this paper an advance design will be presented as a reference and comparison. The trimaran technology superiority in terms of stability because of the arrangement of the hull is such that individual centers of buoyancies have a righting moment about the centre of gravity that helps in stabilizing the vessel. Past studies conducted on trimaran shows that wave resistance of trimarans is significantly lower compared to an equivalent catamaran [13]. For this instance, in theory, trimaran has superior seagoing performance. Since this amphibian aircraft must excel in both hydrostatic and hydrodynamic, advance ideas on how to increase flight and water performance will also be introduced. Retracting the extra components of the floats will reduce the aerodynamic drag. The floats will form a single component embodied to the hull and fuselage when retracted. This will reduce the drag form interference factor added by the floats and boat hull [5], hence decreasing the aerodynamic drag.

1) Boat Hull Calculations: The primary functions of any hull is to give the amphibious aircraft buoyancy, and to provide longitudinal and transverse stability on the water and when underway to takeoff speeds. The float or hull must provide reasonable resistance while in the water so that the aircraft is capable of taking-off with the power it has available. It must also be designed in such a way so as to hold landing impact pressures to reasonable levels. All of these factors can drastically change the form of the hull.

First, in order to find the necessary calculations for the geometry of a boat hull, the fundamentals of Archimedes Principle must be understood. The volume (*V*) required for the seaplane to stay afloat on water will be calculated based on the displacement weight (Δ_0), as shown in eq. (**1**).

$$V = \frac{\Delta_0}{w} \qquad (1)$$

Where (*w*) is the density of the fluid. Calculation of the total volume of the trimaran should take into account an extra 100% of the total displacement, which represents the “reserve of buoyancy” [4]. Based on the literature review, generally the beam is established as the design reference parameter of seaplane floats and hull [6]. The beam is the widest section of the float as shown in Fig. 4.

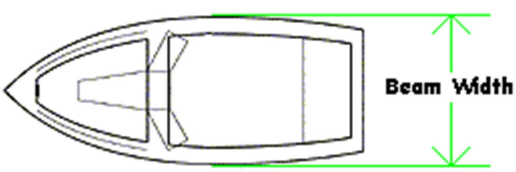

Fig. 4: Beam Width of a Conventional Boat [8]

From fluid dynamics, Tomaszewski came with an empirical formula on how to calculate the beam (*b*) of a hull based on a beam load coefficient (C_{Δ_0}) [6]:

$$b_{hull} = \sqrt[3]{\frac{\Delta_0}{C_{\Delta_0} w}} \qquad (2)$$

The length of the boat hull is calculated using eq. (3).

$$L_{hull} = \frac{R_{LB}\Delta_0}{b_{hull}^2} \qquad (3)$$

where R_{LB} is the length-to-beam ratio. The length of the boat hull is then compared to the minimum fuselage length set by the designer. To calculate the height of the hull, it is simply multiply the beam of the hull times 0.65.

2) Trimaran Hull Calculations: A trimaran is a multihulled boat consisting of a main hull and a two smaller outrigger hulls, attached to the main hull with lateral struts, as shown in Fig. 5.

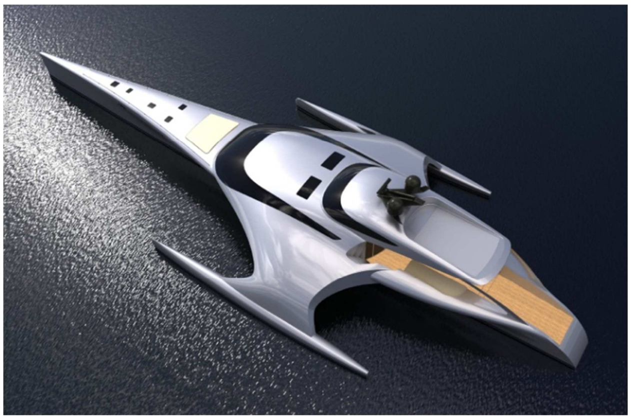

Fig. 5: Trimaran Example [7]

Few studies on the design of trimaran dimensions have been conducted and the empirical formulas given before are well adapted to conventional floats and boat hulls, but not for a trimaran concept. A new approach must then be manipulated in order to find suitable formulas for the design process of the trimaran device. The key characteristic connection between floats and boat hulls is the slenderness ratio of a trimaran (*SLR*) shown in eq. (**4**).

$$SLR = \frac{L}{b} \qquad (4)$$

The slenderness ratio takes values depending upon the functional utility of the vessel in question. The standard values of slenderness ratio are shown in Fig. 6.

SLR	8-10: 1	For slow cruising vessels
	12-14: 1	For performance cruisers
	20: 1	For extreme racers

Fig. 6: Slenderness Ratio [8]

An important component of designing a hull or float is the forebody length. The size of the forebody represents compromising between flight requirements and seaworthiness at low speeds on water. If the length and the beam are too great, the structural weight and the aerodynamic drag limit the performance of the whole seaplane. On the other hand, if the length and the beam are too short, the spray characteristics become a limitation in gross weight and increase the hazards of operation in rough water [9]. The forebody length (l_f) in for a given beam load coefficient is [6]:

$$l_f = b\sqrt{\frac{C_{\Delta_0}}{k}} \qquad (5)$$

From hydrodynamic point of view, the afterbody (l_a) assists getting over the hump and to provide buoyancy at rest. A relation between the length of the forebody and the afterbody is shown in eq. (6) [10]:

$$l_a = (110\% \; to \; 115\%) l_f \qquad (6)$$

Since the total length (L) of the hull or float is as follows:

$$L = l_f + l_a \qquad (7)$$

Rearranging eqs. (4) - (7), and choosing 111% of forebody to afterbody length, the following formulas are obtained:

$$\frac{l_f}{b} = \frac{SLR}{2.11} \qquad (8)$$

$$C_{\Delta_0} = k\left(\frac{l_f}{b}\right)^2 \qquad (9)$$

The only two unknown variables are spray coefficient (k) and slenderness ratio (SLR). Spray coefficient can be selected depending on the mission characteristics shown in Table 1.

Table 1: Spray Coefficient Factors

k = 0.0525	Very Light Spray
k = 0.0675	Satisfactory Spray
k = 0.0825	Heavy but acceptable Spray
k = 0.0975	Excessive Spray

Selecting the appropriate spray coefficient (k) and slenderness ratio (SLR), the beam of the hull (b) can be calculated from eq. (2). With the slenderness ratio (SLR) selected and the beam hull calculated, the total length of the boat hull (L) is calculated using eq. (4). However, there is a constraint in calculating the hull length. The hull length should not exceed the length of the landplane fuselage. With the beam hull other characteristics of the hull can be calculated (Bow Height, Forebody Deadrise Angle, Step Height, etc.). In order to maximize the efficiency of the trimaran concept, the outriggers (floats) should be half the length of the main hull [8]. Therefore, with the spray coefficient (k) and slenderness ratio (SLR) selected, the beam of the outriggers can be calculated from eq. (4). The same approach as the main hull will apply to calculate the rest of the outrigger characteristics.

III. PRELIMINARY TESTING AND RESULTS

A. Preliminary Testing

In order to validate the functionality of the sizing code and to ensure that the sizing algorithms used in the code are working properly over a range of aircraft types, geometry of an aircraft was run through the code to determine how well the coded algorithms predicted the takeoff weight and performance parameters. The code will be validated using the LET L-140 data [11]. The following comparison data obtained from the sizing code is shown in Table 2. A CAD (Computer Aided Design) Model is shown in Fig. 7 of the typical Landplane aircraft.

Table 2: Typical Aircraft Parameters

Parameters	*Typical*	*Let L-410*	*% Error*
Gross Weight [kg]	6,500	6,600	1.52%
Empty Weight [kg]	3,900	4,020	2.99%
Max Fuel [kg]	1,300	1,300	0.00%
Fuselage Length [m]	14.47	14.43	0.28%
Wing Area [m^2]	34.86	34.9	0.11%
Wing Span [m]	19.08	19.7	3.15%
Max Speed [km/hr]	414	390	6.15%
Rate of Climb [m/s]	8.2	7.1	15.49%
Absolute Ceiling [km]	7.2	7.4	2.70%
Thrust Available [N]	21,300	25,500	16.47%

Fig. 7: 3-D CAD Model of Conventional Landplane Aircraft

B. Preliminary Results

Using the initial inputs from Fig. 3 and the initial Gross Weight (GW) of the aircraft, the weight of the boat hull and floats will be calculated using Langley's experimental testing. Calculation of Float Weight (W_f) was elaborated using a comparative curve of area and streamline form [2], in which the following equation was derived:

$$W_f = GW0.0365 + 43.5 \qquad (10)$$

Langley calculates the weight of the boat hull based on statistics using materials from 1935; he calculated that the weight of the boat hull is around 12% the total gross weight of the aircraft.

With the introduction of new materials such as composites, the weight parameters of the floating device could be reduced. Most composite materials have a density of around 1.60 g/m^3, as compared to most aluminum alloys 2.8 g/m^3. It can be safely assumed that the weight of the material can be reduced by 50%.

One of the main goals of this research is to create a modern amphibian that has improved water capabilities. In order to excel in its hydrodynamics, the amphibian must obtain the most suitable design characteristics both in strength and performance. As explained in the design development, using eqs. (2) - (**9**) and selecting the desire spray coefficient (*k*) and slenderness ratio (*SLR,)* the desire dimensions of the trimaran device was elaborated with the aid of the sizing code which will then be added to the landplane aircraft to create the amphibian. The following image (Fig. 8) shows the amphibian aircraft with the trimaran concept.

Fig. 8: CAD Model of Amphibian with Trimaran Concept

The sizing code will then analyzed the hydrostatic, hydrodynamic, structural support, and other parameters in order to compare the functionality of its water and air performance.

The first step is to compare the hydrodynamic characteristics of the amphibian by calculating the water resistance of the floating device. This will calculate if the available thrust will be powerful enough for the amphibian to takeoff from water. To calculate the water resistance (R_w) the following equation is used:

$$R_w = 0.5 C_{R_w} w A U^2 \qquad (11)$$

where C_{R_w} is the coefficient of water resistance, A is the area of load water plane, and U is the velocity of the amphibian. The coefficient of water resistance is divided into wave coefficient and coefficient of viscous resistance. Wave coefficient is the resistance of water to the movement of the body across the formation of waves. Viscous resistance is the resistance caused by the friction between the fluid and the object, in this case the floating device, in which factors such as velocity, geometry, and dynamic viscosity are taken into account. Then using eq. (11) and plotting water resistance (R_w) as a function of velocity (U) the following graph was obtained.

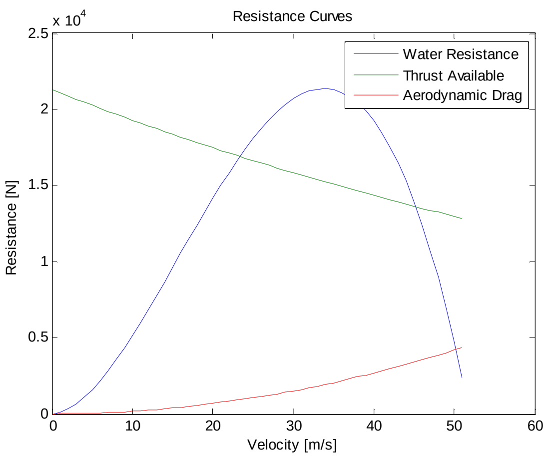

Fig. 9: Water Resistance, Thrust Available and Aerodynamic Drag

The following graph, Fig. 9, shows the water resistance curve exceeding the thrust available at takeoff; then the aircraft will not be able to takeoff from water. The water curve forms a hump at its maximum peak. This peak is the point where the amphibian starts to separate from the water. Clearly, the available thrust of 21,300 [N] is not enough for the amphibian to takeoff from water. By that means, the thrust available must be increased, changing other parameters from the initial landplane configuration. The necessary thrust available for the seaplane to takeoff from water is 30,000 [N], as shown from the following graph.

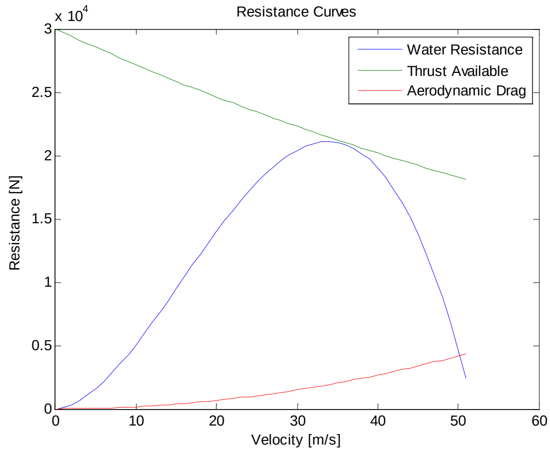

Fig. 10: Water Resistance, Thrust Available and Aerodynamic Drag

Since the seaplane was design with turboprop engines, the available thrust lowers with speed and altitude. Therefore the use of a turbofan engine will be utilized to compare the thrust performance of the seaplane. An example will be to plot the same curves but comparing thrust available of a turboprop engine and a turbofan engine. For comparison purposes, the Thrust Available used will be of 24,000 [N].

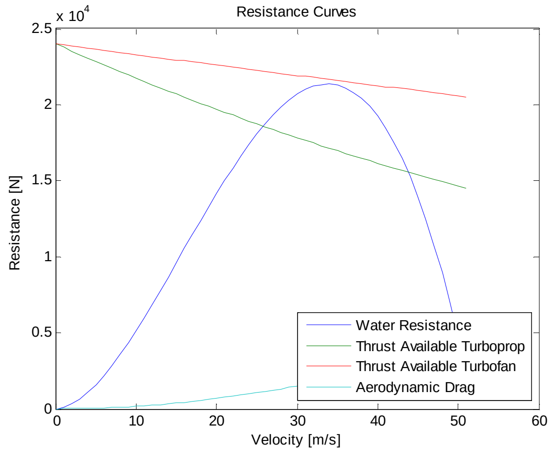

Fig. 11: Water Resistance, Thrust Available and Aerodynamic Drag

Using a thrust available of 24,000 [N], the turbofan engine will be able to takeoff from water, rather than the turboprop engine that will require more thrust (30,000 [N]) to takeoff.

When the sizing code satisfies the water performance, it will then analyse the air performance of the aircraft. It is essential to think in techniques to reduce the aerodynamic drag caused by the outriggers. A useful technique is to retract the floats into a position where the floats will create a single body shape, either to the wing or the fuselage. It is explained when an odd shape component is being calculated, an increase in drag form interference factor must be added to the actual value [5]. It is also explained: “The form factor is a measure of how “streamlined” the component is; it is a function of the component thickness-to-length ratio” [12]. In this case, the form interference factor (*F*) from of a flying boat hull must increase by a 50%, and for floats from 75%-300%, depending on the shape. It was then assumed that the interference factor for the boat hull had an increase of 10%, rather than 50% increased, due to the perfect aerodynamic shape mounted of the hull will be with respect to the fuselage. The outrigger will be retracted into the boat hull, creating a “smoother” body that will result in less aerodynamic drag, as shown in Fig. 12 [14].

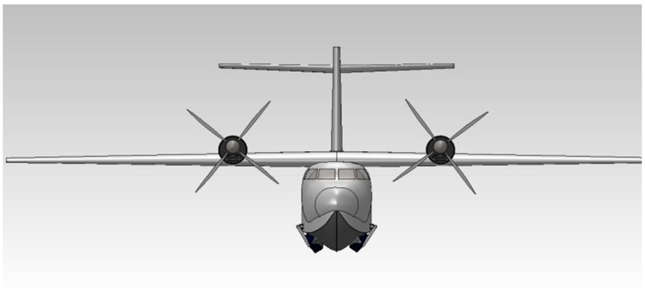

Fig. 12: Trimaran Outriggers Retracted unto the Boat Hull

With the calculation of the aerodynamic drag of the landplane, and the excess drag generated by the vessel, a comparison drug curves with thrust available would be plotted in order to locate the maximum speeds the landplane or the seaplane can attain.

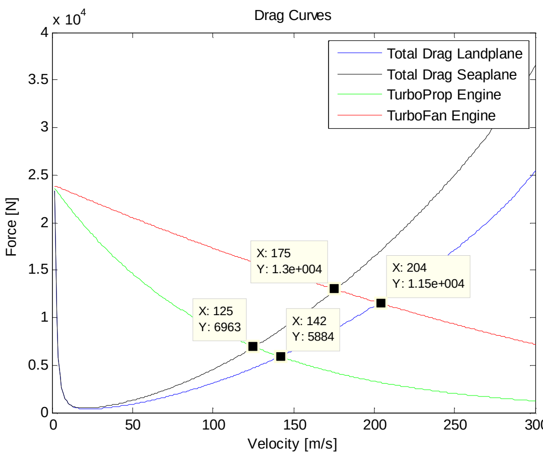

Fig. 13: Drug Curves and Thrust as a function of Speed

Since the seaplane generates more aerodynamic drag caused by the excess of extra components (outriggers), the maximum speed will be less compare to the landplane aircraft.

C. Advance Amphibian Results based on 2050 Concept

The preliminary testing gave an idea unto which method will give the desire results that were given in the points from the 2050 visionary concept. First, instead of using turboprop engines, this amphibian aircraft will be replaced with modern and more powerful turbofan engines that will generate more thrust. A trimaran hull will give the amphibian a greater water speed and resistance. The retracting system will decrease structural support, hence decreasing the extra weight, and the retracting system will decrease significantly the aerodynamic drag at flight. In such case, a new technique could be introduced. Instead of retracting the outriggers and forming a single body with the boat hull, a final solution is to place the floats inside the boat hull, as shown in Fig. 14.

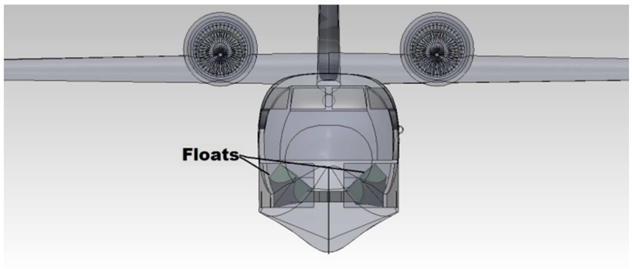

Fig. 14: Example CAD Model with undercarriage Floats

The floats will be retracted inside the boat hull, the same way the landing gear is retracted undercarriage. The only drawback will be the added structural support required, compromising an increase in weight of the strutting.

Then, utilizing the input data shown in Fig. 3, but changing the Thrust Available to 24,000 [N] and a turbofan engine, the following altitude envelope and payload range diagrams were obtained.

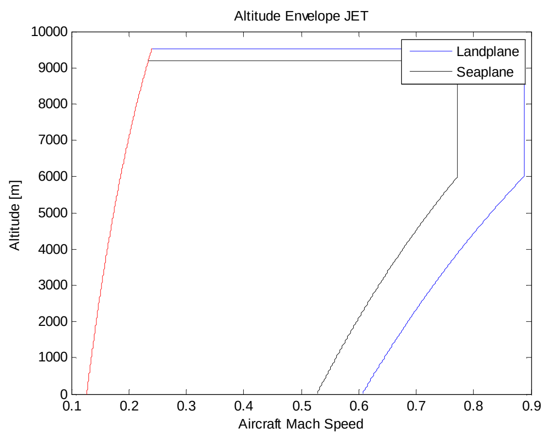

Fig. 15: Flight Envelope

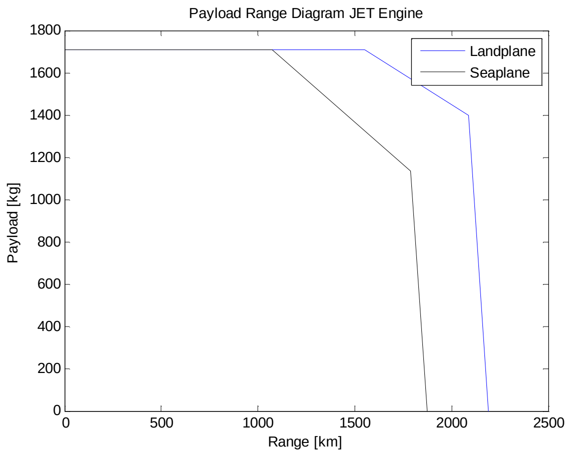

Fig. 16: Payload Range Diagram

Both diagrams show a trend between the air performance of the landplane and the seaplane aircrafts. Certainly, the performance of the seaplane will be less compared to the landplane due to the fact of the extra weight the trimaran generates, as well as the extra aerodynamic drag that will increase thrust consumption.

IV. CONCLUSIONS

The preliminary results show some of the advantages of using the trimaran concept into a seaplane design, and the increase in flight performance when the floats are retracted. The design excels in hydrostatic stability. The water speed that a trimaran shows is also significant, in which water resistance is less compared when using other floating aid devices such as wing tip floats or stabilizers.

For the flight performance, mounting the floats inside the undercarriage decreases significantly the drag as compared to an extended position. The flight performance of the seaplane increases the rate of climb, range, and endurance.

The aim of this research is to design an "out of the box" idea that will stand out not only because of its improved performance, as well as its unique design idea. On a long term basis, a brand new seaplane can be design as well as suitable infrastructure (seaports) in order to increase seaplane market and operations. An advance amphibian aircraft emerges, exceeding both water and air performance on any kind of amphibian aircraft of its type. The theoretical design exceeds the "out of the box" thinking, as well as the aesthetic design. The advance amphibian aircraft gets a futuristic design that will attract the attention of investors, and will get a high social acceptance.

The final results of the Advance Amphibian Aircraft are presented in the following Table 3. As a result, with the aid of Computer Aided Design (CAD) software, SOLIDWORKS, a model was elaborated to show a futuristic picture of this advance amphibian design shown in Fig 17, Fig 18, and Fig 19.

Table 3: Advance Amphibian Aircraft (AAA) Final Results

Parameters	*AAA*
Gross Weight [kg]	6,600
Empty Weight [kg]	3,900
Max Fuel [kg]	1,300
Fuselage Length [m]	14.47
Wing Area [m^2]	34.86
Wing Span [m]	19.08
Max Speed [km/hr]	645
Rate of Climb [m/s]	13.8
Absolute Ceiling [m]	9,195
Maximum Range [km]	1,787
Thrust [N]	24,000

Fig 17: Futuristic CAD Model of a Advance Amphibian Aircraft (AAA)

Fig 18: Futuristic CAD Model of Advance Amphibian Aircraft (AAA) takeoff from Seaport

Fig 19: Futuristic CAD Model of a turboprop Seaplane

ACKNOWLEDGMENT

I want to give a special thanks to my supervisor, Dr. Ladislav Smrcek, for all his collaboration, support, and help throughout this project. Also a special gratitude to the University of Glasgow for the support on equipment and facilities provided in order to conduct this MSc Research Project.

I would also like to thank Dr. Gerardo Aragon for his support and guidance in the elaboration of the optimization sizing code.

Last, thanks to all of my friends and family that gave me advice, guidance, support, and company during this research project.

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THE RESPONSE OF THE CENTRAL EUROPEAN AVIATION MARKET DURING THE PRESENT VARIABLE ECONOMIC PERIOD

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Abstract *– Air transport is a reflection of the economic performance of the global and national economy. The economic crisis has influenced the results of the aviation industry since 2008. Reports about the end of the crisis vary, as far as some optimistic and pessimistic forecasts are concerned. The author examines the development of the air transport market in Central Europe. The study used selected subjects of the aviation market i.e. airlines, airports and air traffic control. The results show the different effects in various segments of aviation, as well as in geographic areas.*

Key words – Economic crisis, airport, airline Air traffic control, recovery.

AIR TRANSPORT AND ECONOMY – EXPECTATIONS UNTIL 2030

Air transport reflects the economic performance of the economy. Air transportation services and economic development interact with each other through a series of indicators. The country's economic activity in turn generates the needs for passenger travel and cargo and the demand for air transportation services. Air transport reflects the economic performance of the economy. Air transportation services and economic development interact with each other through a series of indicators.

The current performance of air transport in Europe generally gives little optimistic signals. The question is whether it is useful to consider the development of air transport and planning for the future.

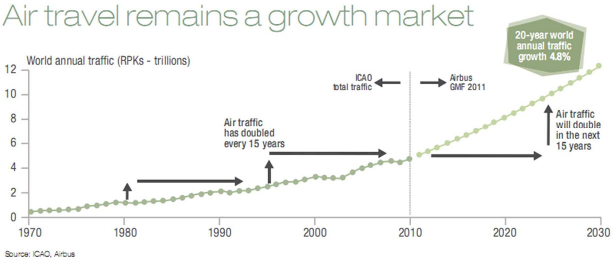

Figure 1 – Airbus forecast 2010-2030 [11]

From the perspective of a longer time horizon, however, the situation appears to be more optimistic. The opinion of reputable entities such as aircraft manufacturers and international organizations can be based as longer time forecast. Expectations of these subjects are very similar. All subjects expect growth of aviation till 2030: Airbus (World years 2011-2030 growth 5,4%, yr. 2020- 2030 growth 4,3%; Europe years 2011-2030 growth 4,2%, yr. 2020-2030 3,8%)[11]; Boeing (World yr. 2011- 2030 growth 5%; Europe 2011-2030 growth 3,5- 5,1% according the destinations) [3], ICAO (World growth yr. 2010-2030 growth 4,7% Europe growth 2010-2030 4,1%)[8]

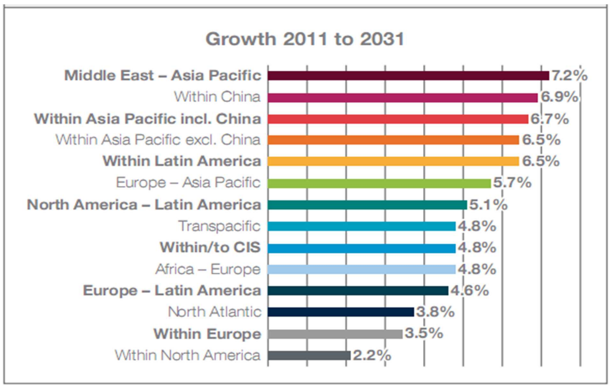

Figure 2 – Boeing annual traffic forecast 2011-2031 [3]

Air passengers and GDP have been increasing in all regions during the last decades. There is substantial variability in the growth rates. This reflects the variability in the nature of interaction between air transportation and economic activity. The next 20 years will not be an exception.

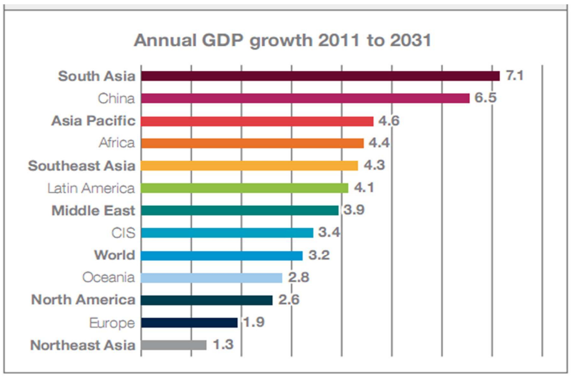

Figure 3 – Boeing GDP forecast 2011-2031 [3]

The expected growth may slow by the debt crisis in Europe, high fuel prices or sale of emission allowances.

CRISIS PERIOD OF AVIATION IN EUROPE AND WORLDWIDE

The financial crisis, which came in the second half of 2008 (Lehman Brothers bankruptcy September 2008) was fully reflected in air transport in 2009. In 2008 there was even a slight increase in the number of passengers compared to the previous year. Emerging crisis significantly affected air freight transport on a global scale. It did not come significantly to other sectors and regions. It is interesting that the crisis emerged first in the freight transport sector, later was recorded in passenger transport segment.

The crisis fully hit the air transport in 2009. Effects of the crisis were worse in Europe than in comparison with the world this year. The worst impact was in the freight transport sector in that year. Decrease of almost 11 percent significantly slowed freight transportation sector.

The following year, 2010, there was a significant recovery in air transport performance. In 2011, the continued The recovery in the transport of passengers and aircraft movements continued in 2011. Absolute figures show that air transport in 2011 surpassed the results of 2008 and reached the pre-crisis level. But it is also evident significant slowdown in air freight transportation.

Performance of freight transport shows that this sector is more susceptible to the effects of the crisis. A significant slowdown in growth of air freight in 2011 may herald a return to the crisis phenomena to air transport sector. Fluctuations in the number of movements during the monitored period reflect also the effects of the crisis. Impact of the crisis in this area is no so deep. On the one hand increases the capacity of the aircraft is increasing especially in Asia. On the other hand low cost airlines replaced the performance the classic of airlines in many cases especially in Europe.

Table 1 *– Performance of air transport worldwide and in Europe 2008-2012*

	Area	2008	2008/7	2009	2009/8	2010	2010/09	2011	2011/10
PAX	Word	4 873 994	0,1	4 796 468	-1,8	5 037 707	6,6	5 440 272	5,3
PAX	Europe	1 509 352	1,2	1 408 493	-5,4	1 466 758	4,3	1 569 907	7,0
Mov	Word	76 968	-2,1	74 137	-5,1	74 454	1,1	77 075	5,2
Mov	Europe	20 900	-0,3	19 388	-6,6	19 263	-0,5	20 146	3,4
Cargo	Word	86 078	-3,7	79 817	-7,9	90 749	15,3	93 149	0,2
Cargo	Europe	17 516	-1,0	15 445	-10,9	17 920	15,5	18 168	0,8

(free line below table)

source: author according [1], [6], [7]

Remark: PAX-Total passengers enplaned and deplaned;

Cargo-loaded and unloaded freight and mail.

Mov-Aircraft movement: Landing and take-off of an aircraft. Values in the table are given in thousands.

CRISIS PERIOD OF AVIATION IN CENTRAL EUROPE

Air transport is a global industry and subject to global influences. Performance of air transport in Central Europe is no exception. Local influences are added to the effects of global and international influences. The subjects from Slovakia, Czech Republic and Poland have been selected for description and research. Air traffic controls were examined by numbers of movements and airport operations. These entities were air traffic control, airlines and airports. The airports in the capital city and major regional airports were chosen for the research of airport area. Two main airlines for were studied. Polish Airlines Lot and Czech Airlines were chosen. In the research is not included any Slovak airline because after bankruptcy of Sky Europe there is no airline with comparable volume of traffic and history. It is necessary to say that the situation of the two investigated airlines does not guarantee long-term exploration in future

Table 2 *– Number of passengers carried by airlines [5], [7]*

Airline	2008	2009	2010	2011
ČSA	3 974 271	4 102 114	4 504 044	4 635 000
LOT	5 626 000	5 464 600	5 061 756	4 251 736

The performance of selected airlines has a downward trend. No significant recovery in operation for each airline was recorded during improvement of air transport sector in 2010 and 2011. The reason is caused by the poor economic situation of both airlines. The unsuccessful attempt to merge between Lot and Turkish Airlines was announced this year. ČSA is in a crisis situation for a long time. These airlines sell assets and reduce the number of aircraft, employees and cancel own net of long-haul flights. ČSA future is uncertain. No optimistic scenario for future is possible. The situation in the ČSA has a negative impact on the performance of the Prague airport.

The situation in the performance of airports is affected by local influences especially in the Czech Republic and Slovakia. Airport traffic in Poland is more following European trends. This trend is caused by significant mobility of Polish people and operation of low cost airlines especially in case of Katowice Airport. Operation of Ryanair and Wizzair positively influences to number of passengers in Brno.

Table 3 *– The performance of selected airports[2,] [4], [13], [15]*

	2008	2009	2010	2011
PRG	12 630 557	11 643 366	11 556 858	11 788 629
OSR	353 737	307 130	279 973	273 563
BRQ	506 174	440 850	396 589	557 952
BTS	2 218 545	1 710 018	1 665 704	1 585 064
KSC	590 919	352 460	266 858	266 143
WAW	9 460 606	8 320 927	8 712 384	9 337 734
KTW	2 426 942	2 364 613	2 403 253	2 544 124

Remark: The number of passenger of passenger is listed in the table. The codes of the airports mean Prague, Ostrava, Brno, Bratislava, Košice, Warsaw, Katowice.

Slow recovery of Prague airport mainly reflect poor economy situation of Czech Airlines. Present position of Ostrava airport is also affected by Czech airlines and absence of low cost airlines operation. Brno airports mainly profits from charter flights and low cost airlines. Slovak airports especially Bratislava are still affected by bankrupt of Sky Europe airlines, their reduction and cancellation of operation during 2009 year. This decline of handled passengers has not been replaced yet.

The different situation is in Poland. The first reason is the potential of Polish market (40 million inhabitants), the more pleasant economy situation and mobility of Polish people. The low cost carriers operation in Katowice is significant factor of airport´s performance. There is based Wizzair airline in Katowice

. The base of airlines is one of the key factors for airport operation. The trends in number of handled passenger confirm this statement. This fact is evident in Prague where ČSA is reducing their operation especially on long haul sectors and Prague is also loosing transit passengers. The troubles of Bratislava are multiplied by vicinity of Vienna Airport. Ostrava airport performances are affected by lack of offer for potential passenger. Improvement of highway connection to Brno and to Katowice will make more difficult the possibility of establishing new routes from Ostrava.

New situation is created by opening of a new low cost airport Modlin which is situated on the south of Warszawa. It will be interesting to see whether the Modlin Airport will creates competition for Warszawa Okiencie Airport or the synergistic effect will be the result of operation of two airports in a relatively small distance.

Air traffic sector fully reflect the trends in air traffic especially in overflying of the air space. The terminal operations are more influenced by local situation at the airports and their performance.

Table 4 *– Movements of Air traffic services [10], [12], [14]*

ATC	2008	2009	2010	2011
PRG en-r	694 191	665 094	683 078	714 279
PRG term	235 842	221 908	205 133	204 301
BTS en-r	299 050	299 487	335 149	387 177
BTS term	19 029	14 614	14 514	n/a
WAW en-r	597 023	553 572	585 000	n/a
WAW term	154 900	142 821	288 000	n/a

Remark: The table shows operations of Air traffic control (Prague, Bratislava, Warszaw). The figures shows en-route (overflying) and terminal (take-offs and landings) at the airports.

The figures shows, that the en-route operations are more sensitive to global influences and less sensitive to local influences. Minimal recovery in terminal operations is reported in Prague and Bratislava. This fact is corresponding with difficulties of local carriers. The en-route operations are copying the trends in European air transport performance.

These trends are obviously more reflected in areas which are in the centre of the region than in the peripheral regions. Central European air traffic controls can benefit from their geographically advantageous position. They are less sensitive to the local economy downtime and reduction of airport traffic, which are reflected in the terminal operations due to increasing international demand for air transport.

AIR TRANSPORT DURING FIRST HALF OF 2012 YEAR

The results of air transport in Europe are rather bad. According ACI report from August 2012 overall passenger traffic at European airports in the first half of 2012 increased by only +2.3% compared with H1 2011. The overall freight traffic among European airports declined by -3.4% in the same period. Aircraft movements at European airports decreased by -1.6% [1].

The passengers traffic within Europe remaining weak at +1.3% while non-EU airport traffic reached growth of +9.1%.

On a monthly basis, passenger traffic in June 2012 increased by +2.9% while freight - although nearly flat at +0.8%. Aircraft movements declined by -0.1%. [1].

According IATA report he expansion of air travel slowed in July. Compared to a year earlier the number of revenue passenger kilometers (RPKs) flown was up just 3.4%. in June this comparison was 6.3%.[7]. IATA released its revised outlook for 2012 in which it says that European carriers' losses are now expected to be €900 million compared to €450 million in its March forecast [7].

According Eurocontrol the Eurozone crisis continued to impact flights in Europe, down 3.2% in May 2012 compared with May 2011 [6].

Figure 4 shows the forecast of monthly movements in comparison with previous year

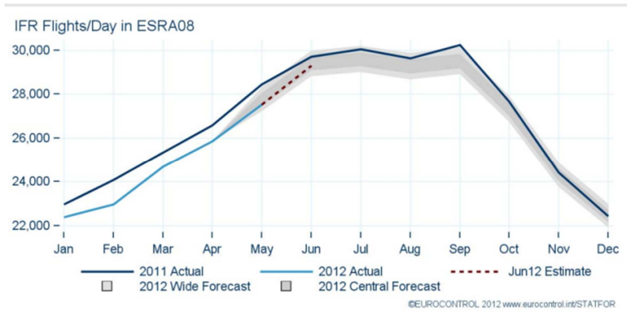

Figure 4 – Comparison of European movements between 2011 (real figures) and 2012 (January-April- real figures ; May-December-forecast) [6]

The expectations of Eurocontrol for number of IFR flights are slightly under the real performance of 2011 year.

This development is also confirmed by results of Air Navigation Services Prague when the -2,7% decrease was reported [14].

The negative trend continues at Prague Airport. There was reported 9,1 fall of handled passengers during first half of 2012 in comparison with the same period of previous year [5]. The reduction of passengers is expected in Bratislava. A million of passengers were reported by the end of August 2012. According airports forecast the results will be similar like in 2011 year.

On the other hang there is existing also positive example. Warsaw airport reported increasing of passenger volume by 8.8% year-on-year and the July was the busiest month ever in the history of the Warsaw airport. The number of aircraft movements fell compared to June 2012, standing at 13,300 (up 2.1% on July 2011) [15].

In total, the airport welcomed over 5.8 million passengers from January to July 2012 (+4% on 2011), including 983,000 travelling on domestic flights, 63.2% more than in the corresponding period a year before [15].

The total volume of handled passengers for both Warsaw airport (Okience and Modlin) should be interesting comparison with the situation before Modlin opening, the first data will be Available by the end of this year because this second low cost airport was opened for European football championship this year.

ACI says that the first six months figures for Europe's airports confirm the uncertain situation facing both the industry and the wider European economy. The first half of the year sows a significant and persistent fall in traffic growth, with the increase in June. There was positive influence from the European football championship doing little to counter this downward trend.

Conclusion

The performance of air transport in Europe shows that the sector operates during unstable period. The main reason is European debt crisis. The important impact has high and volatile price of aviation fuel. The growth may slow by the debt crisis, high fuel prices or sale of emission allowances. The crisis emerged first in the freight transport sector, later in passenger transport segment. Air transport is a global industry and subject to global influences. Local influences are added to the effects of global and international influences. The performance of selected airlines has a downward trend. The situation in the ČSA has a negative impact on the performance of the Prague airport. The situation in the performance of airports is affected by local influences especially in the Czech Republic and Slovakia. Airport traffic in Poland is more following European trends.

The en-route operations are more sensitive to global influences and less sensitive to local influences. Minimal recovery in terminal operations is reported in Prague and Bratislava. This fact is corresponding with difficulties of local carriers. The en-route operations are copying the trends in European air transport performance.

The results of air transport in Europe are rather bad. The passengers traffic within Europe remaining weak while non-EU airport traffic reached growth. This year the number of IFR flights is slightly under the previous year. The negative trend continues at Prague Airport and Bratislava. Warsaw airport reported increasing of passenger volume. First half year results confirm the uncertain situation. in European Air transport.

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CONFLICT RESOLUTION BY SPEED REGULATION

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Abstract *–To overcome the traffic growth predicted by current ATM research programs in Europe and the US, we propose a new model to avoid conflicts based on small speed regulations, as depicted in the ERASMUS project [6], with interval conflict constraints as in [2].*

After a first conflict detection phase, a centralized solver computes new RTAs to dynamically adjust the flight plans during the flight, taking operational costs for airlines and for ATC into account. The resolution would be iteratively performed over a rolling horizon to handle the uncertainties inherent to trajectory prediction.

The described model is currently being implemented using Constraint Programming and Local Search as optimization techniques. Simulations will be carried out with Europe-wide traffic data.

Key words – Air Traffic Management, Speed Regulation,

Conflict Avoidance.

INTRODUCTION

For more than forty years, global air traffic has never ceased to increase. The current traffic control systems are reaching their structural limits, so that the traffic growth might reduce the safety level of the airspace. Thus, new methods and concepts are to be set up in order to adapt to future traffic, as advocated by research programmes such as SESAR[5] [5] in Europe or NextGen in the US. Therefore, in this paper, we propose a model for speed regulation in order to avoid a maximum number of conflicts. This work is built upon the conflict model presented in [2] and uses small speed regulations like in [4] to avoid conflicts.

A standard day of traffic within the european airspace is made of approximately 30,000 flights. Each flight follows a flight plan described as a sequence of waypoints that the aircraft will fly over. The aim of this project is to avoid the air space conflicts in advance by the use of slight modifications of flight speeds, or equivalently by constraining fly over times on waypoints (RTA2), in order to decrease the controllers' workload. Our model assumes that a conflict between two flights that follow intersecting trajectories can only happen on a common waypoint of their routes – catching-up flights are handled by considering multiple waypoints. After a first potential conflict detection step, resulting in a combinatorial optimization problem that generalizes the one presented in [2], the RTA[6] are computed by a centralized system so as to avoid as many conflicts as possible and to optimize operating costs. Then they are transmitted to aircraft during the flight to modify their flight plans. To take uncertainties into account, the problem would be iteratively solved over a rolling horizon (typically 20–30min) as presented in [4].

This combinatorial optimization problem could be solved by state-of-the-art techniques such as Constraint Programming as in [2] or Local Search as in [1].

SEPARATION CONSTRAINTS

As in [4], this model is designed to take into account the functionalities of future Flight Management Systems (FMS) in the SESAR context, which will be able to dynamically accommodate several RTAs on the waypoints of their trajectories with an accuracy of a few seconds. Its output is therefore a set of RTAs for each flight involved in a potential conflict within the time window of the resolution, trying to minimize the number of actual conflicts and their durations.

In this context, the trajectory of a flight i is represented by a sequence of 3D points and associated times corresponding to the waypoints of its route indicated by the flight plan:

$$\left\{ \left(\omega_i^k, \theta_i^k\right),\ k \in [1, n_i] \right\}$$

where the $(\theta_i^k)_{i,k}$ are the decision variables and n_i the number of waypoints of flight i. Furthermore, we note:

- σ_i^k, the curvilinear abscissa (or oriented length along the trajectory) of each waypoint k of flight i;
- v_i^k, (for all $k \in [1, n_i - 1]$), the speed, considered constant, between waypoints ω_i^k and ω_i^{k+1}.

DISCRETIZATION OF TRAJECTORIES

Following the conflict model presented in [2], potential conflicts between two flights i and j are detected by pairwise checks on the points of a discretization of each trajectory, with a grain fine enough to ensure that even the shortest potential conflicts will be taken into account, as described in [3] for example. We note:

$$\left\{ (p_i^{k'}, t_i^{k'}),\ k' \in [1, m_i] \right\}$$

[5] Single European Sky ATM Research

[6] Requested Time of Arrival

the discretization of the trajectory of flight i consisting of a sequence of m_i 3D points $p_i^{k'}$ and associated times $t_i^{k'}$, as illustrated in 1.

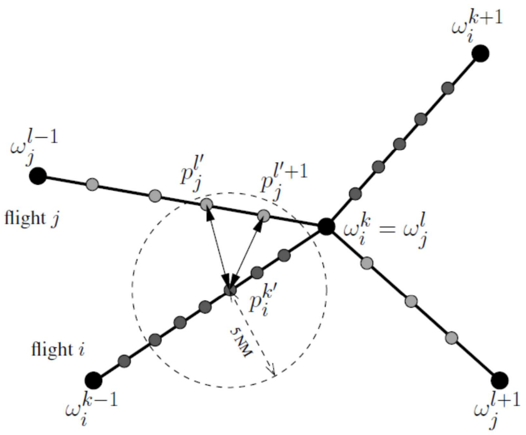

***Figure 1** – Projection in the horizontal plane of the trajectories of flights i and j, which are in potential conflict at their common way point $\omega_i^k = \omega_j^l$. Point $p_i^{k'}$ is in potential conflict with points $p_j^{l'}$ and $p_j^{l'+1}$.*

Similarly to the waypoints, we note $s_i^{k'}$ the curvilinear abscissa of each point $p_i^{k'}$. These abscissæ can be easily computed by adding the distances between the previous points of the trajectory:

$$s_i^{k'} = \sum_{l'=1}^{k'-1} dist(p_i^{l'},\ p_i^{l'+1})$$

providing that the turning points of the trajectory, i.e. the waypoints ω_i^k , are included in the discretization points $p_i^{k'}$. A similar relation would be true for the abscissæ σ_i^k of the waypoints (as they indeed are the turning points), but only during cruise, as the waypoints are too distant from each other to approximate the vertical profile of the descent or climb phase precisely enough.

CONFLICT DETECTION

Two points $p_i^{k'}$ and $p_j^{l'}$ of flight i and j are in potential conflict if their horizontal and vertical distances both violates the separation norm (usually 5NM horizontally and 1000 ft vertically), as depicted in figure 1 for the horizontal plane. For two such points, there would be an actual conflict between flights i and j if they are located at these points at the same time. To avoid a conflict, it is therefore necessary that:

$$\begin{gathered}\forall k' \in [1, m_i], \forall l' \in [1, m_j], \\ \mathrm{dist_H}(p_i^{k'}, p_j^{l'}) < 5\,NM \ \wedge\ \mathrm{dist_V}(p_i^{k'}, p_j^{l'}) < 1000\,ft \\ \Longrightarrow t_i^{k'} \neq t_j^{l'}\end{gathered} \qquad (1)$$

where $\mathrm{dist_H}$ is the distance in the horizontal plane and $\mathrm{dist_V}$ in the vertical plane. For intersecting trajectories, we assume, as in [4], that successive potentially conflicting points are all located in the vicinity of the same waypoint. As the speed is considered constant between two consecutive waypoints, it is possible to translate these conflict inequations 1 to their closest waypoint, such that the conflict constraints can be expressed as a temporal separation at this waypoint.

The resolution will therefore consist in regulating the speed of these flights (through the issuing of RTAs at the waypoints only) so as to avoid conflicts, i.e. ensure that the corresponding inequation $\theta_i^k \neq \theta_j^l$ holds for all the neighbouring pairs of potentially conflicting points $p_i^{k'} \neq p_j^{l'}$.

However, catch-up conflicts along the same route portion (or if the angle of intersecting trajectories is very low) cannot be considered local to a single waypoint. Thus, all potentially conflicting points located between waypoints ω_i^{k-1} and ω_i^{k+1} are reported to a potential conflict associated with ω_i^k. Several such conflicts will then be defined at each successive waypoints as long as the flights follow the same route.

We can now define a generalized (intersecting or catchingup) potential conflict between two flights i and j as the set of conflicting pairs of trajectory points around a single waypoint:

$$\begin{aligned} C_{ij}^{kl} = \ & \{(k',l') \in [1,\ m_i] \times [1,\ m_j],\ \text{s.t.} \\ & p_i^{k'} \text{ and } p_j^{l'} \text{ are in potential conflict near } \omega_i^k = \omega_j^l, \\ & \text{and } \sigma_i^{k-1} < s_i^{k'} < \sigma_i^{k+1},\ \sigma_j^{l-1} < s_j^{l'} < \sigma_j^{l+1}\} \end{aligned}$$

To compute the resulting contraint between θ_i^k and θ_j^l, we first need to express t_i^k as a function of θ_i^k and the speed of the aircraft, which is v_i^{k-1} before waypoint ω_i^k and v_i^k afterwards. Therefore:

$$\begin{gathered}\forall k' \in [1, m_i]\ , \exists k \in [1, n_i]\ , \\ t_i^{k'} = \begin{cases} \theta_i^k + \frac{s_i^{k'} - \sigma_i^k}{v_i^k} \text{ si } s_i^{k'} \geq \sigma_i^k \\ \theta_i^k + \frac{s_i^{k'} - \sigma_i^k}{v_i^{k-1}} \text{ si } s_i^{k'} < \sigma_i^k \end{cases}\end{gathered} \qquad (2)$$

Inequation 1 and equation 2 can then be combined, with four different cases depending on the locations of points $p_i^{k'}$ and $p_j^{l'}$ with respect to waypoint $\omega_i^k = \omega_j^l$. Note that if flights i and j have several distinct (non continuous) potential conflicts, there will be as many (non empty) sets C_{ij}^{kl} of conflicting points:

$$\begin{gathered}\forall (k,l) \in [1, n_i] \times [1, n_j] \text{ s.t. } C_{ij}^{kl} \neq \emptyset, \forall (k',l') \in C_{ij}^{kl}, \\ t_i^{k'} \neq t_j^{l'} \ \Leftrightarrow \\ \theta_i^k - \theta_j^l \neq \begin{cases} \frac{s_j^{l'} - \sigma_j^l}{v_j^l} - \frac{s_i^{k'} - \sigma_i^k}{v_i^k} \text{ if } s_j^{l'} \geq \sigma_j^l \text{ and } s_i^{k'} \geq \sigma_i^k \\ \frac{s_j^{l'} - \sigma_j^l}{v_j^l} - \frac{s_i^{k'} - \sigma_i^k}{v_i^{k-1}} \text{ if } s_j^{l'} \geq \sigma_j^l \text{ and } s_i^{k'} < \sigma_i^k \\ \frac{s_j^{l'} - \sigma_j^l}{v_j^{l-1}} - \frac{s_i^{k'} - \sigma_i^k}{v_i^k} \text{ if } s_j^{l'} < \sigma_j^l \text{ and } s_i^{k'} \geq \sigma_i^k \\ \frac{s_j^{l'} - \sigma_j^l}{v_j^{l-1}} - \frac{s_i^{k'} - \sigma_i^k}{v_i^{k-1}} \text{ if } s_j^{l'} < \sigma_j^l \text{ and } s_i^{k'} < \sigma_i^k \end{cases}\end{gathered} \qquad (3)$$

However, these expressions depend on the (unknown) variable speeds of aircraft, whereas the conflict model presented in [2] uses static bounds for the time difference between flights i and j at waypoint $\omega_i^k = \omega_j^l$. In the next section, we explain how the speed variations are tightly bounded in our operational context, which allows us to approximate the values of equation 3 by small intervals.

SMALL SPEED ADJUSTMENT AND CONFLICT APPROXIMATION

Following [4], we consider the same kind of small speed variation as in the ERASMUS project [6]. Two ratio paramaters $\underline{\alpha} \leq 1$ and $\overline{\alpha} \geq 1$ are introduced to bound the possible speed adjustment, such that if we note v_i^0 the reference speed of flight i, all other speed variables are restricted to take values in a small interval $[\underline{\alpha}\, v_i^0, \overline{\alpha}\, v_i^0]$:

$$\forall i \in [1,n], \forall k \in [1, n_i - 1]\,,\; v_i^k \in [\underline{\alpha}\, v_i^0, \overline{\alpha}\, v_i^0] \quad (4)$$

where n is the number of flights in the instance.

These ratio paramaters are typically chosen in the range $\underline{\alpha}$ = 0,97 and $\overline{\alpha}$ = 1,06 to limit the cost of regulation on the fuel consumption of aircraft and to have the smallest impact possible on standard Air Traffic Control (ATC) practices.

As the speed variations considered are small and bounded, we can bound the values of θ_i^k - θ_j^l described in equation 3 by constants $\underline{r_{ij}^{k'l'}}$ (lower bound) and $\overline{r_{ij}^{k'l'}}$ (upper bound) defined as follows:

$$\forall (k,l) \in [1,n_i] \times [1,n_j] \text{ s.t. } C_{ij}^{kl} \neq \emptyset,\; \forall (k',l') \in C_{ij}^{kl},$$

$$\underline{r_{ij}^{k'l'}} = \begin{cases} \frac{s_j^{l'} - \sigma_j^l}{\overline{\alpha}\, v_j^0} - \frac{s_i^{k'} - \sigma_i^k}{\underline{\alpha}\, v_i^0} \text{ if } s_j^{l'} \geq \sigma_j^l \text{ and } s_i^{k'} \geq \sigma_i^k \\ \frac{s_j^{l'} - \sigma_j^l}{\overline{\alpha}\, v_j^0} + \frac{\sigma_i^k - s_i^{k'}}{\overline{\alpha}\, v_i^0} \text{ if } s_j^{l'} \geq \sigma_j^l \text{ and } s_i^{k'} < \sigma_i^k \\ -\frac{\sigma_j^l - s_j^{l'}}{\underline{\alpha}\, v_j^0} - \frac{s_i^{k'} - \sigma_i^k}{\underline{\alpha}\, v_i^0} \text{ if } s_j^{l'} < \sigma_j^l \text{ and } s_i^{k'} \geq \sigma_i^k \\ -\frac{\sigma_j^l - s_j^{l'}}{\underline{\alpha}\, v_j^0} + \frac{\sigma_i^k - s_i^{k'}}{\overline{\alpha}\, v_i^0} \text{ if } s_j^{l'} < \sigma_j^l \text{ and } s_i^{k'} < \sigma_i^k \end{cases}$$

$$\overline{r_{ij}^{k'l'}} = \begin{cases} \frac{s_j^{l'} - \sigma_j^l}{\underline{\alpha}\, v_j^0} - \frac{s_i^{k'} - \sigma_i^k}{\overline{\alpha}\, v_i^0} \text{ if } s_j^{l'} \geq \sigma_j^l \text{ and } s_i^{k'} \geq \sigma_i^k \\ \frac{s_j^{l'} - \sigma_j^l}{\underline{\alpha}\, v_j^0} + \frac{\sigma_i^k - s_i^{k'}}{\underline{\alpha}\, v_i^0} \text{ if } s_j^{l'} \geq \sigma_j^l \text{ and } s_i^{k'} < \sigma_i^k \\ -\frac{\sigma_j^l - s_j^{l'}}{\overline{\alpha}\, v_j^0} - \frac{s_i^{k'} - \sigma_i^k}{\overline{\alpha}\, v_i^0} \text{ if } s_j^{l'} < \sigma_j^l \text{ and } s_i^{k'} \geq \sigma_i^k \\ -\frac{\sigma_j^l - s_j^{l'}}{\overline{\alpha}\, v_j^0} + \frac{\sigma_i^k - s_i^{k'}}{\underline{\alpha}\, v_i^0} \text{ if } s_j^{l'} < \sigma_j^l \text{ and } s_i^{k'} < \sigma_i^k \end{cases} \quad (5)$$

For one conflict set C_{ij}^{kl}:, bounds of a forbidden interval for the difference of times θ_i^k - θ_j^l at the waypoint can then be computed by cumulating the inequations over the pairs of conflicting points (k´; l´) $\in C_{ij}^{kl}$:

$$\underline{r_{ij}^{kl}} = \min_{(k',l') \in C_{ij}^{kl}} \underline{r_{ij}^{k'l'}}$$

$$\overline{r_{ij}^{kl}} = \max_{(k',l') \in C_{ij}^{kl}} \overline{r_{ij}^{k'l'}}$$

Moreover, the bounds on the speed of each aircraft further constrain the θ_i^k variables for two consecutive waypoints ω_i^k and ω_i^{k+1}:

$$\forall k \in [1, n_i - 1]\,,\; \theta_i^{k+1} - \theta_i^k \in \left[\frac{d_i^k}{\overline{\alpha}\, v_i^0}, \frac{d_i^k}{\underline{\alpha}\, v_i^0}\right] \quad (6)$$

with $d_i^k = \sigma_i^{k+1} - \sigma_i^k$, the distance between ω_i^k and ω_i^{k+1}. In the following, these bounds on the travel time of flight I between two consecutive waypoints are respectively noted $\underline{T_i^k} = \frac{d_i^k}{\overline{\alpha} v_i^0}$ and $\overline{T_i^k} = \frac{d_i^k}{\underline{\alpha} v_i^0}$.

Model

The conflict detection processing of the previous sections can now be sum up with a more standard (and concise) combinatorial decision problem formulation, with variables ω_i^k representing the RTA of flight i on waypoint σ_i^k, for a set of n potentially conflicting flights over the time window considered:

$$\begin{aligned} \text{Find:} \quad & \forall i \in [1,n]\,,\; (\theta_i^k)_{k \in [1,n_i]} \\ \text{s.t.:} \quad & \forall (i,j) \in [1,n]^2, i < j, \\ & \forall (k,l) \in [1,n_i] \times [1,n_j] \text{ s.t. } C_{ij}^{kl} \neq \emptyset, \\ & \qquad \theta_i^k - \theta_j^l \notin \left[\underline{r_{ij}^{kl}}, \overline{r_{ij}^{kl}}\right] \\ & \forall i,\; \forall k \in [1, m_i - 1]\,, \\ & \qquad \theta_i^{k+1} - \theta_i^k \in \left[\underline{T_i^k}, \overline{T_i^k}\right] \end{aligned}$$

The first set of constraints are derived from the conflicts between two potentially conflicting flights i and j, $\underline{r_{ij}^{k'l'}}$ and $\overline{r_{ij}^{k'l'}}$ being the bounds of the forbidden values for the difference of fly times over the conflicting waypoint $\omega_i^k = \omega_j^l$. The second one characterizes the speed limitation for each aircraft as stated in equation 6.

Optimization

Among the admissible solutions of this decision problem, the ones that minimize airlines costs should be preferred. To optimize their operating costs, airlines generally tune the Cost Index (CI) parameter (used by the FMS to optimize the flight parameters along its trajectory) for each flight, which represents the relative importance of the cost of fuel with respect to the cost of flight time, i.e.:

$$\text{CI} = \frac{\text{cost}_{\text{time}}}{\text{cost}_{\text{fuel}}}$$

where $\text{cost}_{\text{time}}$ is in \$ per time unit, and $\text{cost}_{\text{fuel}}$ in \$ per mass unit.

For a given flight i, we can therefore consider that the airline cost is the sum of the extra cost of time and of the extra cost of fuel multiplied by CI_i (the Cost Index of flight i), compared to the reference trajectory at the reference speed:

$$\text{cost}_i = \text{CI}_i \times \text{cost}_i^{\text{fuel}} + T_i^0 - (\theta_i^{n_i} - \theta_i^1)$$

where $T_i^0 = \sum_{k=1}^{n_i-1} \frac{d_i^k}{v_i^0}$ is the total flight time of flight i at its reference speed v_i^0.

If we assume that $v_i^0$is the optimal speed of the flight and that a discrepancy from v_i^0 leads to a proportional increase of fuel consumption during the time flown at this speed, then:

$$\begin{aligned} \text{cost}_i^{\text{fuel}} &= \sum_{k=1}^{n_i-1} \frac{\left|v_i^k - v_i^0\right|}{v_i^0} (\theta_i^{k+1} - \theta_i^k) \\ &= \sum_{k=1}^{n_i-1} \left|\frac{d_i^k}{v_i^0} - (\theta_i^{k+1} - \theta_i^k)\right| \end{aligned}$$

So the cost for one flight can be expressed as:

$$\text{cost}_i = \text{CI}_i \sum_{k=1}^{n_i-1} \left|\frac{d_i^k}{v_i^0} - (\theta_i^{k+1} - \theta_i^k)\right| + T_i^0 - (\theta_i^{n_i} - \theta_i^1)$$

and the total cost of one solution simply is the sum of the costs of all flights:

$$\text{cost} = \sum_{i=1}^{n} \text{cost}_i \quad (7)$$

Note that other parameters could be taken into account, like the number of speed changes, or could use a more realistic function to estimate the effect of the speed discrepancy from the reference speed, provided we could gather enough data from airlines and manufacturers.

INFEASIBILITY

If some conflict constraints cannot be satisfied, it may still be of interest to relax these constraints and search for solutions with as few violated constraints as possible. Furthermore, when a conflict constraint is violated, the longer the conflict lasts, the more hazardous is the operational situation, so it is interesting as well to search for solutions that minimize the duration of all actual conflicts, as proposed in [4].

As the conflict constraints of our model enforce that $\theta_i^k = \theta_j^l$ does not belong to $\left[\underline{r_{ij}^{kl}}, \overline{r_{ij}^{kl}}\right]$, we have to compute the "distance" of the time difference from the center of the interval $M_{ij}^{kl} = \frac{1}{2}\left(\underline{r_{ij}^{kl}} + \overline{r_{ij}^{kl}}\right)$:

$$\text{dist}_{ij}^{kl} = \left|(\theta_i^k - \theta_j^l) - M_{ij}^{kl}\right|$$

The longer the conflict lasts, the closer θ_i^k - θ_j^l is to M_{ii}^{kl}, and the smaller is dist_{ij}^{kl}. So to obtain a measure of the duration of the conflict, the distance is subtracted from the half of thelength of the interval $\left[\underline{r_{ij}^{kl}}, \overline{r_{ij}^{kl}}\right]$, i.e. from $L_{ij}^{kl} = \overline{r_{ij}^{kl}} - \underline{r_{ij}^{kl}}$. Moreover, the cost should be 0 outside the conflict interval:

$$\max(0, \frac{1}{2}L_{ij}^{kl} - \left|(\theta_i^k - \theta_j^l) - M_{ij}^{kl}\right|)$$

The total cost over all remaining conflicts is the sum of all the actual conflicts durations, for all pairs of flights in potential conflict (i.e. $\forall i < j$ s.t. $\exists (k,l), C_{ij}^{kl} \neq \emptyset$):

$$\text{cost}_{\text{conflict}} = \sum_{i<j} \sum_{\substack{k,l \text{ s.t.} \\ C_{ij}^{kl} \neq \emptyset}} \max(0, \frac{1}{2}L_{ij}^{kl} - |(\theta_i^k - \theta_j^l) - M_{ij}^{kl}|)$$

This cost could be combined with the cost defined in equation 7 with suitable weighting to balance the cost of remaining conflicts with the operational one, so as to take both criteria into account for overconstrained instances.

CONCLUSIONS AND PERSPECTIVES

To overcome the traffic growth predicted by current ATM research programs in Europe, we propose a novel deconfliction model based on small speed regulations, following the mixed integer program presented in [4] with a conflict model that generalizes the work presented in [2]. The associated centralized solver would output new RTAs to dynamically adjust the flight plans during the flight, taking operational costs for airlines and for ATC into account. The resolution would be iteratively performed over a rolling horizon (20–30 min) to handle the uncertainties inherent to trajectory prediction.

The described model is currently being implemented using Constraint Programming and Local Search as optimization techniques. Simulations will be carried out with Europe-wide traffic data.

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DO YOU MISS THE INTERNET ON BOARD? THE ECONOMY AND PASSENGERS DO.

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Abstract – *This article deals with the problem of in-flight internet connection offered by airlines. Nowadays, many American carriers offer Wi-Fi connection on the intra-US routes. On the other hand, European airlines are years behind when it comes to connectivity on the boards of their intra-EU flights. Lack of connection has major economic consequences due to unproductivity of business travellers. Moreover, survey shows that European passengers are interested in staying online as much as the American ones. Financial and some technical aspects of on board Wi-Fi connections are described.*

Key words – In-flight Wi-Fi, internet connection, economic aspects, technical aspects, airlines.

I. INTRODUCTION

With growing penetration of laptops, smartphones, tablets and other portable electronic devices into our everyday life, the need for wireless connection to the internet is more and more demanded, not just at our homes but also at the wide range of public places.

This kind of places this can be easily found within the civil aviation market as well. When you are an air passenger, basically you go through two public places. First, airport terminal and the aircraft board afterwards.

In the first case, you usually have no problem to use free Wi-Fi offered inside the terminals by an airport operator. But on the other hand, there can be a problem on board while airborne. Airlines do not offer internet connection on every flight. Right now, we are talking about U.S. airlines, since European ones do not offer the internet connection on intra-EU flights at all.

Thus, the airlines are under the increasing pressure to implement technologies to enable their customers kept in their virtual reality – whether it is for business or leisure purposes.

II. ECONOMIC CONSEQUENCES

For many travellers, aircraft journeys are one of the last bastions of the peace and quiet. But all that may be set to change.

If airlines do not allow passengers to connect to the internet while airborne, this practice is damaging the economy. Person undertaking their business trip are still "at work" when on board. For many of them, it is wasting of the time as they are not able to solve their business relations because of no email access for several hours.

According to U.K.'s consultancy provider Firstsource Solutions, the business travelers' email blackout while flying is costing the British economy around 640 million GBP a year. This is the number for one economy only. There are several comparable economies within the European airspace which can generate more values like this (e.g. France, Germany, etc).

III. CURRENT SITUATION IN EUROPE

Some U.S. airlines allow passengers to use the internet on board of domestic flights, but most European airlines ban it for insurance reasons, despite research suggesting that it is safe to use the web in air transport.

SURVEY

However, according to the new study conducted by research agency YouGov, passengers were inclined to have in-flight internet access. The survey found that half of UK adults would like internet access on board airline flights. The results can be found in the Figure 1.

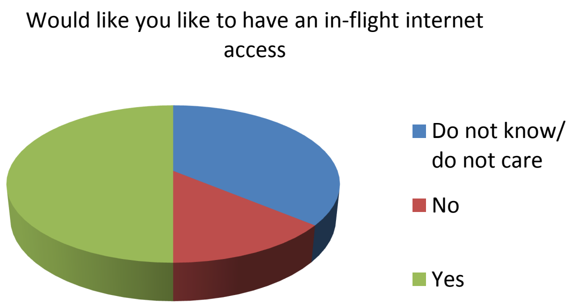

Figure 1 *– Survey by YouGov among UK adults (24 – 55 yrs.)*

On the other hand, only 13 per cent of UK adults said they actually disliked the idea of having in-flight internet, with almost two thirds (64%) of those citing that they did not wish to be disturbed by emails or expected to respond to emails when flying. The survey also showed that a quarter of adults who work in an office (25%) would become stressed anyway if they received a work related email outside working hours.

Among the younger demographic (18 – 24 years old), 75 per cent would like to use internet connection during the flight.

Finally, 32 per cent of over 55 year olds said they would like in-flight internet access showing that this generation is happy to just relax, maybe watch a movie, read a book or enjoy a nice sleep while flying.

Another poll, conducted by The Telegraph (Figure 2), confirms the previous statements. 70 per cent of respondents think that having Wi-Fi on board is a good idea.

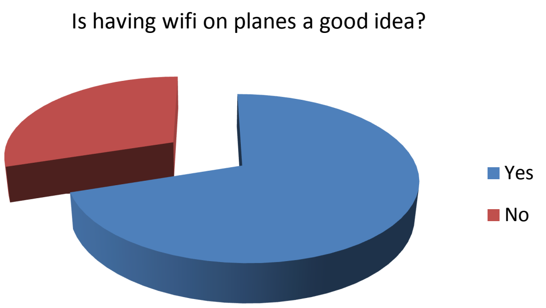

***Figure 2** – Poll by The Telegraph*

Above mentioned data clearly represent current trend. In spite of that, none of European carriers offers what passengers truly want.

IV. Situation in the U.S.

As mentioned earlier, some of the U.S. carriers allow passengers to connect to the internet during the flight.

Launched four years ago, the use of Wi-Fi on U.S. commercial aircraft has yet to catch on, with estimates that the wireless technology is still used by only 7 per cent of the flying public.

There are a number of reasons. With free Wi-Fi at many airports and public locations, passengers do not want to pay as much as 10 USD for a flight of a few hours. Passengers also may not know when Wi-Fi is available on a flight since the airlines provide the wireless service on only a small percentage of their planes.

Many of the major U.S. airlines have now begun to equip their planes with new in-flight Wi-Fi service. Around 8 per cent of U.S. airline passengers use the service, up from 4 per cent at the end of 2010, according to In-Stat, a research and consulting firm. This is likely to increase to 10 per cent of passengers by the end of this year. According to In-Stat, the airlines in the U.S. collected 155 million USD in charges for on board internet service in 2011, and are expected to collect 225 USD million in 2012.

The service primarily attracts regular business customers who fly long distances and want to stay connected to the ground via email. Monthly unlimited plans cost 40 USD a month from Wi-Fi in-flight supplier Gogo, formerly Aircell. GoGo has equipped 1 700 commercial aircrafts with Wi-Fi using a plane-to-ground technology. Its customers include American, AirTran, Delta, Virgin America and others. After a solid start in 2008, GoGo lost a deal on equipping United with Wi-Fi last fall when the airline committed to a relative newcomer, Panasonic Avionics, which relies on a plane-to-satellite technology. Moreover, GoGo plans to focus on a segment of small business jets. According to GoGo, there were 15,6 million connections over in-flight Wi-Fi in 2011 and that figure will jump to 96,9 million connections by 2015.

In a similar fashion, In-Stat has predicted revenues from in-flight Wi-Fi will climb to 1,5 billion USD in 2015. This number is very perspective from airlines' managers' point of view.

Survey

Five hundred U.S. air passengers took part in Fly.com's survey, of which 80 per cent said they would like the option to connect to the internet during a flight. An additional 66 per cent would like to be allowed to talk on their cell phone. The results are shown in the Table 1.

***Table 1** – Survey by Fly.com*

Of the 500 U.S. travellers:	
65%	Think it is important that airlines offer internet access on flights
36%	Would take advantage of in-flight internet access to find information and deals relating to their destination
26%	Would use in-flight internet to catch up on emails

This is good news for airlines that already offer wireless services to their passengers. However, almost half (49%) said they do not expect to pay extra to use their internet connected devices and 27 per cent would pay no more than 5 USD.

On the topic of mobile use during flights, travellers were not quite as enthusiastic with 38 per cent believing that allowing mobile phone use on flights would mean putting up with the annoyance of people talking too loudly. Furthermore, many (59%) do not understand the "flight mode" setting on their mobile device and 46 per cent do not know why they are asked to turn off their devices.

V. Technical Aspects

There is no doubt that what would make air travelling better is the internet access to become a standard. But to become a standard, several steps must be undertaken.

First of all, Wi-Fi equipment needs to be mounted into the aircraft. To equip one airliner, significant financial costs must be invested. One airliner costs as much as 100 000 USD.

Another step to be conducted is to choose optimal technology which could offer reliable and cost-sustainable internet connection (a Wi-Fi network on a flight crowded with online business customers can quickly fail down). At present, airlines are mulling over the most effective way of how to do so. There are basically two options: a ground based-system or via satellites, the latter probably being much faster. Airlines have been split on whether to adopt a ground-based system or satellite-based systems. The ground-based system connects a Wi-Fi hot spot installed in a jet to one on the ground. Satellite-based systems offer faster speeds, more bandwidth and global coverage over oceans, but currently are not as developed.

When talking about intra-US flights which offer web access, we have ground-based system in mind. It can be used from New York to California, but the minute an aircraft head off the coast, the connection fails. When talking about long haul flight over the ocean, satellite-based system is required to implement.

The expense of offering this satellite Wi-Fi has proven prohibitive for airlines that see low usage and high costs to outfit planes with new technology. In spite of that, “international Wi-Fi” is not impossible, just not available as frequently as at the domestic U.S. market.

VI. Situation in the long haul flights segment

Both Europeans and American “continental” markets were described above. At this point, long haul flights segment will be explored.

Though Wi-Fi is increasingly available on domestic flights, it remains expensive and relatively little-used, according to most analyses. On international flights, where it can be argued that it is most needed, Wi-Fi remains a rarity. To prove the previous sentence, we will point a finger at few airlines offering “international Wi-Fi”.

Lufthansa Case

German flag carrier offered the first on board broadband internet access. Passengers can use this feature on many North Atlantic flights as well as flights to the Middle East and South America. This service is now also available on some long haul flights to the Japan and Korea. In 2012, the airline in cooperation with the partner Panasonic Avionics Corporation is implementing this service offer across the majority of Lufthansa’s global long haul network. Online access is provided in all travel classes. During the course of this year, the adopted technology will also enable the passengers to transfer data by GSM and GPRS technology. So in future, once cruising altitude is reached, they will be able to use their mobile phone to send and receive SMS and MMS messages or synchronise data via smartphone.

The option of making mobile phone calls has been disabled in response to the wishes of a majority of the customers. In addition, customers are advised that Internet telephony (VOIP) is likewise not permitted. After opening the browser, passenger will connect automatically to the free Lufthansa portal where he will find the latest business, political, sports and entertainment news.

Qantas Case

Australian airline Qantas started in-flight Wi-Fi in March 2012 by launching an eight-week trial with the service on flights between Australia and Los Angeles, allowing passengers in first and business classes to access the internet. They join airlines that include Lufthansa, and later this year United.

Air France and KLM Case

Browsing the web or watching a live broadcast during the flight will become a reality on board Air France and KLM flights. In partnership with Panasonic Avionics, the two airlines are launching a joint in-flight connectivity programme on board their long-haul flights, with trials in early 2013.

This will enable customers to stay connected with the world through text messages or emails as well as internet connection and ultimately through live broadcasts of TV programmes. Thanks to this new technology, Air France and KLM will offer passengers access to a broad scope of data communications during the flight. On the specially designed in-flight website, a broad range of services will be offered for free, like latest news, TV channels relevant airline and destination information and a unique offer of online magazines.

The trial phase will be conducted over the year 2013 on two Boeing 777-300s, operated by each airline, whatever travel class. They will ask the customers to provide feedback, along with their expectations and suggestions on improving these services.

VII. Pricing

Lufthansa, Qantas, United this year, KLM and Air France next year. This is revolutionary in 2012? For aircraft crossing oceans, it is.

There are several reasons for the slow move to Wi-Fi on international flights. Most of it, predictably, comes down to money. Most Wi-Fi signals on domestic flights are provided by a series of ground towers. All flights over ocean uses satellite connections. The satellite connections are far more expensive propositions for airlines. That cost is increased by what appears to be moderate user interest at current pricing levels.

Passengers are not sure in-flight Wi-Fi is a product worth buying. Sure, there's enough bandwidth to send emails, texts and so on. But when it comes to streaming or downloading, the performance can be poor. According to industry consultants, airlines should invest in the infrastructure, use the Wi-Fi for its own purposes and then give a small amount for free to passengers whose expectations will drop because it is free. Once people start paying for it, they expect a premium service.

When investing such a high amount of resources, airlines need to secure a corresponding amount of revenues. Because of this, internet access is not always free. There are few examples of how much can be passenger charged when trying to connect to the aircraft hotspot. Japanese Airlines on their flight from Tokyo to New York charge 11,95 USD per hour, 24 hours can be gained for 21,95 USD.

Deutsche Telekom offers two distinct tariffs for using internet access at some of the Lufthansa long haul flights. One hour is charged 10.95 EUR (or 3,500 miles from FFP), 24 hours will cost caper 19.95 EUR (or 7,000 miles).

VIII. Conclusion

The internet nowadays is really a portal into another world, and it could, for example, mark the end of everyone having to watch a limited selection of films. With access to all sorts of media and social networks, people can make real good use of their time travelling.

The growth of laptops, smartphones and tablet computers means consumers are increasingly using devices that give them access to the internet on the move.

It is expected that business travellers, who fly long distances, would particularly like to stay connected to colleagues or customers in the office via email. Holidaymakers would also no doubt appreciate the added entertainment value of downloadable games, music and films that in-flight internet could bring to a tedious journey.

In-flight internet providers will need to partner with customer service specialists that can offer effective web- based customer service solutions as phone calls are restricted in the air. Customer engagement platforms such as live web chat, Twitter and online forums will be important in helping passengers deal with queries or problems on board flights.

One day Wi-Fi on airplanes will have seemed inevitable. Consider that Aircell, the company behind GoGo, the Wi-Fi service for most domestic flights, recently announced that it is working on a satellite system that will enable international service by 2015.

The most important lesson of this digital age is that customers want to communicate when they want, wherever they want and via the device of their choice.

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ANALYSIS OF TRAFFIC SAFETY AND PREVENTIVE SECURITY MEASURES IN CIVIL AVIATION OF THE CZECH REPUBLIC

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Abstract *– This paper deals with analysis of causes of events and of effect safety campaigns, which are issued by CAA CZ, on safety of air traffic in the Czech Republic. Based on the analysis of final reports about flight incidents, there were described causes of these events. Recognition involves describe given campaigns, assurance of information, processing and final assessment of efficiency published safety campaigns. In conclusion the obtained results are compared with historical development of civil aviation incidents in the Czech Republic.*

Key words – Incident, serious incident, accident, investigation of accidents, safety campaign, human factor.

I. INTRODUCTION

The causes of accidents are now as in the past, the same (meteorological conditions, human factor, technical failure) or similar. Some causes disappear, others arise. Rather, different importance and share of the total causes of accidents in aviation.

With the gradual development for improving technical performance, reliability and overall Security operated aircraft as well as the technical level of the security airports. Formed and improve the procedures and limits of safe operation of aircraft and airports, which led to an overall increase in the level of safety and in some cases completely eliminating certain causes of accidents (eg: single engine failure in airplanes). By contrast, as I mentioned, some of the causes of accidents incurred because introduced into operation of new technologies (eg, instrument approach).

II. CAUSES OF ACCIDENTS

In the 1918-1939 was the most common cause of accidents technical glitch caused 40% of accidents. It was mainly about engine failure at single aircraft, which resulted in an emergency landing, which was the better option. In those cases, the worse the accident. Later at larger extension and application of multi-engine aircraft, this glitch has lost its importance. It was possible in order to fly with one engine to an alternate airport on the route of flight and land safely.

The second most important cause of the accident was the weather, the bad weather conditions. In this period, the impact of weather occurred in 21% of one accident and another 12% of the accidents played a significant role with other influences.

Another major cause was the human factor. Due to this cause was due to 14% of accidents. The decision as to whether it was or was not an accident due to human error is very controversial. Mostly it is a concurrence of several other causes (technical failure, weather conditions) and subsequent bad decisions pilot. In many cases the accident would not have happened if, for example, better weather and there has been no technical glitch.

Several accidents were caused by so-called systemic deficiencies at the airport. It was exactly 11% of the total. In retrospect, this group is something very special and unique. Today, probably no one can imagine that the plane could take off collide with mower etc..

One of the last category is unknown cause, which includes 9% 1 accident, and it is an accident, which was never found the cause. Accidents that never did not investigate because it was not set up a Commission to investigate the causes of aviation accidents or accidents that relevant documents have been preserved to this day.

Last several accidents belonging to the categories or loss of radio communications related with radio navigation.

During the Second World War (1939-1945) Czechoslovak civil aviation in fact did not exist, therefore the analysis of the causes of aviation accidents is obsolete.

In the period 1945-1960 to the investigation of air accidents began to approach far more responsibly, including drafting detailed statistics and making assessment methodologies accidents. The most serious cause of accidents in this period was human error, which is very difficult to judge, as I mentioned. In most cases due to overlapping of other factors. Human error contributed to thirteen accidents, which is a percentage calculation of 65%. Accidents affected by adverse weather conditions the state are included in the category of human error. Indeed, that pilot must take such measures that the impact of bad weather eliminated. The weather was again involved in these accidents, rather than as the main cause, as the cause of co. Some accidents were several causes (eg human error in coincidence with bad weather conditions, in which there was a controlled flight into terrain, called CFIT (Control Flight into Terrain)).

In six cases there was a technical problem. The four incidents occurred due to uncontrolled instrument approach. This category is specifically designed to highlight the proportion of uncontrolled instrument approach to accidents. The official statistics do not find this kind of cause. accidents in this category can be included in the human factor, because it is either a bad decision of the captain or the impact of bad weather conditions, which, as I mentioned again fall under human error. The last category covers only one accident. This is a loss of connection. Again, it is a purpose-created category, which in any official statistics prominent. It is included here because it has been shown that the importance of communication and navigation aircraft equipment for instrument flight. It can in fact be regarded as a technical malfunction.

The period 1961-1992 is characterized by the onset of jet and turboprop engines. Influence of human factor on the causes of accidents is again only one of many. Usually it is in coincidence with other factors, to which the pilot responded poorly. It is again a chain of events, one of which link is the human factor. As a result, the human factor as the cause of most accidents, the pilot could have its timely and correct intervention to prevent the accident. In this period became 22 accidents out of a total of thirty-four, in which the proportion of qualified human factor. In percentage terms, this amounts to 65%. In comparison with the global scale is about 5% of less, which can be neglected and say that the causes of accidents is human error here at a comparable level as in the world. Distribution of accidents by cause involves first the influence of meteorological conditions. Again this is only a contributory cause these accidents can again usually be included in the category of human error. As already mentioned, the pilot should always be able to take such measures to eliminate these effects. Effect of bad weather conditions occurred in nine accidents, which in percentage terms is 27% of the total number of accidents.

Another cause is uncontrolled instrument approach, in which there have been three accidents, which is 9% of the total. It is a purpose-created category, which has pointed out the influence of this on the overall causes accidents. Again, these accidents can be categorized as human error. For technical reasons were seven accidents, ie. 20% of all accidents. Another significant cause is unstabilized approach. This is a global problem and not exceptional. For this reason, the defined conditions stabilized approach, the crew may continue the approach and when it should be discontinued. As a result of unregulated approach two planes crashed.

Another cause of the accident is called Runway Incursion (Violation Railways). This is the case when the same runway two planes occur at one time. This problem is very timely and a growing number of movements at individual airports becoming increasingly important. One of the causes of aviation disasters may be inappropriate manning Another of the major causes of accidents may be overloading the crew fatigue.

Table 1 *– Number of accidents 1993 - 2011.*

Period 1993 - 2011	Number of accidents
1993	29
1994	31
1995	36
1996	41
1997	40
1998	27
1999	24
2000	30
2001	23
2002	27
2003	38
2004	21
2005	25
2006	36
2007	30
2008	21
2009	42
2010	35
2011	22

III. EVENT STATISTICS (1993 - 2002)

Number of events in each year of the period the downward trend with incidence peaks between 1994 and 1997. The largest number of events are represented in the accident, which was the largest outbreak in 1996 and serious incidents with maximum incidence in 1994. The incident was a maximum incidence in 1999 and other years, the incidence is less important.

The main share of accidents was human factor of 80%. Another important fact was the technical cause of 8%, followed by other causes (7%), unknown cause (3%) and weather (2%).

IV. EVALUATION PERIOD 2003 - 2010

During the years 2003-2006, the number of aircraft accidents occurred at approximately the same amounts, around 10 accidents per year. After 2006 the number of accidents in airplanes dropped to 4 and to the end of 2010, gradually increased, until in 2010 there were 14 accidents.

THE MAIN CAUSES

The largest share of the aircraft causes the human factor. If a technical problem occurred, mostly on LN. Total due at LN technical causes in the period 10 people died. Weather as the main cause of the aircraft involved in at 3% for the whole period. Weather resulted in many cases as a contributory cause. The systemic failures occurred in 5% of cases, mainly due to the operator that his inattention damaged aircraft. In several cases also were surface irregularities on the runway or taxiway. Other causes included those factors that could not be in any of these factors to classify.

V. SUMMARY

How is the apparent meaning of the causes of aviation accidents over the years and thanks to the development of aviation technology, whether the flying, navigation, security, or ground, changed. Previously more prevalent accident due to the default aircraft because the aircraft contained unreliable components and units, which is fostered by the fact that the management wasn´t often backed up. Previously, pilots also use fewer prepared emergency procedures that reduce the risk of accidents when unexpected situations (reading checklists in emergency situations, etc.). Whether because of their complete absence, or their ignorance. In later years, in the period after the Second World War, far more strongly developed commercial air transportation, which come with a greater emphasis on safety measures. Improved to the level of maturity of the aircraft, which during the Second World War, has undergone rapid development. In general, after the Second World War, the number of accidents. And due to technical causes of accidents and other causes bizarre now either disappeared or decreased. At the end of this period was dominated by the influence of human factors as one of the leading causes of aviation accidents.

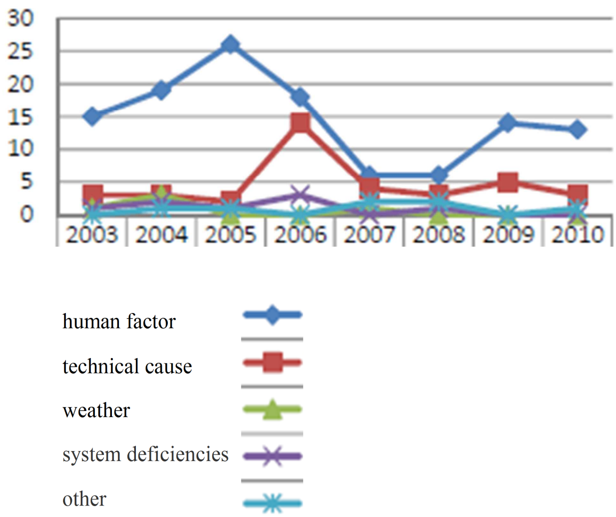

Figure 1 – Number of events by cause

VI. ELIMINATION OF THE INFLUENCE OF HUMAN FACTORS

Expression elimination of the influence of human factors is currently no hiding extensive study, which seeks to define this phenomenon, which also describe the causes of these serious errors. These studies are the basis for a consistent methodology that seeks to reduce the percentage of occurrence of these errors. Eliminate the influence of human factors in aviation is possible in two ways. The first method is the complete elimination of human intervention in the management of aircraft or air traffic control. When piloting large transport aircraft such as the Airbus A-380 that is almost achieved. The aircraft is controlled for most of the flight auto-pilot systems with the exception of emergency situations, where management takes the pilot. Let us not forget, however, that the successful completion of the flight is also involved in managing themselves air traffic management, airport facilities technicians, maintenance mechanics or indirectly responsible for the condition of the aircraft. These people are from today's perspective, the air traffic indispensable. Total elimination is impossible. The second method is the elimination of the above mentioned analysis and definition of human factors and the formation of integrated methodologies. They are produced by different methodologies aimed directly at the actors (pilots, air traffic controllers, mechanics, maintenance, etc.). For example, pilots are SPRM or TEM methodologies that are mentioned and briefly described in the next chapter. But despite all these efforts, in the end it always depends on the actual pilot whether he's going to avoid errors, thus eliminating stress, fatigue, stereotype and other factors.

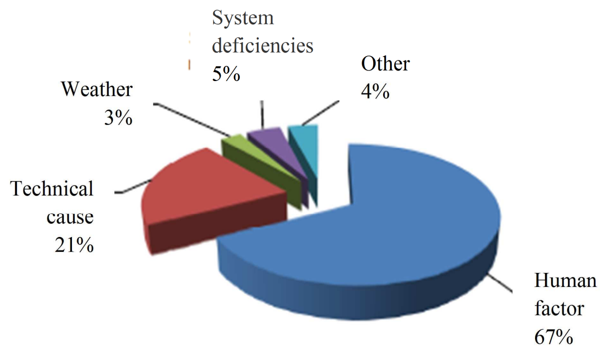

Figure 2 – Percentage of the causes

VII. SAFETY CAMPAIGN

For the past decade has significantly increased the number of accidents. This trend is probably caused by facilitating access to sport and recreational flying public. This may be due to better economic situation of the Czech Republic and the better financial situation and potential pilots also becoming increasingly popular class UL aircraft that are less operationally intensive. This led to the CAA's efforts to reduce this number. One of the efforts is prevention. Safety Campaign published under the auspices of the CAA or directly by the Office, the main instrument of such efforts on preventive measures. These campaigns aviation accidents certainly will not stop completely and it is not their goal. It always depends and will depend on the pilot in the cockpit that can completely rationally and objectively assess the weather conditions, your skills, technical condition and characteristics of the aircraft and a variety of other factors influencing the successful completion of the flight. These campaigns are more likely to aim to highlight the most common problematic aspects of flight or pre-flight preparation and acquaint or re-remind pilots. Safety campaigns are emitted from the end of 2009. So far issued three complete blocks, of which the last third block is underway and its chapters are now published. Each block is also aimed at a different target group. In the next chapter, I described the campaign and tried to evaluate their effect on flight safety, using statistical methods.

The first campaign takes the form of presentation, which is available through the website of the CAA of the Czech Republic. It is chronologically the oldest and was the first in late 2009 and 2010. It was issued Aircraft Association with the support of several other organizations active in air traffic in the country. And namely, in cooperation with the Ministry of Transport, Civil Aviation Authority, the Institute for the investigation of civil aviation accidents and incidents and the Aeroclub of the Czech Republic. The task of the campaign was to highlight sport and recreational pilots on the most common errors and serious problems that affect flight safety. The effort was mainly remind pilots facts and principles that are often neglected. And also again prove to obtain important information (eg state meteorological conditions), and how to behave in certain situations (eg emergency procedures). The campaign is divided into five thematic units.

Thematic units:

a) *Meteorology* - Rain, ice formation, Cloud and fog; Acquisition information on the meteorological situation, etc.

b) *Emergency procedures* - Engine failure after takeoff, landing safety; Principles of selecting areas in need, etc.

c) *Technique of flying*- Corkscrews, Crosswinds, Budget, II. Flight mode etc.

d) *Aircraft technology* - Pre-flight inspection, Petrol, winches etc.

e) *Airspace* - Airspace Classes in FIR Praha, Czech Aeronautical Chart;

The period of development of air traffic accidents in the Czech Republic corresponds to the history of the Czech Republic itself. This is the period of 1993 - present. This campaign was released in late 2009 and 2010, therefore a milestone for its impact will be the beginning of 2010. So years from 1993 to 2009 consider before the campaign period and the years from 2010 to 2011 for the period after the campaign.

The campaign Is focused on deficiencies in technology, methodology, knowledge, etc. Unfortunately, the most serious cause of accidents is the human factor. Throughout aviation history this factor with greater or lesser extent, acts as the main and most serious cause of accidents. For this reason, created a de facto amendment of this campaign, which focused solely on this issue and very aptly named - HUMAN FACTOR IN AVIATION. This sub-campaign created Czech Airlines, more air and cabin crew training school Czech Airlines - CSA Crew Training. Thus, an organization that this issue very intensively. The campaign is divided into three basic issues:

- Human factor and its impact on flying
- Optimization of pilot activities - SPRM (Single Pilot Resource Management)
- Managing threat and error - TEM (Threats and Errors Management)

SPRM area deals with human perception, the ability to understand the situation, the right decisions, to be able to avoid stress, etc. Eg. negative feelings, family problems, or employment may jeopardize the very real decision-making process right pilot. Conversely area TEM trying to pilots familiar with such procedures that can help them avoid errors arising from stereotypical actions, such as the pre-flight inspection aircraft. the campaign pilots trying to present procedures and instructions so as to prevent these often negligent omissions that may lead to an accident.

The second campaign is the chronological order of the other. It was founded in late 2010 and 2011. It was created by the Civil Aviation as aid Aeroclub of the Czech Republic, Institute for the investigation of air accidents, Aircraft Association of the Czech Republic, air traffic management and the Ministry of Transport. Campaign received credit because it is supported by other commercial entities involved with me, either directly or indirectly, to the air traffic in the country. These are for example: Aero Vodochody as Vodochody Airport, Aviation School or F-AIR Air and Cabin Crew Training School Czech Airlines. Previous campaign was targeted primarily for sports and recreational pilots, in terms of the focus of my work, mostly for pilots with PPL licenses and qualifications GLD (qualification for flying gliders). This campaign is aimed more generally, and aims to reach the vast majority of pilots. Office in the course of issuing individual chapters sending all the pilots, which had contact through e-mail notification for a new chapter. For those who were not in the database CAA was able to register on this website and receive this notification as well.

The campaign is processed in the form of nine short videos, which again focus on the most problematic areas. Each video contains an analysis of the causes, examples from real LN and their disastrous consequences or played skits showing what is meant by such lack of discipline. After seeing the video, you can fill out a short test to tell whether the person is properly understood topic. Each part also offers the opportunity to comment and ask questions directly creators campaign.

The third campaign is the third and currently underway. Is published irregularly since June 2011 as an indirect continuation of the previous campaign. Again, the CAA published in cooperation with other actors involved in civil aviation in the country. It is designed very similarly, its chapters again consist of video commercials describing various topics. Yet this campaign is different from the previous one, especially in the target group of viewers. The campaign is aimed at a broader public and to become acquainted with the overall running of the Czech aviation environment. The objectives of this campaign again rather quote the words of spokesman of CAA can not be assessed the impact on air safety, this campaign has, because now underway. But you can say in advance that can be estimated less influence on decision-making of pilots and their overall behavior. This is mainly because the target group itself audience for this campaign is much broader and is not targeted only to pilots themselves, resulting in content and form processing campaign.

VIII. Conclusion

Comparing the current period with the period 1993 - 2003 found that the occurrence of events in individual years unevenly, and can not talk about a marked loss of events or to increase substantially. In contrast, transport aircraft in a period 1939 - 1992 which is the period much longer, it can be observed that the incidence of accidents with the progress of development in this period decreased.

As it turned out, most accidents happen at landing phase. By comparing the current period with the other seasons you can notice a small increase in accidents taxiing phases. accidents in a phase of climb and the approach is again decreased with time.

At all times of the accidents, most came from human factor, the technical defects, which corresponds with the global statistics.

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REGIONAL JETS

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Abstract – *The economics of the small seat capacity (33/50) regional jet are becoming more and more problematic ,as air carriers are looking for better operating efficiencies from new types of aircraft..*

Key words – regional jet, turboprop, fuel costs, airline, seat segment, fuel burn, stage length, GDP, regional airline, engine, biofuel, operating costs, avionics, seat capacity, engine technologies, OEM – original equipment manufacturer.

INTRODUCTION

While the airline industry has experienced a number of significant institutional innovations over the years, including the adoption of hub-and-spoke networks and frequent flyer programs and the use of yield management techniques, true technological innovations have been less frequent. The most significant such innovation over the last fifty years was the emergence of the **jet passenger aircraft in the 1960s.** More recently, the 1990s have witnessed another technological innovation that ,while less dramatic than the jet revolution, is nevertheless significant. This innovation is the **introduction of the regional jet aircraft,** which was made possible by the development of efficient jet engines suitable for smaller planes.

WHAT IS A REGIONAL JET

Under the term of a regional jet most people in the aviation industry see a twin turbofan engine aircraft with a maximum of 100 seats. It is interesting that generally accepted first regional jet is broadly understood to be the Yak 40, introduced in the Soviet Union and flying for Aeroflot already in 1968. Furthermore, it is rather interesting that the Soviets were significantly ahead of the west in developing this category of aircraft. But there were also other new jets with slightly larger size such as the Sud Aviation Caravelle and the Fokker F-28.

The purpose of the regional jet was to replace turboprops on routes which have served small communities and connecting these communities to larger hubs, as well as providing in many cases direct city to city service , bypassing hubs.

REGIONAL JET SEGMENT

The regional jet segment practically exploded in 1989 when Canadian framer Bombardier came to the market with CRJ100, stretching its Challenger business jet into a small airliner seating 50. Bombardier followed up with the CRJ200. That seated also 50 but has been equipped with more efficient engines. Bombardier sold together 1.054 of these regional jets..But Bombardier did not have this market to itself for long. New emerging framer, Brazil´s Embraer saw the opportunity on the market and developed its ERJ135 (37 seats) and ERJ145 (50 seats) which proved to be more popular of the two. The ERJ was launched in 1989 and by the end of 2010 Embraer has sold over 990 ERJs.

The regional jet segment consisted of at least 2.000 aircraft at the end of 2010. To get an idea of the dimensions of the regional jet market we can cite the data from the United States Regional Airline Association which has 62 member airlines . They together fly 160 million passengers per year with aircraft averaging 55 seats and typically fly 457 mile legs. This means that, in the United States ,regional airlines fly 25% of all passengers carried by air and 75% of United States communities rely on regional airline service for their only scheduled air service.

Regional jets offer a previously unavailable combination of attributes. They combine a relatively small passenger capacity ,usually 80 seats or less, with a relatively long range (1500 miles), a high cruising speed (over 500 mph), and a level of passenger comfort that almost equals that of mainline jets. Turboprop aircraft, while providing a similar small capacity ,have a shorter range (less than 1000 miles), lower cruising speed (350 mph), and provide less comfort ,mainly because of higher noise levels and somewhat limited cabin space.

Because regional jets are superior to turboprops on most dimensions ,passengers prefer them. This preference is one of the explanations for the expansion of regional jets service since the late 1990s. Regional jet service gained a foothold over early 1990s and grew dramatically after 1996.

While regional jets have been widely used to replace turboprops as hub feeders from smaller end-points, their attributes admit other uses as well . Since regional jets offer jet-like features but with smaller capacities, they can be used to boost flight frequencies on routes that would normally be served by mainline jets, either by supplementing or replacing mainline jet service. The smaller size of regional jets allows flight frequencies to be raised without the penalty of empty seats , which would be incurred if additional mainline jets were used to boost frequency on route. Yet, there is a disadvantage of both regional aircraft types (turboprops and regional jets) to mainline jets and that is a higher operating cost per seat mile.

FUEL AND LABOUR

Airlines are run in a way similar to supermarkets. Customers pay for services in advance, while the airline pays its vendors anywhere around 120 days after the flight. The cash management is therefore a key activity and is one example of how complex managing an airline is.

The airline sells a seat for a fixed price at the time of sale with future delivery of the transportation but its costs vary, and when volatility increases a projected profit can become quickly a loss. Two big cost inputs for airlines are **fuel** and **labour.**

Using the data from US DoT and 1995 as a base year ,we can see that even though labor costs of US airline industry have grown marginally ,fuel costs have played havoc on costs and this situation is similar in the most of airline industry worldwide. It is therefore little wonder then that the airline industry including the regional airlines had to enter a period of cuts and restructuring ,sometimes quite painful.

Airlines have to keep at cost reductions relentlessly. Whereas fuel costs were 12% of total expenses in 1995, this rose to 27% by 2009. One of the ways how to put the costs down is encouragement to park or to retire older and smaller aircraft which are not anymore that fuel efficient as the new aircrafts. Considering that in 1995 the average stage length was 839 miles, the industry achieved over 0.034 miles per gallon per passenger and by 2009 the industry was operating at average length of over 1.100 miles at 0.021 miles per gallon per passenger. This is a remarkable 38% improvement and demonstrates why the airline industry can fairly point to its fuel efficiency and safety record – it is greener and safer to fly.

LOOKING FORWARD .

Air travel is increasingly a commodity and not just in developed economies only.

In 2009 IATA reported that intra –Asia-Pacific air travelers surpassed those within North America to become the world´s largest air travel market. There is still no doubt that this trend will continue despite certain data showing the slowdown in the China economic growth.

China and India are expected to have relatively robust travel demand. However, it is important to understand that in the new, emerging markets can be seen two types of growth in air transport demand. The first is classic demand from big cities, where critical mass ensures these communities keep their hub status. But when looking at nations like China and India, where governments are determined to ensure relatively rapid growth occurs in many centers within their countries then the growth in demand for air transportation can be seen all over. It won´t only be the established communities. It is these so-called new aviation centres that are going to be highly attractive business opportunities for regional jets.

Twenty years after the delivery of Bombardier´s first regional jet, a change in market dynamics has caused orders for 50-seat regional jets to collapse and production to cease, with no successors planned. Regional airlines appear to be shifting fleets to larger aircraft ,whether turboprop or jet. The larger aircraft offer more capacity and what is most important ,it offers lower operating costs per seat mile. Older 50-seat regional jets are typically moving out of airline fleets ,spending some time in storage and then usually moving overseas to countries in Africa, South America etc.

As of June 2010 total civil aircraft parked was +912, which was up 57% from a ten year low of 1211 in 2007. It is likely that older generations of the parked aircraft will never return to ordinary commercial passenger service.

NEW TECHNOLOGIES

GOING GREEN

Although aircraft CO2 emissions account for cca 2% of total global greenhouse emissions, civil aerospace and airlines are stepping up efforts to develop products with new technologies that will reduce fuel consumption, increase efficiency of operations and generate fewer emissions.

The cost pressure on aerospace and airlines is driving steps that are likely to see older airliners retired before they have lived out their commercial lives. Rising fuel costs mean that older aircraft simply have economics that do not work any longer. During the last oil spike, many airlines parked their older aircraft which many of them were relatively modern. After oil prices eased ,few of these aircraft came back into service.

One the industry hottest topics under discussion is the need to reduce dependence on fossils fuels. The costs are volatile and there is growing demand to become less polluting. Of these two factors, we believe the cost input is by far the greater impetus to move towards biofuels.

Boeing estimates biofuels could reduce aviation-related greenhouse-gas emissions by 60% to 80%. Their solution might include blending algae fuels with existing jet fuel. IATA´s goal is for its members to be using 10% alternative fuels by 2017. The latest oil price spike could only serve to accelerate this effort, making it perhaps happen sooner than by 2017.

ENGINES

Regional jets are clearly under the same pressure as other civil transport aircraft. The search for lower costs is never ending story and this means lower weight, lower fuel burn,better economics. In terms of breaking down the cost impacts, NASA has a research project looking at the next three generations of aircraft. The project is called N+3 and the projected gains in fuel burn for a conventional configuration aircraft, EIS in the period of 2030-35+, is projected to be around 50%, of which 20% would be due to new engines,12% due to airframe improvements (structure + dynamics + etc), and 18% to operational procedures made possible by NextGen (ATC) improvements.

But this is a long way off. Looking at the more immediate future regional jets face the identical challenges of large airliners. Fortunately, regional jets are likely to see newer engines before the larger aircraft. For example, Mitsubishi´s MRJ will use Pratt and Whitney geared fan engine and is expected to fly this year. Bombardier CSeries, using the similar, but larger engine is expected to fly in 2013. The other key engines in the regional segment come from GE and PoverJet.

There are few CIS firms with the current western levels of reliability. Among the firms which are regarded as credible source of power for the regional jet segment belongs Motor Sich of Ukraine, powering the AN 148/158. Unfortunately the aircraft´s performance has not been up to expectation and this is due in part to the engines.

Another source is Aviadvigatel which developed the Soloviev D-30. The D-30 powers the Beriev A-40. This is a 23.000 pound thrust engine, slightly more powerful than used in western regional airliners.

CONCLUSION

The regional market remains quite dynamic. As many airlines migrate to aircraft with higher capacities in search of lower costs there could be seen an evolution within the regional segment. As an example, in turboprops we have seen start off with 19-seaters and now they are at 75 seats and looking at 90 seats

The next generation regional jets are benefitting from engine technologies found on larger jets. This means time on wing for engines is approaching the same high levels .Moreover the avionics on the flight deck are also clearing their way from the latest thinking at Airbus and Boeing to regional jet framers. Fly by wire system is but one example.

Increasing use of latest materials ensures the latest generation of regional jets is increasingly as lightweight and efficient as larger jets. The bigger airplanes will always beat out smaller ones based on economies of scale. However there are a growing number of markets that cannot exploit the larger aircrafts. It is these markets that offer regional jets a successful future.

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Flight global

Flight Magazine

Airside

CIVIL AVIATION EDUCATION - LESSONS FROM THE PAST, CHALLENGES FOR THE FUTURE

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Abstract – *This paper focuses on the issue of the education in civil aviation. It provides a brief overview of the history of the air transport department and sets out challenges and opportunities of the future.*

Key words – aviation education, pilot training, future.

PROLOGUE

Our Department has more than fifty years. It was established 59 years after the first successful, powered, piloted flight of Orville Wright on December 17, 1903 but only 48 years after the first scheduled commercial airline flight which took place on route from St. Petersburg to Tampa on January 1, 1914 so the history of the Air Transport Department is about half of the history of commercial aviation.

This is a good opportunity to look back and evaluate what we have done, but also what we can expect in the future. We are educational institution with one of the longest tradition in civil aviation. We have provided education and training for young people during various political regimes. In the long run I consider this as our advantage. It gave us a wider view, 'setback' and we can compare. Anyway, the pace of changes in recent years has been amazing. Are we able to respond to them?

FIRST STAGE

The 60's of the last century were a good period for the civil aviation. Cheap surplus war equipment was used for training. Aviation benefited from the World War II inventions, technical improvements and technology progress. Pilots, technicians and other aviation personnel were usually ex-military. However, it was clear, that civil aviation workforce should have different profile and different type of training.

In the Czechoslovakia the university education of civil aviation specialists commenced in Žilina in 1961. The Air transport MSc. course started originally at a compound department of road, urban, water, air and other transport. Already in the following year Department of Operation and Economics of Air Transport was established as a separate department focused exclusively on aviation. The first graduates finished the course in the 1966.

During the 60's the Department benefited from a wide base of teenagers who were organised in the semi-military aero clubs and received gliders pilots training free of charge. This was, in my opinion, the best and most natural way of pre-selection of all aviation personnel both for military and/or civil aviation. About 15 % of students had flying experience before enrolment. What were the most important differences between the study programmes from 60's? The dominant feature of the study program 'air transport' was always focusing on economic and operational factors of air transportation.

One of the most significant component of the study programme which enhanced operational knowledge of the students was pilot course - practical and theoretical training which was provided to all students free of charge up to a Private Pilot Licence (PPL). It was very useful hands-on experience. Students completed the course during a summer camp after the third year of study and received extra 30 flying hours in the subsequent two years. Students not only acquired new skills but it was also the best and the most natural way how they verified their theoretical knowledge from flight planning, air traffic control, airspace organisation, aircraft construction, aircraft propulsion, airport and airline operation, meteorology, navigation, aircraft maintenance and others. But it was also strong promotional factor to all who liked to study aviation. The competition among students during the entrance selection process was very high with success rate approximately 1:10. To meet different students' preferences they could select optional subjects during the last two years to specialise more in Economics or Technology.

Table 1-1 *Trend in payment for the pilot training*

Course	Years (from – till)	PPL	CPL	IR	TR	MCC + Line
Air Transport	1962-1989	Yes	-	-	-	-
Professional Pilot	1974-1989	-	Yes	Yes (Slov-air)	Yes (CSA)	Yes (CSA)
Professional Pilot	1989-2008	-	No	No	Yes	Yes
Professional Pilot	2008-2012	-	No	No	No	No

At the beginning of seventies it became clear that professional pilots' education needs new, higher quality and systematic professional training. The department responded to these needs by building up pilots' air school, new pilots training centre the only one in the former Czechoslovakia. The academic part of the curriculum was identical with the air transport MSc course. Those who liked to become commercial pilots had to select in addition theoretical and practical training which was designed in line with the ICAO training manuals requirement. In 1974 Air Transport Department received an accreditation for the new MSc professional pilot course leading to CPL from the Ministry of Education. This course was also free of charge and only the best students could enrol. Their study results were strictly monitored. Both MSc study programmes were attractive and students were highly motivated. After graduation majority of professional pilot students joined Slov-Air company which provided services for agriculture. It was expected, that pilots gain experience and log at least 1500 hours. Then they could receive IR and multiengine qualification in the Slov-Air air school (free of charge) and started they career in the Czechoslovak Airlines where they got type and line training (also free of charge).

The proof that the courses were well designed and successful was that you could find our graduates in the top managerial positions in the most of civil aviation enterprises not only in the former Czechoslovakia but worldwide.

The biggest advantages of the study courses between 1962 – 1989 were:

- the only 'federal' university and had no competition
- excellent selection of students
- attractive curriculum with subjects offering hand-on operational experience
- highly motivated students with top commitment.

However, there were also drawbacks in particular:

- international isolation - no possibility of comparison with 'western' European universities
- no possibility of student exchanges and very limited number of mobilities for teachers.

INTERMEZZO

The situation in the society which followed the fall of the Berlin Wall resulted in so called Velvet Revolution[7] in November 1989 in the Czechoslovakia. The changeover, on the one hand opened new possibilities for us, we became more independent, but on the other side we were cut off from regular funding sources. The practical pilots PPL training for air transport students had to be stopped and the only possibility how to continue with the professional pilots' course was to charge students for practical training.

[7] *There are a lot of definitions of revolution one of these is: A radical and pervasive change in society and the social structure, especially one made suddenly and often accompanied by violence. http://dictionary.reference.com/browse/revolution; Retrieved 26.8.2012*

SECOND STAGE

In the new regime we were able to travel free (if we had money) but what was more important we could compare our results with those at 'west'. To our surprise we were not doing badly during the old regime. In 1993 the Czechoslovakia split and we lost 2/3 of 'former'. There were few other universities which started up to offer similar courses as we did both in the Czech Republic and Slovakia. On top of this many universities offered new programmes which were banned during socialism like management, marketing, business administration, they where new and because of this very attractive for students. This increased competition in the segment of the best students from secondary schools.

Bologna Declaration launched in 1999 by Ministers of Education and university leaders of 29 countries focused on the European Higher Education Area (EHEA) [6]. Bologna enabled students and teaching staff to benefit from mobilities organised mainly through ERAZMUS programme. On the other hand we had to transform our educational system from traditional education, usually with 5 year courses for engineers, to 3 Bc. + 2 MSc. In Slovakia similarly as in much of continental Europe, the previous higher education system was modelled on the German system, in which there was a clear difference of vocational and academic higher education. This mostly had an impact on the old engineer's degrees. The conflation of the two types of degrees was counterproductive in the following cases:

- The vocational three-year degrees were not intended for further study, so those students who also wanted to advance to a master's degree were at a disadvantage.
- The master's degree effectively became the minimum qualification for a professional engineer, rather than the bachelor's degree.
- The academic three-year degrees prepared only for continuing towards master's, so students who entered the workforce at that point were not properly prepared. Yet they would have the same academic title as the fully trained vocationally educated engineers.

As I already mentioned due to decision of our new rector shortly after the revolution we were cut of recourse for flight training and students had to pay for the pilot course themselves. It resulted in dramatic fall in interest for professional pilot course but also for air transport course. For a while we had to accept also 'rich and stupid' and started to struggle with the quality of students.

However, we were able to upgrade the course to meet JAR – FCL standards and we were the only one university and FTO in the former Czechoslovakia offering academic degree combined with ATPL course 'under one roof'. The situation improved gradually. We were able to find additional recourses, form EU research, European projects infrastructural funds, but also sponsors. We gradually got certified for the IFR, ATPL and MCC courses. We also managed to get new FNPT II NCC flight simulator. During the last 3 years we were able to gain new BITD simulator, two flying labs (Seneca V and Diamond 42) and another one Seneca III for IFR training.

We stabilised the FTO and academic courses. Number of students was increasing slowly but surely. Our Department had a very good name in the civil aviation and our students a very good position in air transport industry. The change came with the economic crises in 2008 [2], however, the situation has significantly deteriorated after SkyEurope bankruptcy on August 31, 2009 [3]. SkyEurope bankruptcy meant not only a loss of the major carrier in the Central and Eastern Europe, but especially collapse of labour market for hundreds of pilots and other aviation professionals. Many other airlines bankrupted or had problems in this period: Alitalia, Austrian, Nordic Airways, Olympic Airlines, Spanair, Sterling, Viking Airlines, Wind Jet, Air Adriatic, Axis Airways, Centralwings, Clickair [4] and Czech Airlines. As we know air transport industry healthiness is closely linked to countries economic performance and the problems in aviation indirectly indicate how serious the crisis is.

The situation was mirrored in the students' interest in study of aviation programmes and professional pilot course in particular. We had to face a decline in interest of our Bc. and MSc. courses.

Moreover our department had to fight not only with the consequences of the crisis in aviation, but also with the other competition. In recent years, many new private universities were established[8] offering attractive but ‘escape’ programmes. For some of youngsters it is not important to work in aviation as it was for us. They are different than we were. They would like to get a job which allows them to live a good life, buy a flat, nice car and start a family. The young ones have different priorities, different way of communicating, learning, information retrieval. They live in significantly wider, global life with instant information...

Future

In the forthcoming years we also need to consider problems of declining number of students due to demographic downturn in Europe. World population continues to grow but for more developed countries population has been growing at a slower rate at least since the 1950s. Population is growing slower in Europe and Northern America then it is in other areas of the world (see Fig. 1 – 1). Population in one sub-region, Eastern Europe, has even declined in the past decade [1]. This combined with persisting economic problems limits the number of potential students from Slovakia and the Czech Republic.

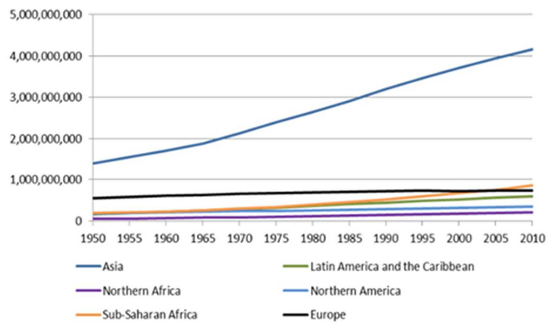

Fig. 1 - 1 *World population by region (Source: Global social change research project World trend reports; http://gsociology.icaap.org/report/demsum.html; retrieved 7.9.2012)*

[8] *There are 23 public and state universities and 13 private universities in the Slovak Republic. Source: The Ministry of Education, Science, Research and Sport of the Slovak Republic; http://www.minedu.sk/index.php?rootId=414; retrieved 8.9.2012*

Our core business is and will be the education and training with strong commitment to Slovakia, the Czech Republic and territory of the Central Europe. However, to diversify our contemplations we should focus our efforts on Asian countries and offer complex educational and training systems to outside EU markets. We should aim at regions where educated workforce is, or will be scarce. This together with expected economic growth determines South East Asia as the most promising region for aviation education. According to Gus Lubin [5] ... ‘young countries will outperform the old countries so India, Philippines, Malaysia and Indonesia look good, meanwhile China is aging’ (see also Fig 1 - 2).

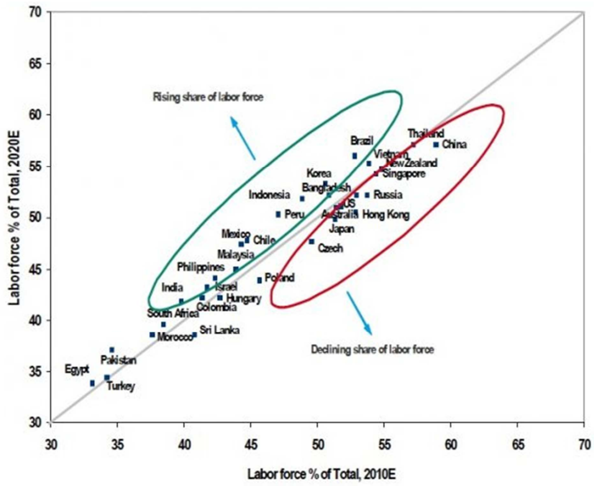

Fig. 1 - 2 *Labor force to total population (%) over next decade (Source: International Labor Organization)*

In cooperation with our partner universities University of Sevilla and The École Nationale de l'Aviation Civile (ENAC) Toulouse we submitted Erazmus-Mundus MSc course in ‘Sustainable Management of Air Transportation System’ – SMARTS this year. This joint study programme was developed by three prestigious universities which have been co-operating in this educational process for a long time. Unfortunately our project has not been selected for financing. That does not mean we are giving up. Besides the possibility to revise the project and submit it again there are also other options which we are considering double and joint degrees. We are already offering our MSc. Air Transport program in English which increases its attractiveness for partners.

Moral

Academia and aviation has always been influenced by politicians, their more or less bright decisions. The question is what we can expect in the future. Where have we got? Where do we get? Even though it may seem that these are wise questions of my little friend Charlie Brown they are not. These are questions of young people who are frustrated from present situation and see no future for them. It is almost the same all over Europe. People are angry with the corruption of politicians, expensive operation of states which fail to function. It is not just the movement in the U.S. ‘Occupy Wall Street’ or ‘Indignados!’ in Spain. The current crisis is not an economic crisis. It is mainly the crisis of morality. People are irritated that those who should represent them are corrupted and follow mainly their own interests. The word ‘politician’ is usually pronounced with contempt. In this environment it is important to find personalities who could serve as an example to young people. One of possible places is academia, a place which still keeps its independence.

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TRUSTING TECHNOLOGY: SECURITY DECISION MAKING AT AIRPORTS

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Abstract *– Security at airports heavily depends on the utilization of sophisticated technology for identifying threats. Yet the decisions about what to do next are dependent on interpretations made by employees. Analyzing data from a field survey of airport employees across European airports, we sought to identify how trust in security technology affects the implementation of security rules and regulations. An analysis of 514 respondents from surveys in eight airports in Europe demonstrated that compliance with security rules and protocols was related to two main categories of trust in technology: one oriented to the technology itself and the other to technology as a means of catching offenders. A further multivariate analysis showed that security decisions by each 'trusting' group tended to reflect its degree of commitment to the organizations' administrative guidelines and the organizations' security attitude. It is demonstrated that this has implications for training and recruitment of security employees for airport security.*

Key words – trusting technology, airport security, security decisions.

INTRODUCTION

The utilization of security technology in airports to detect security threats to travelers and airport facilities is embedded in an organizational framework that links technological output to sets of rules and regulations that govern security employee's behavior. This organizational framework is designed to provide a functional and complete working environment for a security risk management resilience system[9]. (Talbot and Jakeman, 2008). Under ideal conditions such technology and compliance with rules and protocols associated with its output should provide adequate protection against potential threats. Yet, recent evidence in airports has shown that this is not always the case (Kirschenbaum et al, 2012a). There are a consistent and fairly large proportion of airport security employees who utilize security technology but bend the rules and even break them if the situation calls for it. One potential explanation for non-compliance may be based on how employees interpret the technology's output, particularly the degree that employees "trust" the technology; be it trusting the technology completely or perceive it to be the best way to detect threats (Brooks, 2009). We theorize that when such technology is not trusted, there is a higher likelihood that non-compliant security decisions are made. To test this argument, we will explore how and what way "trust" in security technology affects airport security decisions. The implications are far reaching for airport security as well as diverse types of transportation security operations.

TRUSTING TECHNOLOGY AND RULE COMPLIANCE

In order to understand the link between security technology and security decisions, it is vital to recognize that airports are socially based economic organizations composed of complex and interdependent groups of decision makers. (Remawi, et al, 2011). This means that making security based judgments even under a rule compliance framework leave ample room for bending or even disregarding the set administrative rules. But would this also hold in terms of security technology where decisions have been automated? Here, it is not the trusting of the actual physical technological apparatus itself but in trusting the output signals of the technology that may affect actual compliance behaviors. This distinction is important because technology acts as detectors of security threats; they can be seen as instruments that provide employees with information that should make sense (Weick, 2001). But employees may find themselves in situations when the output of the security technology may not match the situation. The classic example of liquid medication exceeding the allowed size but needed by an elderly disabled person during a flight. It is here that trusting the technology or utilizing its output as one of alternative means in making a security decisions becomes paramount.

METHODS

Given the above alternative perspectives of what trusting technology entails, we have posited a simplistic theoretical working model (See Figure 1) which will guide us in our analysis. The model basically argues that trusting technology is a two-pronged construct that may reflect employees complete trust in the security technology devise itself and/or the perception of technology as a means of obtaining output upon which a security decision can be made. The dominance of an employee's trust toward one view of technology or the other will, in our model, have an impact on

[9] The basic underlying assumption made by policy makers and managers alike for maintaining high levels of security rests on an administrative framework governed by both internal organizational rules and protocols as well as externally imposed directives generated by legal authorities.

the likelihood that compliance with the security rules and protocols will be adhered too. Thus, in order to explore how trusting technology affected actual behavior of security related decisions made by airport employees, we generated a series of studies at various international airports in Europe, varying in size and traffic volume, and across different national states and cultures. The first step was an exploratory ethnographic study which laid the foundation for a pilot study and then comprehensive structured questionnaire survey. We used the ethnographic study to provide the raw social data based on actual behavior for understanding the social processes involved in security related activities in airports. Over 250 separate observations were recorded in a number of airports that included a diverse number of air and land sites. Many of the observations incorporated multiple scenarios so that an initial calculation was that over 700 separate behavioral items were extracted and described in detail from the ethnographic observations .[10]

Based on the analysis of the ethnographic study, a full scale field survey based on an extensive and detailed questionnaire was given to a purposely chosen sample of 514 employees distributed throughout the airports' occupational structure at eight (8) airports purposely selected on the basis of their size, distribution and cultural diversity. The structured questionnaire covered a broad range of potential constructs which were discovered in the initial ethnographic observations involved in security decisions. The basis for the measures was linked to our assumption that airports are social organizations that would reflect multiple organizational behaviors generated within its formal and informal structures. A pilot questionnaire survey first tested the reliability and validity of the measures. In certain cases, the questionnaire was translated into the dominant language where the airport was located. The questionnaires were anonymous to meet the ethnical code of the Helsinki Protocols and given out and collected in the same day when possible[11]. In our case, a part of the questionnaire was used; those measures that were relevant for investigating trust in technology. Two key measures of "trusting technology" were employed: Respondents were asked if "I put my complete trust in security technologies?" based on a dichotomous 'yes-no' response. In addition they were asked if "Technology is the best way to catch security offenders?" based on a 4 value Likert type scale from 'completely agree' to 'completely disagree'. The choice of two measures of 'trusting technology' reflected two key perspectives found in the trusting literature: one focusing almost exclusively on the technology itself (complete trust) and the other on the output of the technology (best way to catch offenders). In this way it was possible to not only distinguish how each affected compliance with security decisions related to technology but search for the sources of such decisions.

[10] For more details of the ethnographic method and the results, see Kirschenbaum et al, 2012b The ethnographic study was based on three airports with scripts recorded and categorized by a team of judges. This data set was then analyzed by a software program designed for qualitative data analysis.

[11] It should be noted that the results of an analysis of the ethnographic study closely matched the results of the later performed questionnaire survey providing interactive empirical support for the overall findings.

We also employed three measures of compliance. The first level was based on measuring the degree to which an employee was "bending the rules" asking the question: "I would exceed or bend the rules if the situation called for it". The second level of compliance went beyond just bending the rules but actually "breaking protocol is sometimes necessary". The third level of compliance reflected an even more deviant behavioral pattern as was measured in terms of the question "I would even act against orders" .In all cases a four value Likert type scale from completely agree to completely disagree was measured. Overall, the characteristics of the sample showed that most were male (65%), having an average age of 36.5 years with most under 30 years of age and close to half (42%) married with about a third single (38%).

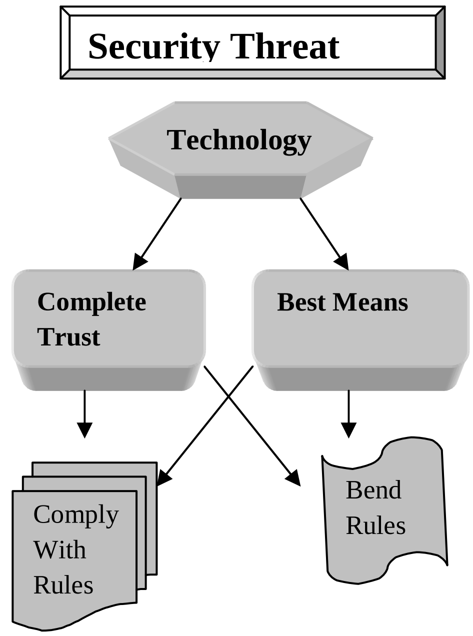

***Figure 1** – Theoretical Working Model of Security Decision Making Tree Linking Trusting Technology and Compliance to Security Rules*

RESULTS

COMPLIANCE WITH RULES

In general, the questionnaire survey results point out that a considerable proportion of the sample had doubts about the ability of security technology to be effective. We found, for example, that just over half (52.4%) of the respondents stated that they put their *complete* trust in technology. In terms of agreeing with the statement that technology is the best way to catch security offenders, the split was toward agreement (51.7% mostly agreed and 14.2% completely agreed) but with still a third disagreeing with the statement (24.4% disagreed and 9.7% completely disagreed). We took these results and explored possible relationships between the compliance behaviors. As usual when using ordinal and interval type data sets, we employed Pearson correlations and Chi Square non-parametric types of analysis. These obviously do not provide the predictive direction of the relationship but do establish the importance of the relationship. What we discovered was the association between them proved to be highly and positively significant confirming that employees who put complete trust in technology also tend to agree to trust its ability to catch offenders. These findings are cross-referenced with parameters that relate to rule bending: "exceeding or bending the rules" and "would act against orders" which is also significantly correlated as well as correlates with "break rules if necessary". This can initially be interpreted to mean that there appears to be a split among the respondents in terms of their willingness to keep or bend the rules.

TRUSTING AND COMPLYING

Following up on these initial results led us to further examine the relationship between trusting technology and compliance. As Table 1 shows, there seems to be a substantive difference in complying with the rules for those having "complete trust" and seeing technology as "best way" to stop threats. Having complete trust in security technology is positively and significantly related to all forms of compliance levels with the rules and regulations. Simply, those who put their complete trust in technology as a means to deal with security threats are less likely to deviate from the prescribed rules and protocols that are generated by the output from these devises.

***Table 1** – Chi Square and Pearson Correlations Tests of Trusting Technology and Rule Compliance*

Comply Measures	***Complete Trust in Security Technology***	***Best Way to Catch Security Offenders***
Bend Rules	χ_p^2 = ns (r=0.096*)	χ_p^2 =22.6* (r=.ns)
Act Against Orders	χ_p^2 = 0.093** (r=0.101*)	χ_p^2 =ns (r=.ns)
Break Protocol	χ_p^2= 0.090** (r= 0.117*)	χ_p^2 =ns (r=-ns)

*P< 0.05; **P< 0.10; ns=not significant

This is not the case for the alternative measure of technology trust based on responses to the question that technology is the 'best way to catch offender'. Here, we note a great deal of latitude in complying with the results revealing no significant correlations and only a hint that there may be significant group differences when it comes to bending the rules. At this point we can only speculate that a behavioral difference between 'complete trust', a form of behavior that leaves little margin for flexibility and viewing trust as the best way to handle a threatening offender, but not the only way to deal with a security matter, is crucial in determining security decisions.

COMPETING EXPLANATIONS

Given the clear distinction in complying with security rules and protocols between employees who trusted security technology completely and those who saw it as the best way to thwart offenders, we next sought to discover the potential explanatory variables for trusting technology. As security related decision making does not occur in a vacuum but is embedded in the social network of relations that security employees find themselves, (Park and DeShon, 2010; Timmons, et al, 2008), we sought a number of reasonable variables that would likely help explain our previous findings. To do so we generated multivariate tests on a number of theoretically potential explanatory variables. In this case, we intentionally utilized statistical tests that would provide us with the robustness and direction of the relationships, namely regression models.

***Table 2** – Regression Model Contrasting Trusting Technology by "Technology is The Best Way to Catch Security Offenders" and "I Have Complete Trust in Technology" with Potential Independent Explanatory Variables.*

Trusting Technology	**Best Way**	**Complete Trust**
Model	Standard Coeff	Standard Coeff
	Beta	Beta
1(Constant)		
Do you use a computer	.126	-.048
X-ray or security imaging machines	.165	.013
In contact with passengers daily	.062	-.056
Passengers are annoying	.097	-.036
Makes a break in my routine	.092	.090
Are good source of security information	-.032	.025
Am trained to recognize security threats	-.052	-.031
Am trained how to respond to threats	.132	-.184
Most threats are false alarms	.041	.003
Ever faced a real security threat?	-.004	-.064
Ever face security threat not trained for	-.115	.067
During your shift Do you work with technological aids	-.007	.025

*p>.05; **p>.01

As can be seen in Table 2, we focused on several possible avenues that would help in explaining rule compliance based on the 'complete trust' and 'best way' responses toward the use of security technology. Possible alternative explanations might be generated, for example, due to (1) employees being familiar with other types of technology; (2) or they are involved in passenger interaction that perhaps makes them more sensitive to threats; (3) being familiar with alternative security information sources; (4) being trained and have proper skills to take advantage of the technology; (5) have alternative ways to recognize threats; and (6) having the initiative in raising the alarm. To examine if these factors do impact on trusting, we ran two separate regression models employing the same independent variables.

Examining Table 2 allows us to contrast the two dependent variables, "Complete Trust" and "Technology Best Way" in terms of the potential explanatory independent variables we noted above. Employing a 0.10 significance levels as noteworthy in explaining the dependent variable, the table reveals that none of the proposed alternative explanatory variables is significant in the case of those who say they have complete trust in security technology. On the other hand, responses that 'technology is the best way to catch offenders" reveals regression model results that show that familiarity with technology – probably on the job experience – and having been exposed to a threat that the employee was not trained for are significant explanatory variables.

COMPLIANT DECISION MAKER

The distinction among the respondents who have complete trust in technology and those who see its output as a means to catch offenders led us to analyze the source of employees having such complete trust in security technology. (See Table 3). Exploring a large number of potential co-determinants explaining 'complete trust' led us to suggest that we were dealing with a special group of employees who fit a profile best described a 'compliant bureaucratic'. This profile was initially discovered when we generated a cluster (factor) analysis of the data set in an attempt to profile employees (Kirschenbaum et al, 2012c). By focusing on characteristics associated with employees by their degree of 'complete trust' in security technology, we note (See Table 3) that the set of significant associations reflect employees who are substantially embedded in the administrative security structure and identify with its goals. Thus, we note that trusting technology completely is significantly correlated with such behaviors as following the bureaucratic administrative protocols (deal only with boss; ask security officer, await orders), receive peer group support for such actions (friends alike) and identify with security goals (safety of passengers).

***Table 3** – Significant Variables Associated with Employees Having "Complete Trust in Security Technology"*

Variable	Correlation	
	$\chi 2$	R
Safety/Security of Passengers is foremost	4.618*	.099*
Receive Information everyday	9.53**	.152**
Receive Updates from my Boss	6.09**	.130*
Friends have similar backgrounds	3.99*	.104*
Deal only With my Boss	8.69*	-.136**
Await until given orders before alarm	11.67**	-.131**
Ask Security officer before acting	6.47	-.106*
What I do is important	11.16**	-.088*
Not doing job right endangers passengers	6.22	-.078

*p>.05; **p>.01

CONCLUSIONS

Our objective in this paper has been to explore and evaluate the link between trust given by airport employees to security technology and their degree of behavioral compliance with the prescribed security rules and protocols that such technology dictates. The evidence from a sample of employees in airports scattered throughout Europe showed that this relationship is complex as trusting security technology is seen by employees as alternatively trusting the devise itself or as the best means to catch offenders. In the analysis we found that in terms of complying with the rules and protocols, those employees who completely trusted security technology tended to follow the rules while those who viewed it as a best means of catching offenders tended to bend or break the rules if the situation called for it. A closer examination of this behavioral pattern strongly suggested that specific characteristics of those who viewed technology as completely trustworthy and those who viewed technology as a means of catching offenders were singly different. Employees who completely trusted security technology were characterized by their organizational commitment to administrative directives and the security ethos. Those seeing technology as a best means to catch offenders were likely to have dealt previously with security technologies and face threats not trained for, likely sensitizing them to the vagaries and false alarms that occur during airport security operations.

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ANALYSIS OF OPTIONS AND THE PROPOSAL TO INTRODUCE THE CLASS F AIRSPACE IN THE CZECH REPUBLIC

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Abstract *– This article focuses on the analysis of possibilities of currently unused class F airspace in the Czech Republic for a small uncontrolled airport. This airspace class will allow the introduction of IFR operations at those airports. Additionally, this article includes the necessary adjustments to the legislation and indicates possible obstacles in practical realization.*

Key words – class F, IFR, airspace, safety.

I. Introduction

Nowadays it is necessary to move aviation in the Czech Republic further. This can be achieved by increasing the number of quality airports, and quality can be obtained by introducing IFR traffic. This, however, brings many necessary changes either in legislation or regulations. The introduction of IFR traffic also increases safety.

Situation – we are flying VFR and weather can be described with the word CAVOK. Suddenly, clouds begin to form and weather conditions are rapidly deteriorating. We should land, but in the vicinity is not any airport. Then, in few more minutes the Earth is no more visible. What now? Emergency situation for the pilot, which could be easily solved by the introduction of instrument approaches at uncontrolled aerodromes, where he could change to IFR and land safely.

So, if we introduce IFR operations at uncontrolled aerodromes we increase safety and sudden weather deterioration will be no longer problem. But before this implementation we need to identify and apply the changes to the aviation industry. These relate mainly to processes and procedures at the airport and legislative framework.

II. The reasons for the Class F introduction

Currently, the Czech Republic airspace is up to 1000ft AGL classified as G. It is based on ICAO Annex 11 and transformed into Czech national standard L 11. However, in the Czech Republic airspace are the rules for using class G modified and IFR flights is banned in class G. Aerodrome traffic zones (ATZ) around Czech uncontrolled aerodromes are also class G and because of this it is impossible to introduce IFR traffic on them. Since the class G airspace is appropriate to preserve, as it is defined, it is necessary to create a new one. In ICAO airspace classifications is class F, which we can use to allow entry of aircraft flying under VFR and IFR conditions to some airspace.

Another reason for implementing the F airspace is increasing safety in General Aviation in the Czech Republic. The introduction of IFR operations at small airports will reduce risk of an accident, because the pilot will have an opportunity to land safely in the time of bad weather.

Class F airspace also enables implementing IFR operations at airports without the need to create ATC at the airport and CTR and TMA around it, which would all need to be done with the change from an uncontrolled aerodrome to a controlled one.

III. Definition of Class F airspace

Class F airspace is defined in standard L 11 and allows VFR and IFR flights, where for IFR is provided beyond flight information service also air traffic advisory service. For IFR flights is also a requirement for establishing permanent two-way radio communication. This definition is based on ICAO Annex 11. We have in the Czech Republic a small change, when air traffic advisory service is not applied.

IV. Requirements for airspace around uncontrolled IFR airports

For the introduction of IFR operations at uncontrolled airports is necessary to ensure safety. Uncontrolled airport means no ATC service and therefore the presence of Aerodrome Flight Information Service (AFIS) is essential at the aerodrome. It is also required to maintain constant two-way radio communications between a pilot and AFIS officer.

V. Options for introducing class F airspace

There are three ways to implement class F airspace and these are:

- Changing the class of ATZ airspace at the aerodrome, where we want introduce IFR operations.
- Creating activated class F airspace in close vicinity of the aerodrome.
- Introducing Traffic Information Zone (TIZ), classified with class F.

CHANGING THE CLASS OF ATZ

Aerodrome traffic zone is in the Czech legislation defined as airspace with 3NM radius from the aerodrome reference point and reaching up to 4000ft AMSL. ATZ airspace class is G.

With the class change of the ATZ an interesting situation would have been created in the Czech Republic airspace. Here will be two types of ATZ, in maps indistinguishable, but with radically different style of operation. Therefore it would be appropriate to act together and introduce the class F airspace in all ATZ.

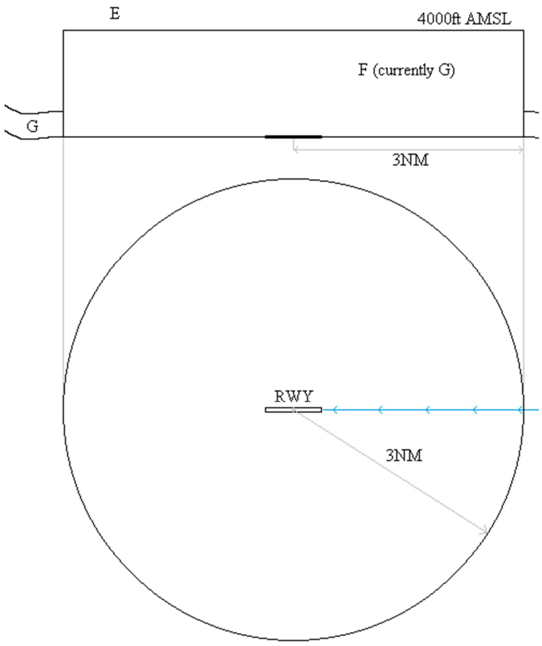

***Figure 1** – Aerodrome Traffic Zone*

THE INTRODUCTION OF ACTIVATED CLASS F AIRSPACE

The second way to allow IFR operations at uncontrolled aerodromes is change the class of airspace around the airport from G to F. A model can be taken from the German airspace, where the class F airspace is used just to protect IFR operations at uncontrolled aerodromes and is activated only for IFR flights. If there is no aircraft flying under IFR, this class F airspace is deactivated and is replaced by class G.

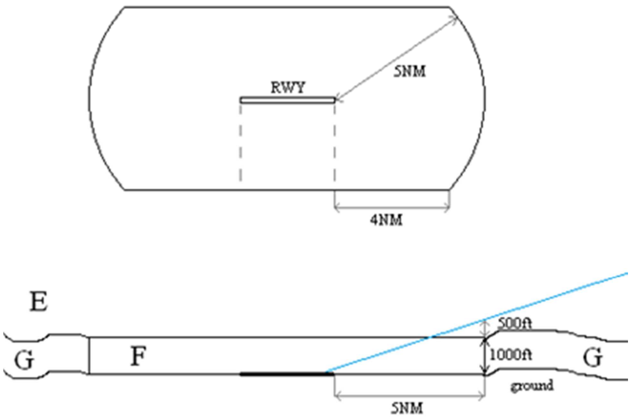

***Figure 2** – Proposed activated class F airspace*

TRAFFIC INFORMATION ZONE

Traffic Information Zone is a third option for the introduction of IFR operations at small airports. Based on the Scandinavian model it introduces at small airports airspace equivalent to CTR, where the size of TIZ area is based on the needs of IFR routes.

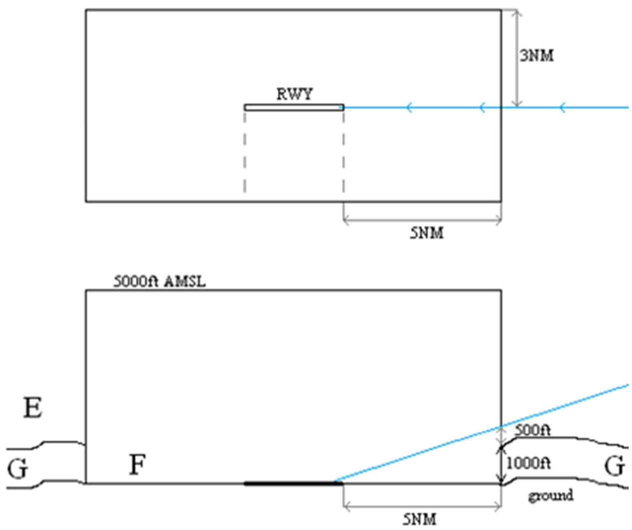

***Figure 3** – Example of Traffic Information Zone*

SELECTING THE OPTION FOR CLASS F INTRODUCTION

Changing the class of ATZ faces two problems arising from the way of change to the class F airspace. If we change only some ATZ, under this abbreviation will be hiding two types of airspaces differing in classification and operating rules. There is the potential risk of confusion. The second option is to change every ATZ to class F, which is feasible, but not necessary, since IFR traffic cannot be introduced to all uncontrolled aerodromes. ATZ has one more drawback and that is the size of its radius. 3NM is not sufficient to descend 1000ft with standard 3° glideslope and therefore ATZ would need larger radius. For these reasons and in view of that ATZ is at Czech uncontrolled airports well established it is appropriate to leave it as is.

The possible introduction of class F airspace, activated only when there is need to protect IFR traffic (following the German model), is unsuitable for use in the Czech Republic due to boundary between class G and E airspaces, which is 1000ft AGL. This is very low and so it will be necessary to raise the upper limit, which already falls within the E and beyond the capabilities of simple changes classes of airspace.

The most appropriate type of airspace for the introduction of class F in the Czech Republic appears to be the Traffic Information Zone. This space would replace the ATZ at aerodromes, where the IFR operations will be introduced. Compared to ATZ and activated class F, TIZ has a larger size so it can absorb IFR operations with sufficient safety boundaries. The proposed dimensions of 5NM from the runway threshold and 3NM on each side of the runway centerline together with height 5000ft AMSL allow ATC to give approach clearance and maintain separation with procedural control.

VI. Barriers to implementation class F airspace

The only obstacle to the introduction of Class F airspace is the need to noticeably change the aviation regulations because class F is currently unused.

VII. The proposed amendments to the regulations for the implementation of the class F airspace

***Table 1** – Changes in legislation and rules*

2	Definition of TIZ, AFIS; Operations at the airport and in the vicinity
11	Appendix N – Aerodrome Flight Information Service (AFIS)
7030	Communications
IP	Specification of differences between ICAO Annexes and L standards
IP	Implementation of TIZ
	Update for pilots training

Main changes in L 2 standard

In Chapter 1 is needed to add a definition of TIZ: Traffic information zone (TIZ). An uncontrolled airspace of defined dimensions extending upwards from the surface of the earth to a specified upper limit within which two-way communications is required for all aircraft and flight information is provided by an ATS unit [4]. Furthermore it is necessary to change the definition of AFIS unit – the old formulation: “Aerodrome flight information service unit (AFIS unit). A unit established to provide flight information service and alerting service for aerodrome traffic at uncontrolled aerodrome and in ATZ” [5], and the new one: “Aerodrome flight information service unit (AFIS unit). A unit established to provide flight information service and alerting service for aerodrome traffic at uncontrolled aerodrome, in ATZ and in TIZ”.

In Chapter 3, section 3.2.5 it is necessary to add “TIZ” in all places where is mentioned “uncontrolled aerodrome” or “ATZ”. Example of change - the old formulation: “An aircraft operated on or in the vicinity of an aerodrome shall, whether or not within a control zone or ATZ: “[5], and the new one: “An aircraft operated on or in the vicinity of an aerodrome shall, whether or not within a control zone, ATZ or TIZ: “.

Similarly, it is necessary to add some variations resulting from the introduction of TIZ. Example of change - Aircraft shall report:

…

v) place of leaving the circuit;

vi) place of leaving ATZ;

vii) place of leaving TIZ;

Main changes in L 11 standard

In the standard L 11, changes concern Appendix N, namely:

In the paragraph 1.1 it is necessary to add a definition of TIZ: „1.1.4 Traffic information zone (TIZ). An uncontrolled airspace of defined dimensions extending upwards from the surface of the earth to a specified upper limit within which two-way communications is required for all aircraft and flight information is provided by an ATS unit.“ [4].

In the following paragraphs where ATZ is noted is needed to supplement the possibility of TIZ according to the following example: Paragraph 1.2 - the old formulation: “AFIS is provided to all known aircraft that are operating at the airport and in ATZ.” [5], and the new formulation: “AFIS is provided to all known aircraft that are operating at the airport and in ATZ/TIZ.”.

Main changes in L 7030 standard

In standard L 7030 there is the need of minor changes in the Communications part, where is required to maintain two way radio communication in uncontrolled airspace TIZ.

Main changes in AIP CR

One of the main changes is the need to update GEN 1.7 DIFFERENCES FROM ICAO STANDARDS, RECOMMENDED PRACTICES AND PROCEDURES and write down all above mentioned changes to it.

It is also necessary to modify formulation in the AIP for uncontrolled aerodromes to make it clear that Traffic Information Zone (TIZ) can exist around them.

In the ENR 1.1, “1.1.2.1.1.1 Aerodrome Flight Information Service (AFIS) is provided on an uncontrolled aerodromes published in AIP CR, Volume III and in Aerodrome Traffic Zone (ATZ) or in Traffic Information

Zone (TIZ) of these aerodromes within aerodrome operational hours and encompasses the following information:

…

i) Relay of departure clearance“

and “1.1.2.1.1.2 Establishing of the radio contact with AFIS unit is compulsory for an aircraft equipped with radio set, operating on an uncontrolled aerodrome and/or within an ATZ/TIZ, when commencing taxiing and/or prior entering an ATZ/TIZ. Pilots shall transmit their reports whether or not an Aerodrome Flight Information Service (AFIS) is provided. To enter TIZ aircraft must be equipped with radio set.”

In the ENR 1.4 is necessary to change the number of classes of airspace used in the Czech Republic: “1.4.1 Classification of airspace - The airspace is divided into five classifications C, D, E, F and G which equate with those recommended by ICAO. Airspace classified as C, D and E is controlled airspace. “, next describe the use of class F:

Class F airspace comprises:

– TIZ of all uncontrolled IFR aerodromes;

and change table of airspaces used in the Czech Republic, where the added class F will have the same parameters as the class G with one change in the column separation assurance, where will be inscribed “IFR from IFR”.

In the ENR 6.1.1 – to the map mark the uncontrolled aerodromes with IFR operations and their TIZ.

In the AD part is necessary at every airport, where will be TIZ implemented, enter this airspace to the map.

VIII. Conclusion

This article shows three ways to implement class F airspace in the Czech Republic to increase airspace flexibility. Of these three options - ATZ, activated class F, TIZ - appears to be the best the last mentioned - Traffic Information Zone. With this type of airspace it is easy to implement protective area around the aerodromes, which is the first step to the implementation of IFR operations on uncontrolled airports.

Also shown here is one way how to modify the legislation in order to implement TIZ with class F airspace. When incorporated into Czech legislation, TIZ will allow new class of aerodrome to be born – uncontrolled IFR aerodrome.

Acknowledgments

This analysis was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS12/165/OHK2/2T/16.

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LEISURE VERSUS BUSINESS PASSENGERS: BELGRADE AIRPORT CASE STUDY

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Abstract – *This paper examines two major segments of business and leisure passengers who start their travel at Belgrade Airport. Cluster analysis differentiated those two segments which were used as input for further descriptive analysis. The paper provides similarities and differences of their requirements and characteristics relying on several surveys which were conducted at Belgrade Airport in the period between 2002 and 2010. Political and economic environment in Serbia in the last two decades, together with increased penetration of low-cost carriers, represent the main factors which have influence on both number of passengers and their mix at Belgrade Airport. The result of data processing in SPSS software and analysis concerning gender, age, employment, permanent place of residence, place of final destination were used for the purpose of profiling both business and leisure passengers at Belgrade Airport. Data analysis also shows difference in evaluation of factors which these two segments take into consideration when choosing airline to fly with.*

Key words: air transportation, leisure passengers, business passengers, surveys, Airport Belgrade.

I. INTRODUCTION

Segmentation, targeting, and positioning together comprise a three stage process. First, one has to determine which kinds of customers exist, then to select which customers one is best at trying to serve and, finally, to implement segmentation by optimizing one's products/services for that segment and communicating that one has made the choice to distinguish oneself that way. Segmentation involves process of identifying a group of customers who have sufficient in common that they form a viable basis for a product/price/promotion combination.

Generically, there are three approaches to marketing [1]. In the *undifferentiated* strategy, all consumers are treated the same, with firms not making any specific efforts to satisfy particular groups. This may work when the product is a standard one, where one competitor cannot really offer much more than another one. The second one is the so-called *concentrated* strategy where one firm chooses to focus on one of several segments that exist while leaving other segments to competitors. For example, Southwest Airlines focuses on price sensitive consumers who prefers low ticket price to other service features. In contrast, most airlines follow the *differentiated* strategy. They offer high priced tickets to business travellers who are inflexible in that they cannot tell the precise time of flying in advance, but filling the planes up partially. Remaining seats on the plane are then allocated to more sensitive customers.

Prior to 1980s, air travel was the privilege of the wealthy and only they could afford to fly. Business passengers prevailed in global market accounting for approximately 60% of total market share (Table 1.). The situation today is completely the opposite. Increasing segment of leisure passengers encompasses two major subsegments – those who travel on holiday and those who travel to visit-friends-and-relatives (VFR).

Table 1 – *Global market share: Business versus leisure passengers throughout decades [2]*

	Segment of Business passengers	Segment of Leisure passengers
ˈ70s of 20th century	60%	40%
ˈ80s of 20th century	50%	50%
ˈ90s of 20th century	35%	65%
1st decade of 21 century	20%	80%

This paper examines characteristics of both leisure and business passengers, mainly focusing on their differences and similarities. Alongside the price elasticity and the value of time, as major attributes which distinguish these two segments, the paper also investigates many others which can influence airline as well as airport. All findings are the result of a unique database gathered from surveys conducted at Belgrade Airport in 2002, 2003, 2005, 2006 and 2010. The paper provides an overview of political and economic circumstances in Serbia in the last decades for better understanding of behaviour of these two segments and their impact on airlines and airport operations.

II. LITERATURE REVIEW

Application of segmentation is a topic of central importance in airline industry and airport systems in order to meet requirements of different kind of customers profitably. Separation between business and leisure passengers is common and widely used in many a priori segmentations. Shaw emphasizes the importance of identifying “customer” in the leisure and business air travel market [3]. In addition, he found that business passengers are primarily concerned with convenient flights (suitable frequency of flights, timings, punctuality, seat accessibility) with frequency of flying much higher in contrast to leisure passengers. Therefore, business passengers are willing to pay high fares in order to satisfy their specific needs. Business travel is in the focus of many researches nowadays. For example, Mason and Gray have investigated the short haul business air travel market in Europe using a conceptual benefit segmentation that addresses the industrial nature of the market [4]. This paper suggests division of short haul business passengers into three distinct segments obtained by iterative cluster analysis: the schedule driven segments, the corporate cog segment and the informed budgeter segment. Lian and Denstadli investigated the segment of business passengers in Norwegian air travel market [5]. Their special interest was in analyzing structure and motivation of business travel in the future regarding innovative communication technology that can jeopardize airline industry.

Teichert et al. developed two approaches of segmenting air passengers [6]. The first one relies on the use of class flown as an a priori segmentation criterion. The second one is alternative segmentation specified by combining preference patterns for product features (flight schedule, total fare, flexibility, FF program, punctuality, catering, ground services) with behavioral and socio-demographic variables. They argued that the first approach does not sufficiently capture the preference heterogeneity among customers and leads to a misunderstanding of consumer preferences. It is regarded as common sense that both business and leisure passengers can fly either economy or business class. O’Higgins and Claussen investigated perspectives on business class aviation and benefits delivered to passengers in relation to the fares paid [7]. There are a few studies that have analyzed the LCCs user’s preference and segments. Martinez-Garcia and Royo-Vela have evaluated the travel preferences of LCC passengers at secondary airports by indentifying market segments applying an ad-hoc approach, while Mason has attempted to evaluate the propensity for business passengers to use low cost airlines in EU short haul market [8].

The authors of this paper were highly inspired by the paper of Dresner in which he investigated how differences between business and leisure passengers may affect airlines or airport operations [9]. As low-cost airlines increase their market share in the world and in Serbia as well as, the percentage of leisure to total passengers will substantially increase. It must be indicated that air travel market in Serbia significantly differs from even those in Europe and especially in America. Thus, comparing to which extend results of our research at Belgrade airport coincide with the findings of Dresner’s paper would be very useful in positioning ourselves against American air travel market.

III. POLITICAL AND ECONOMIC ENVIRONMENT IN SERBIA IN LAST DECADE

Political and social events that took place in early nineties in former Yugoslavian republics have changed their former economic situation and overall state that have been exacerbated and whose consequences had tremendous impact on all its members. Sanctions imposed on Yugoslavia in 1992 by UN Security Council have largely paralyzed the entire country’s economic activity. In the same year, inflation has reached an unprecedented rate of up to 19810%. During 1993, the country has been hit by hyperinflationary crisis with a monthly inflation rate of up to $5x10^{15}$ (period from 1st October 1993 to 29th January 1994). Traffic volume at the Nikola Tesla airport has sharply dropped from 1991 due to the country’s isolation and a ban on traffic to and from countries which are the members of UN Security Council. Thus, traffic volume has reached its minimum of only 339 thousands passengers in 1993. (Figure 1) [10].

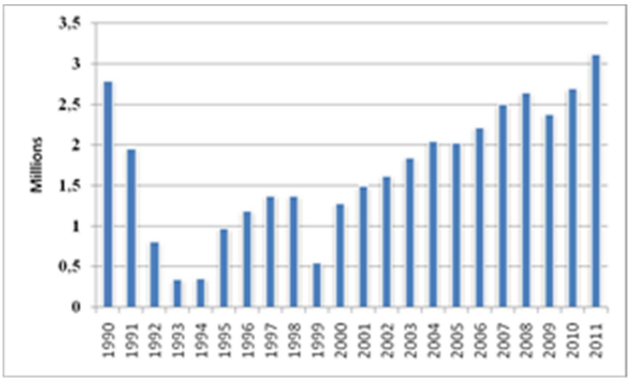

Figure 1 *– Total number of passengers at Belgrade Airport in the period from 1990 to 2011*

Transition that occurs after several years of economic isolation is an inevitable phase through which all countries with former socialist system of government have to pass in order to integrate into the European Union. Qualitative changes derived from this process imply a particular form of integral market economy, creating more favourable business environment and institutional infrastructure. Although the transition process can be long and difficult to sustain because it requires the existence of certain preconditions and execution of many actions, it is evident that it brings positive effects. These effects assume mutual opening (entering) of markets of Serbia and the European Union towards one another and promotion of cooperation. Proper and effective segmentation would be of interest both for the airlines that currently use the airport resources as well as for the needs of Nikola Tesla airport from which the largest number of travel from Serbia to other destinations of Europe and the world perform.

For better understanding of air traffic demand in Serbia, it is useful to consider demand drivers at macro levels. Air traffic demand is influenced by the following factors: income, ticket price and service quality (network and frequencies). Income is usually expressed as Gross Domestic Product (GDP), which represents a basic measure of all final goods and services generated within the borders of a country in one year. According to Gillen, demand for air travel with respect to income (per capita GDP) varies from 0.8 to 2.6 depending on what countries are being linked [11]. According to ICAO surveys, the elasticity of demand for air travel is closely related to GDP. Also, it is noticed that although traffic volume growth is twice as fast as GDP growth, the curve shape of both parameters is very similar and followed the same cyclic changes, which points out a high correlation between them. This rule could be applied at the Belgrade Airport and this is presented in Figure 2.

***Figure 2** – Annual traffic growth in air transportation and GDP growth in the Republic of Serbia*

The generators of the GDP growth in 2011 were as follows: the supply of electricity, gas and steam, the construction and mining industries. The highest GDP has been recorded in the sector of trade, administrative and service activities. It is worth to mention that average net monthly salary in Serbia has been quadrupled in the last decade (from 90 EUR in 2001 to 363 EUR in 2011) allowing generation of additional traffic.

Although air transportation in Serbia, followed by recovery of the entire economy, has recorded continuous growth in the past ten years, it still has not reached that level of traffic that was recorded in the late 80s. The main reasons of slow air transportation development in Serbia are a very low standard, existence of strict visa regime to some countries in the world as well as delayed ratification of the Open Sky agreement which prevented the development of an open market for air traffic services in Serbia and introduction of low cost flights. However, increasing number of passengers at Belgrade airport can be partially attributed to low-cost carriers that entered Serbian market in the last few years.

Additional Supply at Belgrade Airport: Low cost carriers

As it was mentioned above, additional supply at Belgrade Airport affected the demand in terms of increasing number of passengers in both segments. In the period from 2006 to 2010, four low-cost carriers introduced Serbian market. They have spurred the current network, offering new flights spread across Europe. Their entering the Serbian market has been primarily caused by abolishing the visa regime for Serbian citizen to EU countries. In June 2006, Serbia temporally began to apply the Multilateral Agreement on the European Common Aviation Area (ECAA). According to this agreement, any company from any ECAA member state is allowed to fly between any airports in all ECAA member states. All these circumstances led to Serbia becoming an attractive market to low-cost carriers. It is evident that low fares, offered by such companies, have shifted the mix between business and leisure passengers, such that the percentage of leisure passengers has increased. It must be indicated that purchasing power of Serbian habitants is still sufficiently low that travelling by plane is only reasonable if the price of air ticket is twice or three times cheaper than what competitors offer by other modes of transportation. ELFAA (European Low Fares Airlines Association) study supports this claim indicating that 59% of passengers using the LCC service represent the newly-created demand and those passengers would not have used air traffic services in the absence of low fares service [12]. Further, this new market consists of passengers who would not have travelled at all in the absence of low fares services (71%) or would have taken another mode of transport (29%). Table 2 shows the list of low-cost carriers currently operating from the Belgrade Airport with the network of cities that they serve.

***Table 2** – Low-cost carriers operating from Belgrade Airport*

Low cost carriers	Starting Date	Current Destinations
Germanwings	September 2006	Stuttgart
Norwegian Air Shuttle	April 2007	Copenhagen, Oslo, Stockholm
Fly Niki	February 2010	Vienna
Wizzair	April 2010	London (Luton), Gothenburg, Memmingen, Malmo, Rome, Stockholm, Eindhoven

Perhaps the most significant benefit of the LCC services has been the development of tourism and stimulation of new traffic rather than diverting existing traffic. With ticket price significantly lower than their competitors' on these routes, low-cost carriers are more attractive to leisure passengers due to their higher "price sensitivity". Although less proportion of business passengers is carried by these airlines, there is still a slight proportion of those "more sensitive to price"-passengers who are willing to use low-cost services. These business passengers prefer price of ticket to frequency of flying or convenient time of flying and in most cases they pay for their trip by themselves. Although, legacy and low-cost operators focus on different categories of passengers, it is evident that the arrival of low-cost competitors affects the established airlines to lower their prices. Thus, for example, an on-line cheapest flights to Vienna before the arrival of Niki was 217 EUR, and now Jat Airways and Austrian Airlines have tickets on special offer at the price of 99 EUR.

IV. Data

Data was obtained from surveys that were conducted at Belgrade airport. Belgrade airport is a primary international airport and is declared together with airport Nis for commercial airline operations by Civil Aviation Authority. Airport Nis has only a few flights per day and the annual volume of traffic significantly lower as compared to Belgrade airport. Therefore, passenger survey at this airport was out of focus in our research since it would not have considerable effects on the overall results.

The surveys were designed to allow for a general analysis of the Belgrade airport passenger profile. They were performed once a year during the period of one week. There were five such surveys between 2002 and 2010. The analysis of data on passenger profile was conducted as part of Department of Air Transport Research (mainly undergraduate and graduate research reports). The assumption used prior to surveys was that the characteristics of departing and arriving passengers were very similar because of the fact that the flows in two directions were symmetrical. Thus only departing passengers were interviewed due to the activities and the time that they spend in the terminal.

The interviews were carried out at the airport lounge after security control and passport control, but before proceeding to gate. Passengers on the various flights were chosen randomly by poll-takers who posed questions by "face-to-face" method and filled out the questionnaires. All the questionnaires were then processed in SPSS software and were afterwards available for further analysis. Table 3 contains basic information about the surveys. It must be noted that survey from 2010 had a slightly different questionnaire and targeted sample of passengers on specific flights and therefore its results are not comparable to the results from other surveys. Thus, results of this survey will be presented separately in Chapter V.

Table 3 – Information about the surveys

Year	Belgrade Airport Survey Week	Number of questionnaires	Number of passengers
2002	21.04 - 27.04.	1058	2274
2003	30.05 - 05.06.	1039	2732
2005	12.12 - 18.12.	1109	2146
2006	18.12 - 24.12.	1141	1898
2010	15.03 - 21.03.	1509	2713

V. DESCRIPTIVE ANALYSIS

Each of the questionnaires from 2002, 2003, 2005 and 2006 consisted of 18 questions divided into two parts. The first four questions were used to gain insight into the general socio-economic characteristics of passengers such as gender, age, employment, permanent place of residence, while remaining 14 questions referred to passengers' behavior regarding the air travel. This second set of questions provided necessary statistical data on purpose of flying, frequency of flights, number of checked bags, factors that are being considered when choosing an airline, the selected class in airplane and etc. It must be underlined that these four surveys encompassed the connecting passengers as well. First part of this analysis is devoted to processing the socio-economic characteristics of passengers. As already mentioned, statistical SPSS program was employed to code the data and analyze it using descriptive statistics.

Trip Purpose

Trip purpose was classified as follows: business, tourist, private, and other. It is important to mention once again that the surveys in 2002 and 2003 were performed in the spring, but not including Easter holiday period, while the surveys in 2005 and 2006 were in the month of December, before Christmas holidays. Fig. 3 indicates that in 2002 and 2005 majority of passengers (55% and 57% respectively) were traveling for business purpose, while proportion of those traveling for leisure purpose in 2003 and 2006 was slighty higher (53% and 61% respectively). The term "leisure passengers" applies to all passengers not traveling on business purpose such as: vacation, visiting friend and family, medical and other private reasons.

Figure 3 *– Passenger percentages by trip purpose*

Gender Profiles

Until now, the business travel market has been overwhemingly dominated by men. Such trend can be seen at our surveys where around 80% of all business passengers are men (Fig. 4). Regarding the leisure segment, an approximate balance between males and females can be observed, with slight predominance of females in 2002, 2005 and 2006.

Figure 4 *– Passenger percentages by gender*

Age Profiles

Regarding the age, some well establised assumption are confirmed: business passengers tend to be concetrated in the middle aged 30-55 age group. One major finding can be drawn from Fig. 5: comparing to business passengers, proportion of leisure passengers is higher in 18-25, 55-65, and over 65 age group. This is quite expectable since young adults (18-25) and population over 55 usually have a high propensity to fly due the higher disposable income and more time available. Proportion of business passengers is higher in 26-39 and 40-54 age groups, which is also logical since this period of life (26-54) often coincides with period of lower disposable income of leisure passengers due to the costs associated with family life. On the contrary, this is the most fruitful period of life for business passengers.

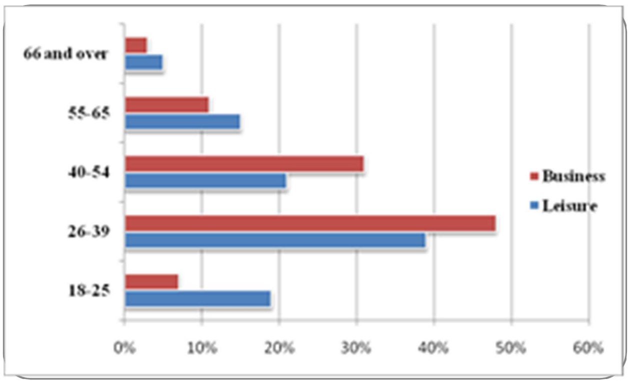

Figure 5 *– Passenger percentages by age in 2006*

Permanent place of residence

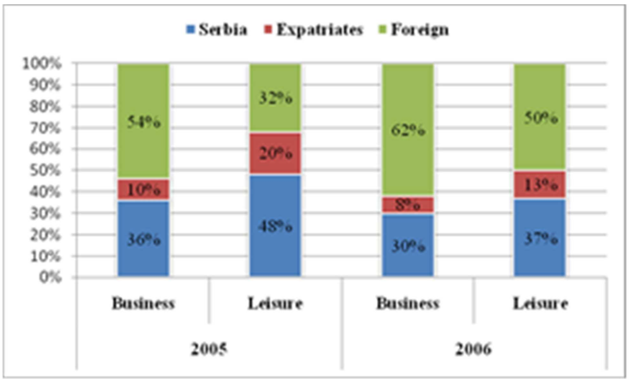

Figure 6 *– Passenger percentages by place of residence*

Passengers were classified by residence as: those living in Serbia, expatriates (Serbian citizen living abroad), and foreigners. Based on Fig. 6 some conclusions about passengers structure could be made. Foreign passengers account for a significant proportion of the total number of passengers in both business and leisure segment. Their proportion in business passengers are slighty higher than in leisure passengers (54% in 2005 and 62% in 2006). 48% of leisure passengers in 2005 were Serbian citizens, which together with 20% of expatriates, build the majority of 68% of total leisure segment. In 2006, Serbian citizens together with expatiates constituted exactly a one half of the total number of leisure passengers. Unlike the Serbian citizens who tend to show reluctance to participate in surveys, foreign passengers are used to it and willing to give answers. Thus, it might be the case that these figures do not reflect the real picture.

Permanent place of residence – Serbian and Montenegro citizens

Our special focus was to investigate which parts of Serbia and Montenegro are responsible for generation of air traffic and what are their proportions in overall figures. Not surprisingly, approximately 60% of all passengers originated from Belgrade Area (the city itself with its broad suburbs). This finding indicates that Belgrade is the city with the "heaviest" economic and political potential in Serbia and it will certainly be so in the future. Fig. 7 shows that business and leisure segments were almost equal regarding the proportions of regions which represent permanent place of resident of respondents in 2005. In 2006, increasing proportion of passengers originating from Montenegro was evident in both segments (24% of business and 19% of leisure passengers compared to 12% of each segment in 2005). Constant proportion of passengers originating from Autonomous Province of Vojvodina can be observed in both leisure and business passengers in 2005 and 2006 (12% with the exception of 7% in 2006 in business segment).

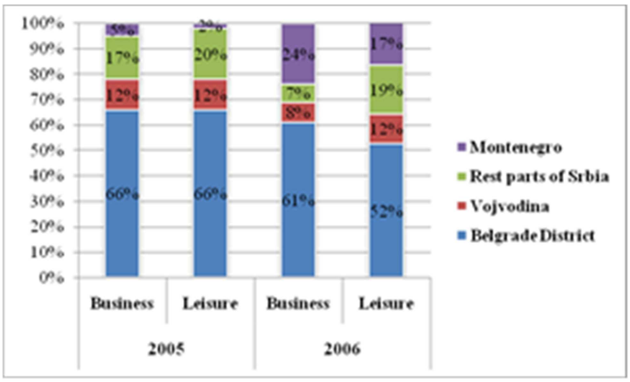

Figure 7 *– Passenger percentages by place of residence (only Serbian and Montenegro citizens*[12]*)*

Sector of employment

Fig. 8 shows the distribution of business and leisure passengers regarding the criterion of (non)employment. Vast majority of business travels were carried out by the passengers who were employed in private companies (more than 60%). The term "self-employed" applies to independent passengers such as lawyers, musicians, some doctors etc. Those passengers account for less than 20% of all business passengers. Among the business passengers there are around 15% of those employed in public companies. Only small amount of business passengers are retired (less than 5%).

Concerning the leisure passengers, they are present in all six indicated categories. But still, around one third of them are employed in private companies. This could be reasonable implication to conclude that those passengers have higher disposable income to afford leisure travel. Approximately 20% of total leisure passengers are employed in public companies. Proportions of students and retired passengers are almost the same accounting for around 15% of total leisure passengers. This high proportion of retired passengers might be explained by situation where recent population migration has left strong residual ethnic links between communities (e.g. grandparents visit their families abroad or VFR travel). Proportions of unemployed and self-employed passengers are quite low within the segment of leisure passengers (accounting for around 5%).

[12] The State Union of Serbia and Montenegro effectively came to an end after Montenegro's formal declaration of independence on 3rd June 2006, and Serbia's formal declaration on 5th June. Up to this date, Serbia and Montenegro constituted the state union.

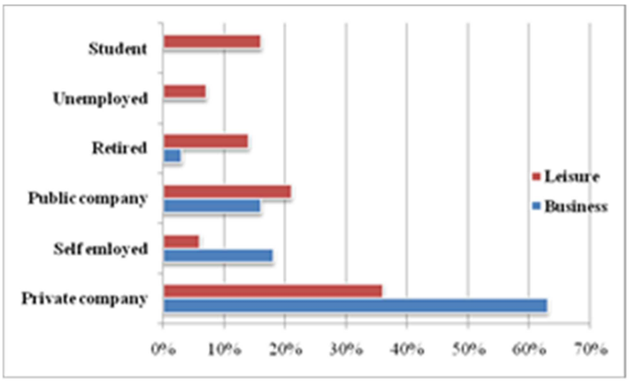

***Figure 8** – Passenger percentages by employment criterion*

Frequency of flying

It is well known that business travel belongs to market characterized as higly concetrated. In all countries, business travels are carried out by a small number of individuals, each of whom travels by high frequency. Concerning this claim, Serbian market is not an assumption. Fig 9. demonstrates that more than 60% of business passengers are well experienced in using air services with frequency of flying between one and three per month which is between ten to thirty flights on an annual basis[13]. Approximately 25% of business passengers fly once in three months which means around four trips annually. 10% of business passengers travel one to two times annually. Proportion of business passengers who undertake their travel less than once in a year is insignificant (2%).

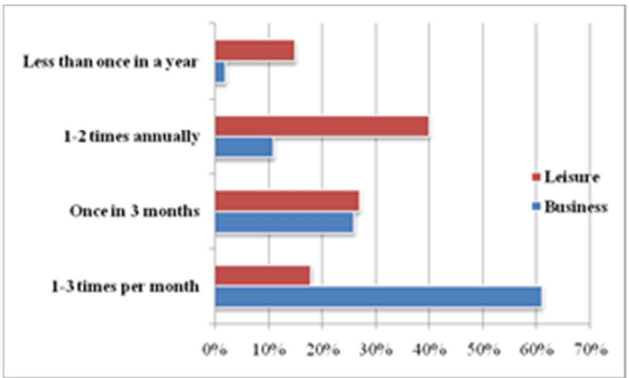

***Figure 9** – Passenger percentages by frequency of flights in 2006*

Among the leisure passengers, the highest proportion of them (40% of total leisure passengers) fly one to two times per year. Proportion of those leisure passengers who travel one to three times per month is the same as those who travel less than once a year (accounting for around 15%). 25% of leisure passengers fly once in three months.

Although expected, all these findings could have impact on both airports and airlines. Our conclusion concerning this topic is highly correlated with the one given by Dresner in his paper about similarities and differences between leisure and business passengers. Due to the high trip frequency, business travellers become expert, familiar with standards offered by airlines and airports. On the other hand, leisure passengers fly less frequently which can cause the need to arrive at the airport earlier. Thus, we completely agree with Dresner that early arriving passengers may pose less of a burden on security line than late-arriving passengers, allowing for less space to be allocated to security and for fewer security personnel.

Number of bags checked

Our a priori expectation that leisure passengers carry more baggage than business passengers has been confirmed by this survey. Almost equal proportion of business and leisure passengers checked one bag (higher than 50%). More than 20% of business passengers have no bags for check in. There might be two reasons for this. First, business passengers travel for shorter time period. Second, they have fears that their possessions could be mishandled and fail to arrive at the destination at the same time and thus they put their luggage into cabin overhead bins. On the contrary, only a slight proportion of leisure passengers have no bags for check due to the nature of their trips. Fig. 10 shows that leisure passengers are likely to check two (30%) or more than two bags (10%) compared to around 15% of business passengers who have two bags to check and 5% of them with more than two bags.

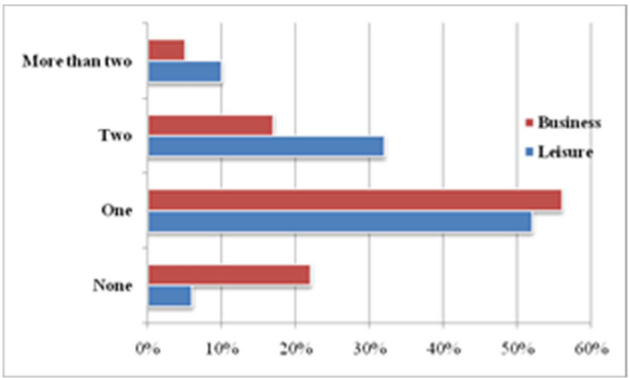

***Figure 10** – Passenger percentages by bags checked in 2006*

The differeneces between these two segments regarding the number of bags checked indicate that changing mix of passengers could have impact on baggage handling capabilities of airports and airline.

[13] Thereby, upon one flight we consider one departure which means that we were rather interested in the number of travels on business purpose undertaken by business passenger than on sum of flights carried by business passengers.

Valuation of factors considered when choosing airlines

Surveys include questions which are designed to ask passengers to grade the factors that one considers the most important in choosing an airline. For this purpose, scale ranges from 1, indicating factor as not important to 5, as very important, was used.

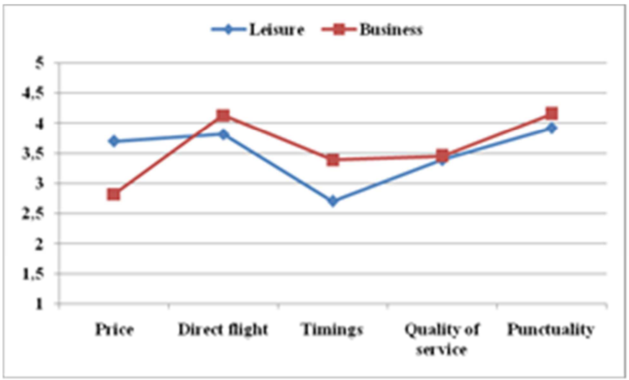

***Figure 11** - Evaluation of factors considered when choosing airline*

It is evident from Fig. 11 that both business and leisure passengers have the same order of priority regarding the features such as direct flight, punctuality, timings and quality of service. Although, the business passengers have valuated direct flight and timing significantly higher than leisure passengers, both segments tend to have same preferences towards characteristics of airline service. Both segments place major emphasis on punctuality. The "punctuality" refers to reliability to be on time most often and consequently to enjoy security of planning the schedule. Punctuality is of crucial importance to business travelers, with flight delays meaning inconvenience, missed appointments and potentially the loss of customers. Direct flight together with suitable timing of flight will enable business passenger to make day-return trips. Quality of service is placed lower on the list of priority if an airline meets business passenger's requirements regarding direct flight, timings and punctuality in the most appropriate manner. Price of ticket is the second important factor valuated by leisure passengers when selecting a carrier. This confirms the theory that the most dominant requirement in leisure market is a cheap air fare. For business passengers, price of the ticket is still on the bottom in the list of requirements.

2010 Survey

Data from the latest survey will be used here as the most recent and reliable. Flows towards destinations with the most expected demand for private and business trips were considered as well the ones with best offer of transfers to other destinations. Those were primarily Austria, Germany, Switzerland and France, i.e. directions west and north. The following charts and tables provide results from this survey. This survey shows that 47% of passengers fly on business purpose, while 53% of total passengers are on their leisure trip.

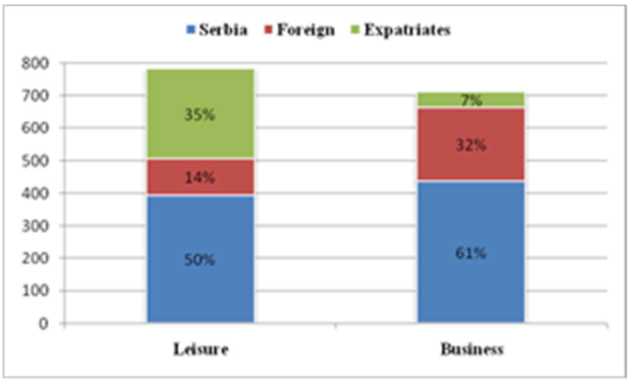

***Figure 12** - Residence and Trip Purpose*

The first conclusion that can be drawn from Fig.12 is that the percentage of Serbian citizens, residents plus expatriates, was prevailing and comprised about 85% in leisure segment and about 70% in business segment of passengers. Although significant, proportion of foreigners in business segment has declined compared to previous surveys from 2005 and 2006 when their proportion in total business passengers accounted for 54% and 62% respectively.

Most frequent destinations

Table 4 and 5 represent the top ten final destinations of business and leisure segments [13]. It can be easily observed that the first several destination countries in both segments are the ones with the largest population of expatriates such as Germany, Austria, France and Switzerland. Since this survey was conducted out of winter and summer peaks, those destinations reflect major leisure passengers flow.

***Table 4** – The most frequent final destination among business passengers*

Final Destination	Frequency	Percent
Germany	172	24%
Austria	101	14%
France	78	11%
Switzerland	55	8%
USA	44	6%
Spain	25	4%
Italy	23	3%
Belgium	21	3%
Netherlands	19	3%
Other	175	24%

***Table 5** – The most frequent final destination among leisure passengers*

Final Destination	Frequency	Percent
Germany	194	24%
France	125	16%
Switzerland	120	15%
Austria	104	13%
USA	59	7%
Spain	30	4%
Canada	26	3%
UK	22	3%
Italy	12	2%
Other	100	13%

VI. Conclusion

This research has shown similarities and differences between two major segments of passengers: business and leisure, emphasizing once again importance of proper and effective segmentation. By providing a review of economic and political situation in Serbia, we tried to explain its effect on both number and changing mix of passengers. It is well known that the emergence of LCCs on the market is contributing to changes in air travel demand, making price perhaps the most important factor when choosing carriers. Since the Serbian market is characterized as a lower disposable income economy, substantial decrease in air fares has especially favored the leisure segment to use air service. Increasing proportion of expatriates in leisure segment can partially be explained by lower air fares offered by low-cost carriers. With their networks connecting Belgrade with all countries with which Serbia has strong ethnical links, low-cost carriers could seriously jeopardize the legacy carriers by diverting a proportion of the existing traffic. However, the introduction of low-cost carriers in Serbian market has primarily attracted a significant proportion of the leisure market.

Although the findings of our research are not surprising, they support many theories about characteristics of two segments observed. Furthermore, these findings provide useful marketing information to airline managers of both low-cost and legacy carriers as well as to airport authority. Based on our research, one can see that business passengers highly value features of service such as: direct flights together with punctuality, then time of departure and quality of service while price of the ticket remains aside, if all previous requirements are fulfilled. Profile of "an average business passenger seen at Belgrade airport regarding the surveys is as follows: he is male, a citizen of Serbia (Belgrade), tends to be concentrated in the middle-aged 30-50 age group, mainly employed or an owner of a private company with frequency of flying around one to three times per month, and in most cases has only one bag to check. On the other hand, typical leisure passengers at Belgrade airport could not be described so straightforwardly since their socio-demographic characteristics are changeable throughout the time. Still, some conclusions can be drawn: leisure passengers could be both males or females, citizens of Serbia or expatriates, encompassing all ages and employment statuses, traveling to Germany, France, Switzerland and Austria during out-of winter and summer peaks with frequency of flying one to two times annually and with one or two bags to check. Those passengers are primarily interested in the features of airline service such as: direct flight, punctuality and price of air fares. They do not find time of departures and quality of service so significant when choosing airline to fly with.

All findings could have sufficient implication primarily to Belgrade airport authority. As low-cost carriers increase their market share, the mix between leisure and business travelers will shift, with leisure passengers accounting for a greater percentage of total passengers. This conclusion we share with Dresner in his paper about airports serving the Washington-Baltimore metropolitan region. Although, he indicates that airline and airport managers have to be more aware of the increasing number of total passengers than of the changing mix, we argue that increasing number of leisure segment at Belgrade airport might result in labor requirements for additional baggage handlers, some requirements for new security equipment and reduced capacity for revenue-generating freights in the belly of aircrafts.

Further studies could be based on investigation of propensity of business travelers to use low-cost services concerning their increasing market share at Belgrade Airport in the last few years. Regarding the leisure segment, it is of fundamental importance for airlines to explore all their characteristics regarding decision-making unit in order to meet their subtle requirements and to create marketing and advertizing in the most effective manner.

Acknowledgement

This research has been supported by Ministry of Education, Science and Technological Development, Republic of Serbia, as a part of the project TR36033 (2011-2014).

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MECHANISM OF THE SECONDARY SLOT TRADING

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Abstract *– The increasing imbalance between the airport capacity and demand urges airport management to seek for an optimal allocation mechanism that efficiently utilizes slot scarcity. The current slot allocation system has been widely criticized to be inefficient, leading to a decrease in the economical welfare and less market competition. Recently, there has been a strong case for a secondary market tailored to better describe the market dynamics and promotes capacity efficiency. The system managed to increase the allocative and productive efficiency at hub airports serving mainly long haul network carriers. However, little attempts have been made to assess the economical performance of the system at airports serving diverse market segments. Accordingly, the research aimed to identify the variation in aeronautical and commercial revenues between traded airlines due to the introduction of secondary slot trading.*

Key words – slot allocation, secondary trading, market, congestion, airport, airline.

INTRODUCTION

The growth of the air transport through the last decades shows that industry plays a key role in the regional economies and in the integration of the global economy as a whole (Czerny et al., 2008). However, this development poses great challenges to the airlines, airports, regulators and politicians. A particular problem arises that the growth of the demand does not go along with the respective growth of the airport capacity. The resolution of the excess demand is generally based on the International Air Transport Association (IATA) administrative slot allocation system. The most important principle is the "grandfather's right" that allocates capacity based on historic use. The current system is highly criticized by economists since it relies heavily on the administrative rules and does not consider the "willingness to pay" as a critical measure for slot allocation. The inability of the IATA allocation system to achieve an "ideal system of allocating airport capacity" that describes the market behaviour has promoted the search for other slot allocation alternatives.

SECONDARY TRADING

Current administrative slot allocation mechanism does not necessarily contribute an efficient economical and social outcome and thus it is essential to reform the current slot-allocation system to reflect the market mechanisms (Gremminger, 2006). The secondary trading refers to the redistribution of slots among airlines as illustrated in Figure 1. The basic difference between the primary trading and the secondary trading is that the latter improve the allocation of the primary airport slots (Czemy et al., 2002). This ensures that all slots are efficiently allocated to the appropriate airlines with minimal disturbance to the scheduling procedures. Other academic researchers and consultants moved one step ahead to highlight that slot trading has a substantial impact on the social welfare, market dynamics, level of competition, and the efficient use of airport capacity (NERA 2004, Mott MacDonald 2006). The following sections describe the socio-economic impact of the secondary slot trading and its implication on the market performance at congested airports.

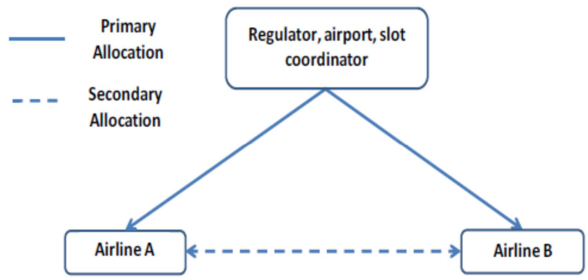

Figure 1 – Primary and secondary slot allocation methods

Source: Czerny and Tenger 2002

SOCIO-ECONOMIC APPROACH

Airports have increasingly been recognized as full-fledged business enterprises that provides different services to airline industry customers. Airports traditionally have been viewed by airlines as natural monopolists controlled by governmental organisation (Starkie, 2001). Since the middle of the 1980s, the airport sector has managed to evolve from a public utility to a commercialized industry that vigorously exploits the aeronautical and commercial revenues. Moreover, public airports have been under a growing pressure by their governments to become financially self-sufficient with less reliance on government support. The commercial revenues have grown faster than the aeronautical revenues and become a main source for income to the airport. The increasing commercialization and privatization have created an intense pressure on airport operators to fully utilize the slots and maximize revenues. Seig states that the best approach to maximize airport profits is through the "use it or lose it" rule that ensures stability and reduces demand fluctuation (Seig, 2010). Airports are not able to maximize the slot revenues by changing the landing and take-off fees according to the changes in demand. Air carriers that witness a temporary decrease in the demand offers more flights to attract more passengers when the "use it or lose it" holds to avoid losing the slot. Thus, the carrier behaviour decreases demand fluctuation and accordingly the risk of forgone revenues are shared between the airport and the airline. The losses are less severe if the commercial revenues share at the airport is large. The major drawback of the "use it or lose it" rule is that the mechanism increases the airport profit while it decreases the social welfare and the airline profits. In addition, the "use it or lose it" rule is not the ideal mechanism to utilize slot scarcity and maximizes airport revenues during high demand (Seig, 2010).

The introduction of the secondary slot trading creates more value for society through stimulating both productive and allocative efficiencies. Allocative efficiency is related to the use of slots for destinations that are highly valued by the society. Productive efficiency is related to the total number of slots that maximize the number of passengers or the maximum revenue management per passenger kilometres (Mott MacDonald, 2006). Slot trading stimulates the allocative efficiency by providing an indication of the value of the slot for potential slot buyers and sellers. In this way, if the value of the slot an airline provides is less than the opportunity cost, the airline will be willing to trade this slot. The airline that pays directly to the slot is better aware of the opportunity costs of the slot. Consequently, the airline is more incentivized to use the slot for larger aircraft at more remote destinations and thus productive efficiency is developed. The increase in demand results in a shift of price from P0 to P1 as illustrated in Figure 2. The consumer welfare increases due to the price reduction for existing consumers and the potential attractions for new passengers (blue area between prices P0 to P1). The producer surplus will decrease as the result of reduction in air fare. However, the producer surplus will increase (shift from S0 to S1) only after the compensation of the slot price by the increase in the volume supplied.

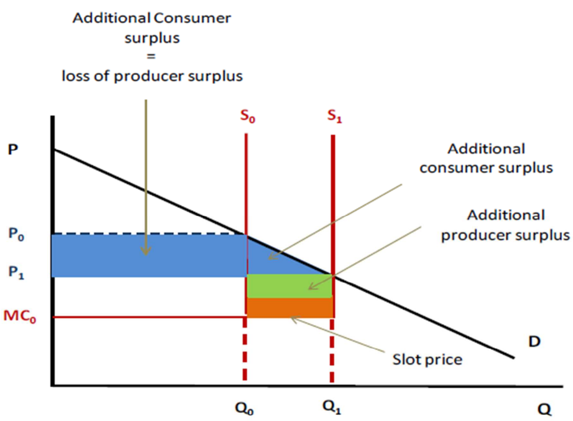

Figure 2 – Consumer and producer surplus (shift in supply)

Source: Mott MacDonald 2006

Further to the increase in the capacity for existing routes, the slot trading contributes a change in the mix of flights such as new destination routes that are more attractive in terms of generalized cost. This results in a shift of demand from D0 to D1 and in an increase in the consumer surplus as illustrated in Figure 3. The shift of the demand curve does not result in change in price (P0 = P1) and thus contributes a social welfare increase by providing more destinations to consumers. The generated producer surplus depends also on the slot price. The contribution of the secondary slot trading on the socio-economic growth of an airport indicates that a net increase in the consumer and producer surplus is achieved through a potential shift in demand and supply.

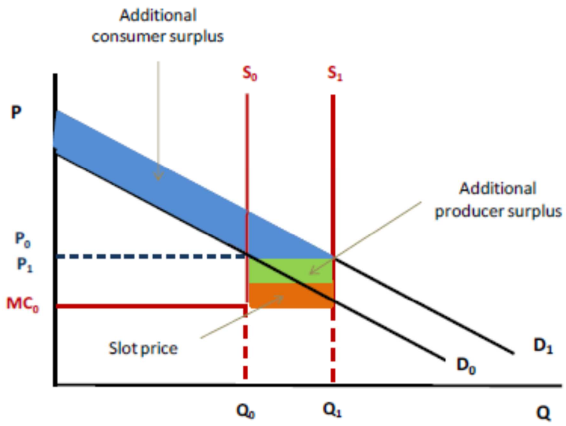

Figure 3 – Consumer and producer surplus (shift in demand)

Source: Mott MacDonald 2006

MARKET DYNAMICS

The secondary slot trading introduces opportunity costs that enhance the market mobility at an airport. The level of slot mobility depends on the efficient allocation of airport capacity. The larger the allocation efficiency is, the larger the corrective power of secondary slot trading becomes (NERA, 2004). At the most heavily congested airports mainly in Europe, the proportion of primary slot allocation is at its lowest. At London Heathrow, less than one percent of the slots are allocated by the coordinator (Wit et al., 2007). However, the share of secondary slot trading at the European airports mainly London Heathrow and London Gatwick is increasing significantly during the recent years reflecting the market dynamics. The share of traded slots at London Heathrow has increased from 5.92% to 8.98% between the years 2008 and 2009 while the share at London Gatwick has increased from 7.23% to 10.64% during the same period (Table 1).

Table 1 – Impact of secondary slot trading on market dynamics

	London Heathrow Airport				London Gatwick Airport			
Season	No. of Transactions	Slots/ Week	Total Slots/Week	% Traded Slot/Total Allocated	No. of Transactions	Slots/ Week	Total Slots/Week	% Traded Slot/Total Allocated
S03	8	236	9,268	2.55%	3	52	5,628	0.92%
W03-04	7	172	9,042	1.90%	6	205	4,118	4.98%
S04	9	262	9,338	2.81%	6	140	5,485	2.55%
W04-05	5	109	9,098	1.20%	0	0	4,320	0.00%
S05	3	68	9,371	0.73%	8	41	5,886	0.70%
W05-06	8	130	9,174	1.42%	4	7	4,495	0.16%
S06	11	139	9,435	1.47%	8	69	5,820	1.19%
W06-07	6	109	9,210	1.18%	4	27	4,497	0.60%
S07	10	235	9,462	2.48%	8	9	5,874	0.15%
W07-08	9	182	9,235	1.97%	7	34	4,495	0.76%
S08	17	220	9,482	2.32%	28	194	6,060	3.20%
W08-09	17	244	9,271	2.63%	8	113	4,267	2.65%
S09	15	313	9,512	3.29%	11	264	5,758	4.58%
W09-10	10	409	9,280	4.41%	5	267	4,242	6.29%
S10	18	435	9,524	4.57%	9	246	5,658	4.35%

Source: Compiled by Author from Airport Coordianted Limited (ACL) website

Most stakeholders including airlines and airport authorities strongly support the mechanism of slot trading as being an effective method to stimulate market dynamics and the main advantages are as follows:

1. Simplicity and efficiency

2. Speed and limited costs of administration

3. Ease of coordination with other slot regulations

4. Continual optimization and adjustments of network

5. Easier exit from market

6. Efficient usage of scarce resources (SDG, 2011).

The increase in slot mobility is subject to the willingness of airlines to buy or sell slots. Not all airlines are in a position to trade slots and loss of revenues may continue due to the airlines holding their slots (NERA, 2004). Several reasons may lead to airlines holding their slots such as:

1. Airlines may hold slots that are inefficiently operated to prevent other airlines to market entry and expansion (NERA, 2004).

2. Airlines may overestimate the opportunity cost of their slot.

3. Airlines may view the slot as an asset and try to hold it in light of future network development and an increase in slot prices. This mainly applies to airlines with stable financial position (NERA, 2004)

4. Airlines may have an optimistic view about their potentials to increase route profitability.

5. Airlines may lack information regarding other potential sellers of slots in a secondary market.

6. Airlines may not be willing to trade slots due to the instability of the slot price at the market (NERA, 2004).

CAPACITY UTILIZATION

The introduction of monetary trading for slots has proved to stimulate the efficient allocation of airport capacity (Wit et al., 2007). As stated previously, the allocation of slots reflects the airline willingness to pay. Slot trading is a step towards integrating the congestion cost into the market price. Accordingly, the slot trading mechanism is a more efficient way to use the airport capacity since other external costs are considered in the process. The contribution of slot trading to the airport capacity is summarized as follows:

1. Airlines optimize the capacity through the use of larger aircraft that generates better yield. The analysis of historic secondary trades shows that the average aircraft size has increased by more than 33% (SDG, 2011). The uplift is mainly due to the trading between short and long haul carriers. London airports (Heathrow and Gatwick) that have introduced slot trading still have the largest aircraft size compared to other European airports as illustrated in Figure 3. The estimated growth of passengers considering that slot trading is implemented in all European slot coordinated airports is equal to 1.2% by the year 2025 (SDG, 2011).

2. Airlines re-structure their route network for better utilization of capacity through increasing the number of long haul routes on valuable slots. This mainly due to the high value of slot per passenger kilometre (Wit et al., 2007).

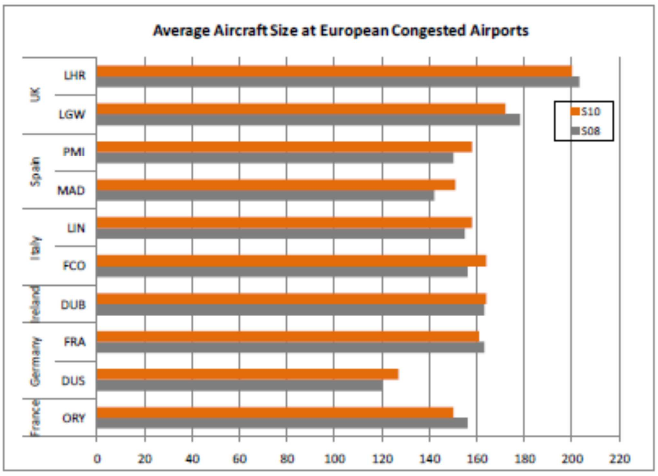

Figure 3 – Averageaircraft size at European congested airports

Source: Stear Davies Gleaves Consultant (2011)

The efficient use of airport capacity is subject to risk of speculation since traded scarce slots may be anticipated with an increase in the slot price. This stimulates the inefficient use of the airport capacity and thus slot buyers have an obligation to use the slot for at least two schedule periods (Stockmann, 2006). Second, the current primary mechanism for slot trading results in windfall profits for new entrants (Wit et al., 2007). For instance, all the allocated slots through the 50% new entrant process (slot pool) are able to sell their slots to other airlines after a given period without having paid for these slots. Accordingly, the following section assesses the impact of the secondary trading on the market concentration and competition.

MARKET UTILIZATION

The European Commission (EC) states that the introduction of the secondary slot trading system facilitates the market access and promotes market competition (Wit et. al., 2007). However, there is a potential risk that the private benefits of an airline might become excessive which distorts competition and reduces rather than enhance the social welfare (Gremminger, 2006). Moreover, Lijesen states that larger carriers are at a better financial position to acquire existing slots from other airlines leading to an increase in their market share (Lijesen, 2004). These carriers benefit from new destinations and frequencies that generate substantial network economies and higher profits. In other cases, the dominant carrier may strategically obtain slots to limit competition with other carriers. As a result, the increasing market concentration translates into higher airfares for consumers (Pagliari, 2001). However, the secondary slot market may contribute positively to the market competition only if a large number of slots are traded to an airline (Leveque, 1998).

The academic review of the secondary slot trading shows controversial results related to the impact of the system on the market dynamics and competition. Till today, the European Commission lacks the administrative regulations that prohibit market monopoly and ensure transparency and higher market competition. Main issues were raised regarding the level of neutrality and independency of the coordinator given that most of these organizations are funded by national airport management companies or airlines. Moreover, the lack of definition regarding the slow ownership may encourage excessive competition. In this regard, section 2.4 describes the experience with the secondary slot trading at congested airports under different regulations and ownership.

CONCLUSION

The secondary trading is considered the most practical approach for implementation since it provides a smooth transition towards higher slot efficiency without major disruptions for airline scheduling. The system stimulates slot mobility for airlines that are more conscious to the true slot value and thus a growth in competition is achieved. The socio-economic review of the secondary slot trading indicates that the system maximizes the consumers' and producers' surplus through higher capacity utilization. This results in an increase in the average aircraft size per slot and profit maximization for an airport. Experience with secondary trading at United States and European airports shows that the market concentration has increased significantly by dominant carriers and the level of competition between airlines has distorted. Moreover, airlines tended to appreciate more the monetary value of the slot which resulted in an increase in the rates of slots rents.

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INCREASING AIR TRAFFIC: WHAT IS THE PROBLEM?

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Abstract – *Nowadays, huge efforts are made to modernize the air traffic management systems to cope with uncertainty, complexity and sub-optimality. An answer is to enhance the information sharing between the stakeholders. In this position paper, we present a framework that bridges the gap between air traffic management and air traffic control on one side, and bridges the gap between the ground, the approach and the en-route centers on the other side. We present a system with three essential components which are the trajectory models, the optimization process and the monitoring process. The uncertainty around the trajectory is captured with a Bayesian Network where the nodes are associated to random variables of the time of overflight on metering points of the airspace and of the traveling time of the routes linking these points. The resulting Bayesian Networks defines the airspace and Monte-Carlo simulations are done to estimate the probability of sector congestion and delays. Then, an optimization on the parameters of the Bayesian Networks is done to reduce these probabilities. Besides, a monitoring process is responsible to update the actual situation of the airspace. Consequently, the system manages directly the uncertainty through the trajectories and determines an optimal state of the airspace. This latter can be communicated to the controllers in the form of objectives. The ideas behind this system were validated with the help of air traffic controllers at Thales Air Systems. This paper presents a new formal specification of this global optimization problem.*

Key words – Air Traffic Control, Mathematical Modeling, Bayesian Network, Optimization, Monitoring.

I. INTRODUCTION

For the next years, an increasing demand on the worldwide airspace will result in restructuring the air traffic management systems. This restructuring will address the inherent problems of uncertainty, complexity and sub-optimality. A better exchange of information between the stakeholders would allow the enhancement of the current situation. Nevertheless, the information must be exploited in a way that the complexity will not increase. Otherwise, the capability of the controllers to handle traffic will decrease which is the opposite of the initial goal. Therefore, decision support tools are essential for this data processing task in order to give only the relevant information to the human after a series of underlying analyzes. These ones encompass many functions such as prediction, correction and optimization. In addition, real-time monitoring is a core component that should be taken into account in the development of future systems.

In this work, we propose a model to address the uncertainty and perform optimization in the tactical phase of Air Traffic Flow Management. The novelty of the research is to address directly the uncertainty and the real-time monitoring aspects. The main benefit is to anticipate the congestion points by enhancing the information sharing between stakeholders. Also, this would improve the resilience of the system in case of weather hazards. We believe that an inter-sector coordination (Letter of Agreement) can be prepared through objectives on the trajectories. For the controller, it consists of bringing the flight to a geographical point within a time interval. This can be done by giving the clearances manually or by communicating the objective directly to the pilot. Then, the objective can be easily entered in the Flight Management System (FMS) of the aircraft. These objectives associated to geographical points, termed *metering points* in the following, are the core of our approach. In terms of acceptability, the responsibilities of the controllers do not change because they are not obliged to fulfill the objectives since the safety has priority over optimization.

This article is organized as follows: Section II presents a literature survey of the air traffic flow management problems. Section III gives the framework definition, while in Section IV the airspace model is presented together with a preliminary analysis of its properties. Section V describes the optimization problem over the model and Section VI gives a toy example. Section VII presents a Monte-Carlo approach in order to simulate trajectories over a realistic airspace. Finally, Section V concludes the paper and states some open questions that will be eventually addressed in our future research.

II. RELATED WORK

The literature on Air Traffic Flow Management is quite rich in the Operational Research community since the beginning of the nineties. Different problems have been addressed with different levels of complexity, and two different axes can be used to classify them. First, the static approaches consider a single stage while the dynamic approaches are multi-stage. Static problems perform an optimization once and for all, whereas dynamic problems construct partial solutions on-the-fly, based on new information, e.g. better forecast of weather and traffic demand. Second, the problems can be either deterministic or stochastic. In the stochastic case, the constraints and the decision variables are not known with certainty. Different scenarios are defined through a tree scheme for reducing the problem to a deterministic equivalent model. A thorough literature review of these approaches can be found in (Augustin A.), and the remaining of this Section will described the most well-known in turn.

The *Ground Holding Problem* minimizes the sum of airborne and ground delay costs when the demand of the runway exceeds the allowed capacity. It does so by assigning ground delays to flights. The first variant of the problem, the *Single Airport Ground Holding Problem*, was defined by (Odoni). Later, a stochastic and dynamic version of the same problem was described by (Richetta), and recently addressed by (Mukherjee), who overcome some limitations of the previous model such as modeling the change on marginal probabilities over a finite set of scenarios and allowing revisions to assigned ground delays of flights. The objective functions considered can be a trade-off between efficiency and equity and might be non-linear.

The second variant is the *Multi Airport Ground Holding Problem*. It was formulated by (Vranas P.). This work was the first approach to model a network of interconnected airports and connecting flights with delays propagating through the network, and addresses the static and dynamic cases of the problem. However, strong assumptions are made: the sector capacities are unlimited and rerouting and speed changes are not allowed. These assumptions are unrealistic in a congested airspace such as the European one. Thus, (S. S. Bertsimas D.) presented the Air Traffic Flow Management Problem with sector capacities and rerouting. Also, the decision variable of a time slice is assigned to one only if the flight arrives **by** this time slice in a given sector, resulting in tightening the structure of the linearized problem. Note that this work uses realistic instances with several thousand flights.

Finally, the *Air Traffic Flow Management Rerouting Problem* was defined by (G. L. Bertsimas D.) which is the most complete description of the real system. They integrate all the phases of a flight, ground and air delays, rerouting, continued flights and cancellations. The validation instances are of the same size than the National Airspace of the United States. Also, (A. A.-A. Agustin A.), (A. A.-A. Agustin A.) developed a formulation based on the routes of the network instead of the nodes, both for the deterministic and stochastic cases. All the problems mentioned so far were solved with 0-1 programming techniques. These techniques are powerful enough to address large-scale scenarios.

Stochastic Optimization was used by (Oussedik S.) to handle sector congestion with take-off delays and alternative routes while managing the airlines constraints. (Barnier N.) Modeled the slot allocation problem, which consists of assigning slots to flights in the sector and respecting the capacity constraint. This problem was solved with a Constraint Programming model. Furthermore, the minimization of air traffic complexity in a multi-sector planning paradigm was addressed by (Flener P.) also with Constraint Programming. Moreover, optimal path planning under weather uncertainty is addressed by (Aspremont A.) with Dynamic Programming techniques.

In all previous models, uncertainty was eventually addressed by using a finite number of scenarios. Nevertheless, the sector load prediction is an essential issue to consider. As a matter of fact, a poor estimation of the time required to travel along a route will generate unnecessary regulations. Approaches based on trajectories have failed to predict the state of the airspace beyond a time horizon of 20 minutes, leading to the design of aggregate models (Sridhar B.). These models have been used by (Bayen) to achieve control over one sector with a multicommodity network. Due to the fine discretization of time along the edges, the size of the optimization problem is huge.

However, to the best of our knowledge, no system has yet addressed the real-time monitoring and optimization of a large-scale network by modeling the flight plan with temporal uncertainty in a continuous domain and the purpose of this paper is to propose a model allowing us to foresee such a system.

III. FRAMEWORK DEFINITION

The framework used in this work is different from the ones of the literature. The time horizon considered is from current time up to 2 hours which is referred to the *strategic phase* in air traffic control. The idea behind the strategic phase is, on the one hand, to bridge the gap between the air traffic flow management (ATFM) and the air traffic control (ATC), and on the other hand, to bridge the gap between the ground, the approach and the en route phases. This is named a *gate to gate* solution. The ATFM is responsible for validating the flight plans of the entire day by considering the sectors capacity constraints while the ATC is responsible to ensure the aircraft separation and to minimize the delays. The idea behind the strategic phase is to take into account the information from the ATC and predict accurately the future sector load. Then, regulations or clearances can be applied on incoming flights in order to respect the sector capacity and reduce the complexity at the ATC level. In other words, the current information is used to reduce the future complexity.

Today, the controllers are responsible for applying regulations or clearances to manage their airspace. As said previously, the decision support tool must not increase the workload by communicating too much information. We think that objectives on metering points will suffice to create the multi-center collaboration. So, the responsibilities of the controllers are not impacted, but they have additional information on the global state of the airspace i.e. a low value on temporal objective indicates that the flight can go directly to the next metering point without causing a congested situation in the following sectors. On the other hand, a high value indicates that airborne delays should be applied to reduce the workload in the following sectors. From the ATFM view, the model integrates the Central Flow Management Unit (CFMU) slot allocations of the European context. It is important to notice that the uncertainty comes essentially from these departure slots. A slot is defined around a calculated time of take-off t_d as an interval: $[t_d - 5 \quad t_d + 10]$. So, the uncertainty of departures is around 15 minutes. The following model will be a way to evaluate the impact of such intervals.

The objectives are affected by the evolution of the uncertainty generated by weather conditions, aircraft performances and interaction between aircraft. In a purely deterministic world, a global optimization should be done once and for all in order to find the global optimal plan. As seen, such problems can be solved for huge airspace, but the complete solution can hardly be implemented due to the departure slot uncertainty of 15 minutes. This uncertainty will here be integrated at the model level, and monitored in a closed-loop way, as it diminishes with time. If everything goes as planned, the objectives will be slightly modified according to the evolution of the variance. In the case that an unforeseen event occurs, the objectives will be modified in function of its severity.

IV. SYSTEM OVERVIEW

This Section introduces the rationale of the proposed way to manage the uncertainty and optimize the state of the airspace at different time scales. The temporal scope is from the current time up to 2 hours. The geographical scope is in the order of multiple centers in a congested area, e.g., the European airspace.

The system consists of three processes: model creation, monitoring and optimization. The model creation receives new flight plans, and creates one Bayesian Network for each flight plan once and for all (in particular, all possible alternative routes are known at creation time). The periodic monitoring adjusts the parameters of the model following observations from the real world. This process ensures that the model of the actual situation is consistent with reality, a critical issue for doing accurate prediction when sampling. The optimization process optimizes the current situation by proposing modifications of the flight plans in order to reach an optimal state. Then, these new plans (schedules at different metering points) are communicated to the controllers, who implement them their own way.

INPUTS

The inputs of the system are the airspace structure and the flight plans. The airspace is defined by a set of metering points located in different sectors where ingoing and outgoing points are distinguished from the others. One flight plan is defined as a directed acyclic graph (DAG) where the nodes are defined as pairs (metering point, schedule), containing all possible alternative routes for this flight. A flight plan also includes the estimated time of departure, the estimated time of arrival and a statistic of the time required to travel along the routes linking the successive metering points. This statistic can be determined by different means: statistics on flight position recordings when they are sufficient. It can also be defined with a simulator that can model non-deterministic phenomenon like the effect of the wind, errors on the cruise speed, on the flight altitude changes etc. In any case, the following model is enough general to take into account any statistic under the form of a probability density function. To obtain it, one can generate the histograms and approximate them with density estimation techniques, e.g. kernel density estimation. To reflect the aircraft performance, a lower bound and an upper bound are also associated to routes.

TRAJECTORY MODEL

The model used to express the uncertainty around a trajectory is a Bayesian Network (BN). This is a natural choice since it is a DAG composed of random variables (RV) and their conditional dependencies. A node is equivalent to a RV and an edge between two nodes represents that the first RV has a direct influence on the second one. The BN framework can then be used to do inference when new information arrives as time goes by. For more information on BN, see (Friedman).

Compared to other approaches from the literature, BN is a framework that deals directly with uncertainty. Some continuous distributions can express a rich set of scenarios, potentially an infinite number, with only few parameters. It is mainly used to infer unobserved variables and so, it is well-adapted for predicting the time of arrival on the following metering points. Many algorithms exist to do inference. Also, learning is an important topic in BNs. Techniques exist for learning the parameters of the RV. This will be important in the monitoring process. Optimization can be easily integrated in this framework. Note that exact algorithms, like message passing, efficiently use the structure of the network to do this task. In the case of huge networks, powerful approximate inference algorithm, like particle-based, exists too. In our case, this set of tools is well adapted to the graph structure of the airspace network. The interactions between metering points, flights and sectors can be captured through this representation.

In the context of ATFM, the metering points are 3D points of interest (longitude, latitude, altitude) such as coordination points between sectors or convergent flows points. In order to keep the representation as compact as possible, only the points included in the flight plan at hand are part of the network. Let $G_f = (V_f, E_f)$ be the DAG giving the anticipated routes as well as acceptable alternative routes of flight f. Two particular vertices of the DAG are distinguished: V_0 is the origin and V_d is the destination. Associated to a point i of the route, a probability density function (pdf) $f_{T_{f,i}}(t_{f,i})$ gives the probability distribution that f will flight over this point over time. At this point, the pdf of V_0 is known, i.e. the CFMU slot or the estimated time of entrance in the airspace. Let's determine the pdf of the others. To this end, we use the pdf of $T_{f,i\rightarrow i+1}$, the probability distribution of the time required to go from i to $i + 1$. Also, we make the assumption that the time required to go from i to $i + 1$ is independent of the time of arrival at i. Then, we suppose that $T_{f,i+1} = T_{f,i} + T_{f,i\rightarrow i+1}$, i.e. the time at the current point is the sum of the time at the previous point with the time required to go from the previous point to the current one. To make sense, the pdf of $T_{f,i+1}$ will be determined in function of the pdf of $T_{f,i}$ and $T_{f,i\to i+1}$. We use the joint probability distribution $f_{T_{f,i},T_{f,i\to i+1}}$ and we integrate along the line $t_{f,i\to i+1} = t_{f,i+1} - t_{f,i}$.

In terms of density probability function, we have:

$$\begin{aligned} f_{T_{f,i+1}}(t_{f,i+1}) &= \int_{-\infty}^{\infty} f_{T_{f,i},T_{f,i\to i+1}}(t_{f,i}, t_{f,i+1} - t_{f,i})\, dt_{f,i} \\ &= \int_{-\infty}^{\infty} f_{T_{f,i}}(t_{f,i})\, f_{T_{f,i\to i+1}}(t_{f,i+1} - t_{f,i}) dt_{f,i} \\ &= \left[f_{T_{f,i}} * f_{T_{f,i\to i+1}}\right](t_{f,i+1}) \end{aligned}$$

The second line is obtained with the independence assumption. The third line expresses the fact that the pdf of the sum of two independent RV is the convolution of their pdf. If we suppose that the trajectory is defined as a series of RV $(T_{f,i}, T_{f,i\to i+1})_{i\epsilon[0..n-1]}$ where n is the number of points of the trajectory, we can find that the pdf of any RV $T_{f,i}$ is the convolution of all the previous pdf in the sequence. This can be proven by induction.

Then, in a real-time system, we would like to take into account new information. This can be done with the conditional pdf:

$$f_{T_{f,i+1}|T_{f,i}}(t_{f,i+1}|t_{f,i}) = f_{T_{f,i\to i+1}}(t_{f,i+1} - t_{f,i}) \quad \text{(Eq. 1)}$$

which simply translates the pdf of the time of traveling of $t_{f,i}$ time unit. This does not change the previous result. As a matter of fact, we can remove the pdf of the observed random variables, because there is no more uncertainty associated to them, and replace the first remaining pdf with a conditional pdf.

At this point, we have the necessary concepts to create the trajectory structure in our BN. This corresponds to a path, the sequence of metering points, and the RVs of traveling linked to them. So, we can make a query on the BN by using the joint pdf and its relationship with conditional pdf. For the sake of notation, let $\mathbb{P}(T_{f,i}) = f_{T_{f,i}}$ and $\mathbb{P}(T_{f,i}|T_{f,j}) = f_{T_{f,i}|T_{f,j}}$. Here, we use the Markov property:

$$\mathbb{P}(T_{f,i+1}|T_{f,1}, \cdots, T_{f,i}) = \mathbb{P}(T_{f,i+1}|T_{f,i})$$

which states that the conditional pdf of the future point does not depend on the past points given the current one. This simplifies the computation of the queries that required the joint pdf. With the chain rule and the Markov property, one can write:

$$\begin{aligned} \mathbb{P}(\cap_{i=1}^{n} T_{f,i}) &= \textstyle\prod_{i=1}^{n} \mathbb{P}\left(T_{f,i}| \cap_{j=1}^{i-1} T_{f,j}\right) \\ &= \prod_{i=1}^{n} \mathbb{P}\left(T_{f,i}|T_{f,i-1}\right) \\ &= \prod_{i=1}^{n} \mathbb{P}(T_{f,i\to i+1} - t_{f,i}) \end{aligned}$$

where $\mathbb{P}(T_{f,i\to i+1} - t_{f,i})$ is the translated pdf defined at Eq. 1.

Notice that, for now, the graph structure of the resulting BN is a forest, a disjoint union of trees. Consequently, all trajectories are independent. To manage the case of diversions, we change directly the structure of the BN by removing the old path and adding the new one. Notice that after the modification, all RVs connected by a path to any modified RV are impacted and the associated pdfs must be computed.

The modeling of the uncertainty of the trajectory will be useful during the optimization process to evaluate the objective function and the constraints. This should also capture the actual situation of the airspace updated by the monitoring process. Contrary to the existing works on stochastic optimization of the ATFMP, the uncertainty is modeled directly in the trajectory through the metering points.

SECTOR OCCUPANCY MODEL

In the ATFM context, the usual way to measure the complexity of an airspace configuration is to count the number of flights that will go through the sector during a given time interval (e.g., one hour). Given the flight plans of the day, the complexity of every sector is predicted in order to determine the potential congestion time, and when appropriate, to issue regulations for certain flights. To this end, a capacity threshold on the number of flights is used. Similarly, in the proposed model, the sector constraint enforces that the number of flights in a sector is below a threshold during a given time slice.

Nowadays, the time slice has a constant size of one hour. The reason behind this coarse discretization consists to absorb the uncertainty of the trajectories. In other word, we can be sure that the flight will be in that interval at a given moment. This has the effect to lower the effective capability of the controller to handle traffic. Figure 2 shows the consequence of a coarse temporal discretization. Assuming that the threshold of the capacity constraint is two flights, on the 60 minutes, this sector would be congested whereas two flights will land at the beginning and one flight will take off at the end of the time slice. With a finer discretization of 15 minutes, only the time slice x_1 will be congested. Nevertheless, to achieve a finer discretization, the prediction capabilities of the model must be of the same order of magnitude than the time slice size. This will be an important element to validate on the real dataset.

To define formally the sector constraint, let $S_{i,[t_0,t_1]}$ be the random variable that models the number of flight traveling in

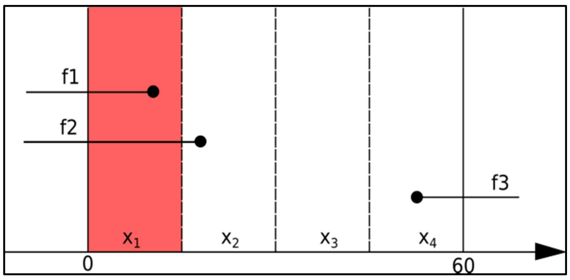

Figure 6: Effect of coarse time discretization

sector i during the time interval $[t_0, t_1]$. In the BN, we create a node S_i connected to every boundary points for every trajectory. Then, the pdf associated to S_i is defined in function of pdf of the boundary points, which can become easily cumbersome. Notice that to be a valid pdf, this definition shall respect the following property:

$$\sum_{j=0}^{\infty} \mathbb{P}(S_{i,[t_0,t_1]} = j) = 1, \quad \forall\, t_0 < t_1 \in \mathbb{R} \bigcup [-\infty, \infty]$$

i.e. that the probability that there are any number of aircraft at any time interval is equal to 1. Notice that this formulation can be used to describe the sector occupancy for any intervals. It simply changes the integration bounds of the underlying pdfs. Finally, let $C_{i,[t_0,t_1]}$ be the binary RV that models the fact that a sector i is congested during the time interval $[t_0, t_1]$. Then,

$$\mathbb{P}(C_{i,[t_0,t_1]} = 1) = \mathbb{P}(S_{i,[t_0,t_1]} > c_i)$$

where c_i is the capacity of the sector i.

MONITORING

Finally, the monitoring process is responsible for maintaining a consistent model of the actual situation of the airspace. Information from radars, aircraft and the weather centers can be taken into account to estimate the values of the distributions of the random variables of the BN. The task undertaken in this process is filtering which estimates the current value given past observations. Concretely, the monitoring changes the pdfs and integrates observations of overflight time by creating conditional pdfs. By example, when a flight takeoff, the exact time of departure in known and the 15 minutes of uncertainty vanishes. This must be taken into account in the subsequent optimization phases.

V. OPTIMIZATION

Now that we have an airspace model, we want to optimize the time of over flight in order to reduce the probability of congestion for every sector and minimize the delays incurred by resulting regulations. To do so, we need an optimization problem with an objective function to minimize, decision variables and constraints.

OBJECTIVE FUNCTION

For the purpose of optimization, objective functions have to be defined. As a matter of fact, the interests of each stakeholder of the airspace are often antagonistic or ill defined. A cost index quantifies the benefit of a trajectory for an airline. Usually, this cost index is not communicated explicitly to the controllers and so, integrating the airlines preferences in the model can be difficult at this point. Nevertheless, the initial flight plan is supposed to reflect the interest of the airlines and is validated by the CFMU. Let A be the vector of time of arrival for every flight, usually given by the airline. With our airspace model, we can obtain an estimator of this value with the expected time of arrival:

$$\hat{A}_f = \mathbb{E}(T_{f,a}) = \int_{-\infty}^{\infty} t f_{T_{f,a}}(t) dt$$

Consequently, the cost function shall penalize the delays on the expected time of arrivals:

$$\mathcal{F}(\hat{A}, A) = \sum_{i=1}^{N} |\hat{A}_i - A_i|^p, \quad p > 1$$

where $\hat{A}$ is the vector of expected time of arrival for all the flights. The definition of the aggregation of the cost function of individual flights to obtain a global cost function is not unanimously accepted. As a matter of fact, it can have a major impact on the benefits of the airlines. The equity is a serious issue in the domain and must be addressed in this model. To do so, we use a super linear function, as in (G. L. Bertsimas D.), where the exponent p will penalize the situation where all the regulations are assigned to a few flights for the benefit of the others. Regarding the fitness landscape of the objective function defined previously; it is indeed possible that it is multimodal. Consider for instance two flights that wish to enter a sector that has a capacity threshold of one. Two optimal solutions are to delay either the first or the second flight. This kind of symmetry implies that the landscape is multimodal.

DECISION VARIABLES

The decision variables model two types of regulation. The first one is the rerouting regulation, which modifies the path of the original flight plan. Here, we simply choose to keep the initial route or to choose an alternative in the set of possible routes for a given aircraft. Once an alternative is chosen, the BN must be modified and inference must be recomputed. This operation has a computational cost and an operational cost in terms of complexity. For this reason, the modification of these decision variables shall be penalized. Nevertheless, when observing the change in the cost function with different alternatives, we can assess of the robustness of the solution with rerouting. Moreover, it can be a mean to evaluate if a rerouting strategy is appropriate to decrease the cost function of a flight. Besides, this permits to model the uncertainty around a weather phenomenon that will require the rerouting of a flight.

Once the rerouting decision variables are fixed, the second regulation concerns the times of arrival on the metering points. This is done through the parameters of the chosen traveling time pdfs of the airspace model. On one hand, a change on the mean can suggest that the flight might change its current speed and, on the other hand, a change on the variance might suggest that the flight will commit to arrive at the metering points with a greater precision. Besides, these parameters must be bound to respect the aircraft performance constraints. An upper bound for the number of decision variables is $A \cdot \mathrm{M} \cdot P$ where A is the cardinal of the set of alternatives, M is the maximum number of traveling time RV per alternative and P is the maximum number of parameters for modifying the pdfs of traveling time. Consequently, the number of decision variables can rapidly increase in function of these values.

SECTOR CONSTRAINT

The sector constraint can be used as a hard constraint or a soft constraint. For the first case, a feasible solution must satisfies $\mathbb{P}(C_{i,[t_0,t_1]} > c_i) \leq \varepsilon$, i.e. that the probability that the sector i is congested during the time interval $[t_0, t_1]$ is under a threshold ε. For the second case, the soft constraint will be part of the objective function in order to minimize the probability that a sector is congested.

VI. Example

In this section, we present a toy example of use of the airspace model. This will permit to understand the limits of a theoretical approach with very simple pdfs and will translate by the use of approximation methods, which are simpler for computer-based simulations.

So, let's imagine the case of two aircraft following the same flight plan. The sequence of waypoints is: 1-2-3-4. 2 is an ingoing waypoint and 3 is an outgoing waypoint of the sector S1. Table 1 gives the parameters of the uniform distribution of the input pdfs. The expected time of arrival for both flights is at time 46. Also, we choose a capacity of 1 aircraft for sector S1. Figure 2 shows the resulting BN where the blue nodes are RV of the trajectories and the big yellow node is the RV of the sector occupancy.

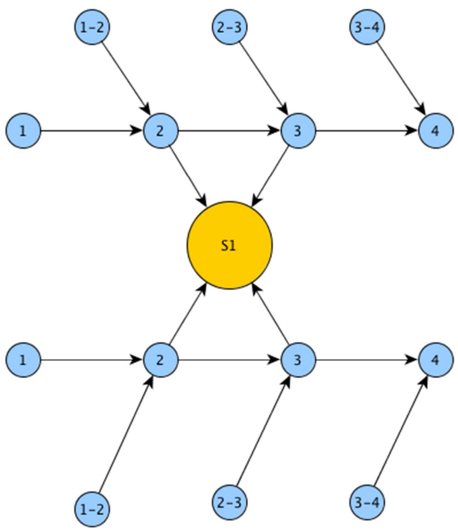

Figure 7: BN for two trajectories and a sector

With the d-separation in BN, we can see that the two trajectories are independent if S1 is unknown because it is a v-structure. If S1 is given, then the information on one trajectory will impact the pdfs of the other trajectories. Moreover, we can see the Markov property because there is only one edge going out of a RV of metering point going toward another metering point.

	Lower Bound	Upper Bound
1	-5	10
1-2	10	12
2-3	15	20
3-4	12	18

Table 4: pdfs given as input

Now, imagine that the pdf at the point 1 and the pdfs of the traveling time between points are all uniform distribution: $\mathcal{U}(t_0, t_1)$. The pdf at point 2 is then the convolution of two uniform distributions. The pdfs at points 3 and 4 are the convolution of the resultant and a uniform distribution.

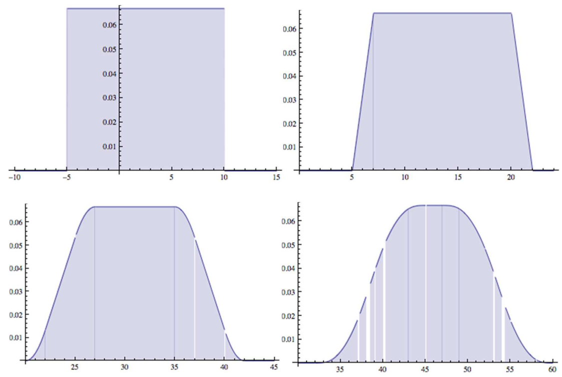

Figure 8: Convolution resultants on pdfs

Figure 3 presents the resulting pdfs obtained by the convolution operator. The up left figure shows the pdf of the origin point 1. We choose the CFMU interval. The up right figure shows the pdf at point 2, the down left shows the pdf at point 3 and the down right figure shows the pdf at point 4. With the Central Limit Theorem, we remark that the resultant of the sums of independent RVs tends toward the Normal Distribution as the number of RVs increases. To do the computation, we use Mathematica8. We can see that the number of pieces to define the function increases rapidly. For the pdf of 4, the function is defined with 24 pieces.

Now, the probability that the flight i is not in sector 1 in the time interval $[t_0, t_1]$ is

$$\begin{aligned}\mathbb{P}\big(F_{i,s,[t_0,t_1]} = 1\big) &= \mathbb{P}\big(T_{i,2} > t_1\big) + \mathbb{P}\big(T_{i,3} < t_0\big) \\ &\quad - \mathbb{P}\big(T_{i,2} > t_1, T_{i,3} < t_0\big) \\ &= \mathbb{P}\big(T_{i,2} > t_1\big) + \mathbb{P}\big(T_{i,3} < t_0\big) \\ &= \int_{t_1}^{\infty} f_{T_{i,2}}(t)\,dt + \int_{-\infty}^{t_0} f_{T_{i,3}}(t)\,dt\end{aligned}$$

which corresponds to enter the sector after or to exit the sector before the interval. Note that these two events are mutually exclusive. Consequently, the probability to be in the sector is: $1 - \mathbb{P}(F_{i,s,[t_0,t_1]})$. So, we can define the probability that the sector 1 will be congested:

$$\begin{aligned}&\mathbb{P}\big(C_{1,[t_0,t_1]} = 1\big) = \mathbb{P}\big(S_{1,[t_0,t_1]} > 1\big) \\ &= \mathbb{P}\big(S_{1,[t_0,t_1]} = 2\big) \\ &= \big[1 - \mathbb{P}\big(F_{1,1,[t_0,t_1]} = 1\big)\big]\big[1 - \mathbb{P}\big(F_{2,1,[t_0,t_1]} = 1\big)\big]\end{aligned}$$

From the last equality, we remark that the flights are not required to be at the same moment in the sector to be taken into account in the probability. Consequently, the probability that the sector is congested during $[-\infty, \infty]$ is equal to one. For the same considerations as described in the sector occupancy model section, it is important to consider small intervals. On the contrary, the intervals must not be too small because the probability that the two aircraft will be in the same sector during a small interval decays rapidly.

As an example, let $t_0 = 5$, $t_1 = 10$ and $\varepsilon = 0.75$, we obtain $\mathbb{P}\big(C_{1,[10,20]} = 1\big) = \frac{196}{225} \approx 0.87 > \varepsilon$ and so, we consider that a regulation must be undertaken in order to reduce this high probability. For now, the objective function is equals to 0 since the expected value of the pdf at point 4 is 46. If we change the parameters of the uniform distribution of 1-2 for [12,14], that is we delay a flight for 2 minutes, then the probability drops at

$\frac{56}{75} \approx 0.747 < \varepsilon$. On the other hand, the objective function is now equal to 2, for $p = 1$. This toy example shows that the model is adequate to model the uncertainty of the trajectory at a high-level. Besides, we can see that the objective function does not take into account the variance of the RV of arrival time. In the latter, this issue shall be addressed.

VII. Monte-Carlo Approach

From the example, we can see that working with the pdfs with a symbolic computation approach can rapidly become cumbersome. Consequently, we will rely on Monte-Carlo simulations to estimate the sector congestion pdfs. From (Andrieu C.), we know that a Monte-Carlo method used the fact that:

$$\frac{1}{N}\sum_{i=1}^{N} f(x^{(i)}) \xrightarrow{a.s.\ N\to\infty} \int_X f(x)p(x)\,dx$$

where $x^{(i)}$ is a sample drawn from the pdf $p(x)$. This is an unbiased estimator and, by the law of large numbers, it will converge almost surely to the expected value. In our case, scenarios are built with trajectory sampling for statistical analysis on expected time of arrival and sector occupancy. A scenario is complete when it gathers one sampled trajectory per flight plan. This process gives as an output a set of M scenarios $\mathcal{D} = \{\zeta[1], \cdots, \zeta[M]\}$. The elements of this set are referred to particles in an approximate inference context. Of course, the accuracy of the Monte Carlo simulations depends directly on M and a sensitivity analysis shall be done on the real dataset in order to determine the order of magnitude of M in order to obtain good approximations.

Stochastic Optimization Problem

The goal of modeling a Stochastic Optimization Problem is to address uncertainty over the outcomes of a system by considering the most likely ones. In our system, this is done with Monte-Carlo simulation, which generates the scenario set $\mathcal{D}$. The optimization process contains its own copy of the airspace model for evaluating the solutions without affecting the monitored airspace model. Then, the optimization process starts from the actual situation as a default solution and generates a new set of parameters for the model. A trajectory sampling method is used to generate a new set of scenarios and these are statistically analyzed in order to determine the variation of the aggregate cost function under the sector capacity. A possible stopping criterion for this iterative process is to monitor the value of the cost function, and to stop whenever it stays stable during a predefined time interval. This stopping criterion should work even in the case where we do not have enough information on the landscape of the cost function. However, other stopping criteria could be envisioned.

Sector Constraint Approximation

As seen previously, an estimate of the probability of congestion can be the ratio between the numbers of scenarios where the sector is not congested over the total number of scenarios. This probability is computed for every time slice and so, this creates a stochastic process. So, a finer discretization has a cost in the number of random variables in this stochastic process to be estimated.

An efficient way to estimate this stochastic process is to determine the time intervals during which the flight is in a sector. This is straightforward with the sampled times at the entrance and exit points of the sector. Afterward, we can count the number of intervals that intersect with the time slice and compare it to the threshold.

Objective Function Approximation

In the Monte-Carlo approach, the landscape of the objective function is not explored directly, but approximated with a huge number of simulations. In this case, it is often more relevant to maintain a pool of good solutions since a solution is better than another solely with a given probability.

Finally, regularization terms will probably be necessary in the objective function, in order to obtain realistic solutions. The rerouting must be penalized since it adds a workload to the controller and the pilot. The means of the traveling RVs should also be modified only slightly, and in a consistent way, in order to minimize the number of changes in the flight behavior. Finally, the variance should always reflect the uncertainty of the system and should be integrated in the objective function. These considerations will be more easily taken into account with the Monte-Carlo approach due to its flexibility.

More generally, it is very likely that several different objectives will have to be considered for realism. Most probably, the optimization problem might become multi-objective - even though the ultimate output of the optimization process in the context of the proposed system should be a single set of changes for all flights. Hence some decision-making algorithm might also be needed here - unless some human supervision can be imagined. This could lead to the creation of a new role, e.g. multi-sector planner who will be in charge of using the system.

VIII. Conclusion and Perspective

In conclusion, a new system is presented to cope with uncertainty, complexity and sub-optimality. The novelty is to define the trajectories as a stochastic object, i.e. a part of a BN. Thereafter, these objects evolve with the real system and are updated by a monitoring process to keep a consistent model of the actual situation. From it, an optimization process determines the optimal airspace configuration towards which the system should tend. The optimal airspace is communicated to the controllers in the form of objectives on the trajectories. Moreover this model is compatible with the current Air Traffic Control system and does not imply a complete reorganization of control centers. As a matter of fact, the controller is still responsible for rerouting flights at the tactical level. The new information is only a time interval on points of the trajectory, which will create a collaborative environment between the controllers.

Many research topics are encompassed by our system. First, the definition of the metering points needs an extended analysis from the past trajectories. Trajectory clustering techniques can be used to determine the flows and the underlying points. Thereafter, because of the number of decision variables, the multi-objective context, the graph structure of the trajectories and the use of Monte-Carlo simulations for evaluating the quality of a solution, evolutionary optimization techniques seems good candidates to address this problem. Besides, powerful filtering algorithms should be used to keep a consistent model of the actual situation. The prediction of the sector load depends on it. Finally, because of the stochastic context, a sensitivity analysis shall be done on the number of scenarios required to get good estimates.

This article gives the theoretical tools to determine exactly the pdfs. In the following works, we will determine the relation between the rate of convergence of the approximation and the number of required scenarios. Equity in the objective function shall also be addressed.

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THE EXHAUST EMISSIONS MEASUREMENTS FROM THE PZL SW-4 PUSZCZYK HELICOPTER DURING A PRE-FLIGHT TEST

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Abstract *– this paper presents the results of the tests on the exhaust emissions from a turboprop engine used for the propulsion of PZL SW-4 Puszczyk helicopter. The tests were conducted in pre-flight conditions. The paper presents the test results and their analysis that enabled the determining of the values of the brake-specific emissions at selected load points. The load values were determined based on the courses of the parameters recorded by an on-board flight recorder during the pre-flight test. The obtained values of the brake-specific emissions as assigned to the engine load conditions were used for the evaluation of the emissions of the helicopter under actual operating conditions. The load conditions of the powertrain were determined based on the analysis of the operating data as obtained from several archival flight records. The analysis enabled an obtainment of the values of the exhaust emissions generated during the actual operating conditions of the helicopter.*

Key words – emissions, turbine engine, helicopter, pre-flight test.

INTRODUCTION

The increasing demand for transport tasks dedicated to helicopters is directly translated into growth of the number of such types of aircraft in use. This, in turn, is significant for the condition of the natural environment. The emission of carbon dioxide and particulate matter is still a severe threat and, at the same, time an obstacle in the development of contemporary combustion engines - turboprop engines in particular [1, 2, 4, 5]. The current provisions relating to the effects of the aviation transport upon the environment as introduced by the Environmental Protection Agency and International Civil Aviation Organization mainly relate to noise and exhaust emissions with particular consideration of nitric oxides [3, 6]. They relate to turboprop, turbofan and jet engines and include requirements for apparatuses and stationary testing procedures depending on the operating conditions of an engine [6]. Turboprop engines used in helicopters are classified with respect to all standards, but no limits of exhaust emission are determined. Therefore, an attempt was made to evaluate the exhaust emissions generated by engines of PZL SW-4 Puszczyk helicopter in its actual operating conditions.

METHODOLOGY

OBJECT OF TESTS

The tests on the exhaust emissions generated by a helicopter turboprop engine were performed on PZL SW-4 Puszczyk (Fig. 1) with its powertrain composed of two turboshaft Rolls-Royce 250-C20R/2 engines (Fig. 2). The exhaust emission tests were performed in real operating conditions of the helicopter during a pre-flight test. PZL SW-4 Puszczyk was fitted with an on-board flight parameter recorder that not only records such parameters as flight velocity and altitude, but also the position angles of the helicopter and the operating parameters of the engines.

Figure 1 *– PZL SW-4 Puszczyk helicopter*

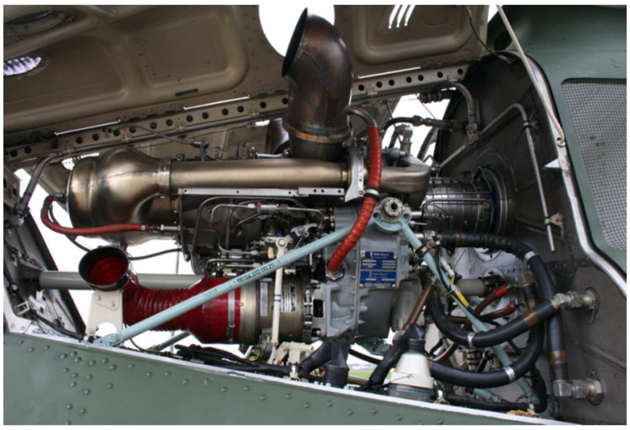

Figure 2 *– Turboshaft Rolls-Royce 250-C20R/2 engines*

Figure 3 *– Placement of the exhaust gases probe*

The basic technical parameters have been shown in table 1.

Table 1 *– Basic technical parameters of the Rolls-Royce 250-C20R/2 engine*

Name	Symbol	Range	Unit of measure
Power output	N_e	380	kW
Unit fuel consumption	g_e	0.465	g/kWh
Mass flow rate	G_p	1.7	kg/s
Compression rate	Π	7.9	–
Engine weight	m	78	kg

The exhaust emission tests were preformed in the actual conditions of the helicopter operation during a preflight test. The PZL SW-4 Puszczyk helicopter is fitted with a flight recorder whose purpose is recording airspeed, altitude and helicopter angles as well as the operating parameters of the engines.

Measurements equipment

The exhaust emissions were measured in the actual operating conditions of the helicopter. This approach required installing a system of exhaust gases uptake in the helicopter near its exhaust in such a manner as to make it possible to operate the helicopter (Fig. 3).

A duct feeding the exhaust gas sample to the analyzer was conducted through an open window in the loading space of the helicopter. Semtech-DS portable analyzer manufactured by Sensors was used for the measurement of the concentration of the exhaust components (Fig. 4).

Figure 4 *– View of the exhaust emission analyzer*

The analyzer enabled a measurement of the concentration of carbon monoxide, hydrocarbons, nitric oxides and carbon dioxide. The exhaust gases were introduced into the analyzer through a measuring probe that maintained the temperature of 191°C and then were filtered out of the particulate matter (only in the case of diesel engines) and the concentration of hydrocarbons was measured through a flame ionization detector. Next, the exhaust was cooled down to the temperature of 4oC and the concentrations of the following were measured respectively NO_x, CO, CO_2 and oxygen [2]. The analyzer measures the concentration of carbon monoxide, hydrocarbons, nitric oxides and carbon dioxide as per the characteristics given in tab. 2.

Table 2 *– Characteristics of Semtech DS (a portable exhaust emission analyzer) [6]*

Parameter	Measurement method	Accuracy
CO	NDIR, measurement range 0–10%	±3% of the measurement range
HC	FID, measurement range 0–10 000 ppm	±2.5% of the measurement range
NO_x	NDUV, measurement range 0–3000 ppm	±3% of the measurement range
CO_2	NDIR, measurement range 0–20%	±3% of the measurement range
O_2	Electrochemical, measurement range 0–20%	±1% of the measurement range
Exhaust flow rate	Mass flow rate	±2.5% of the measurement range
Exhaust temperature	Up to 700°C	±1% of the measurement range
Warm up time	900 s	
Response time	$T_{90} < 1$ s	

EMISSION TESTS RESULTS AND ANALYSIS

During the pre-flight test of the helicopter, concentrations of the exhaust components were measured. The results of the measurements of the concentration of CO_2, CO, HC, NO_x were presented as measurement values for several minutes' measurement initiating from the moment before engine startup until several seconds following the stopping of the engines. The test course was additionally recorded by the flight parameter recorder. The obtained courses were compared and, then, used for further analysis of instantaneous values of engine loads (Fig. 5).

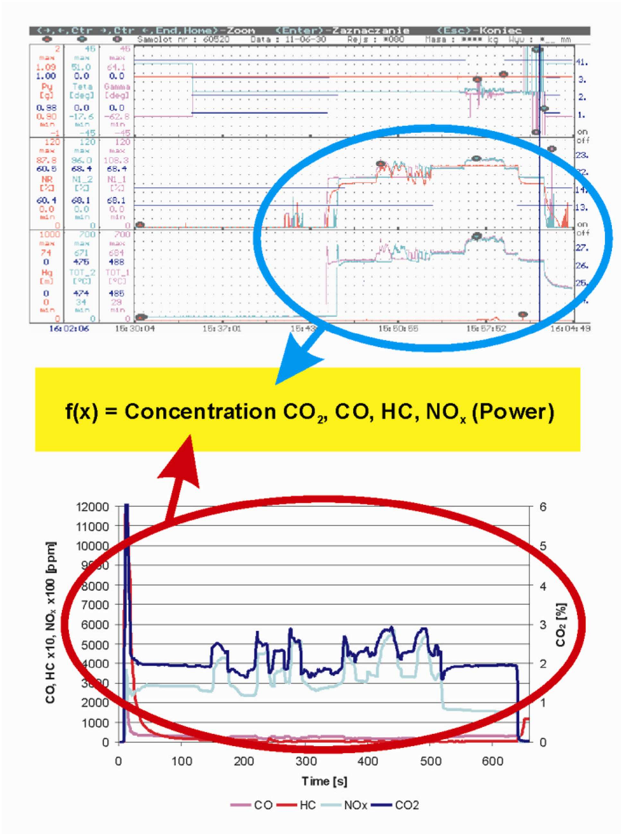

Figure 5 *– The compared courses of concentration of individual exhaust components and the course of the operating parameters of engines as recorded by the flight parameter recorder during the pre-flight test of the helicopter*

On the basis of the recorded course, engine loads in time were determined. During the pre-flight test engines work under approximately 10% of maximum load for 7% time of the test, under the loads ranging from 60÷65% of the maximum load for approximately 13% of time and under 95 % of maximum load for approximately 80% of the test (Fig. 6).

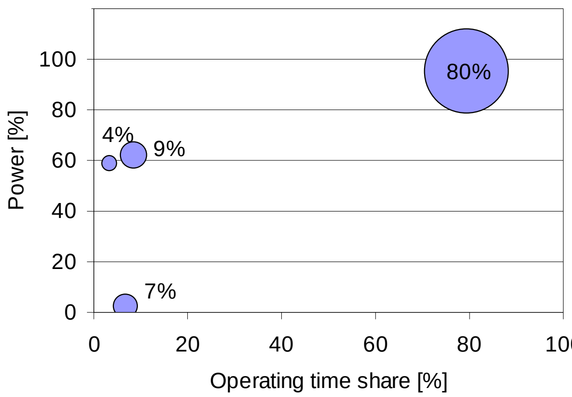

Figure 6 *– Test operating time share of the powertrain of the PZL SW-4 Puszczyk helicopter during the preflight test*

On the basis of the available flow characteristics of Rolls-Royce 250-C20R/2 engine and the measured instantaneous value of air excess coefficient, exhaust gas rate in individual points of load was measured.

The obtained values of instantaneous exhaust flow rate, multiplied by the measured instantaneous value of the concentration of a given exhaust component yielded the instantaneous emission of the individual exhaust components during the test (Fig. 7–10).

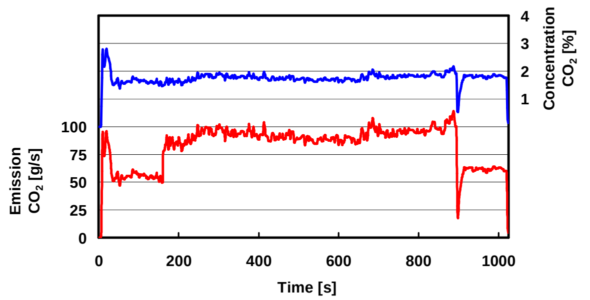

***Figure 7** – The course of the instantaneous concentration and emission rate of CO_2 in the exhaust gases during the test*

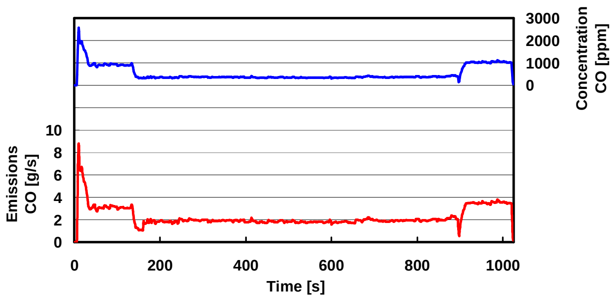

***Figure 8** – The course of the instantaneous concentration and emission rate of CO in the exhaust gases during the test*

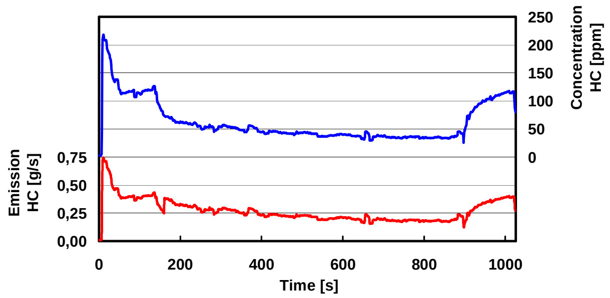

***Figure 9** – The course of the instantaneous concentration and emission rate of HC in the exhaust gases during the test*

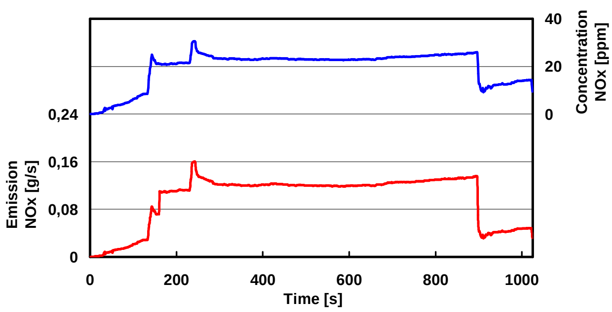

***Figure 10** – The course of the instantaneous concentration and emission rate of NO_x in the exhaust gases during the test*

The obtained values of the exhaust gas concentration as multiplied by the instantaneous value of concentration of an exhaust component resulted in instantaneous values of emission rate of particular exhaust gas components during the performed test. The obtained courses of instantaneous value of the concentration of the individual exhaust gas components were compared to the instantaneous values of the engine loads recorded by the on-board flight parameter recorder. The comparison resulted in obtaining of values of unit-based emissions of exhaust gas components for individual points of engine loads (Fig. 11). It results from the obtained data that the largest ecological nuisance is the stage of starting up and warming of the engine under small loads. With an increase of load, one may observe a decrease in the values of brake-specific emissions. It is particularly the case in the emission of carbon monoxide and hydrocarbons. The values of unit-based emission of carbon dioxide and nitric oxides change insignificantly for 75÷95% of the maximum engine load.

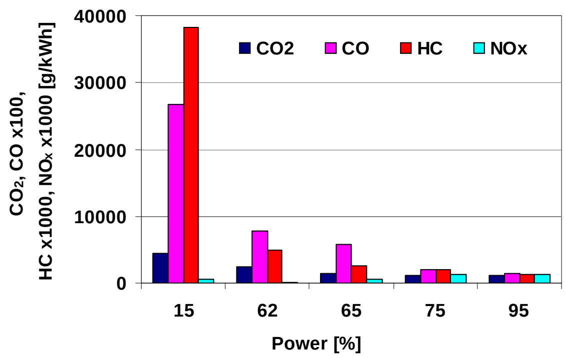

***Figure 11** – The values of brake-specific emissions generated by the powertrain of PZL SW-4 Puszczyk helicopter during the pre-flight test and for individual load values*

The values of unit-based exhaust emissions as determined for individual engine loads may be multiplied by the percentage share of time of engine load during the pre-flight test performed. This allows obtaining values of unit-based exhaust emissions constituting individual characteristics for a given engine in a given pre-flight test (Fig. 12).

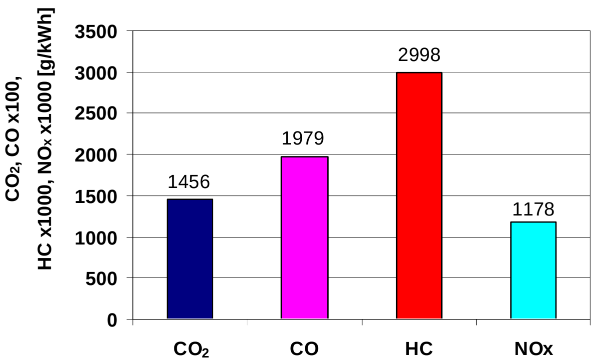

***Figure 12** – The values of unit-based exhaust emissions as generated by the powertrain of the helicopter during the pre-flight test*

The unit emission of CO_2 was approximately 1456 g/kWh, CO approximately 19.8 g/kWh, HC approximately 3 g/kWh and NO_x approximately 1.2 g/kWh.

CONCLUSION

The conducted exhaust emissions tests from PZL SW-4 Puszczyk during the pre-flight test enabled an obtainment of data on the concentration of exhaust gas components in the exhaust gases of a helicopter turboprop engine. A further analysis of the results as compared to the engine operating parameters provided values of brake-specific emissions generated by the powertrain for individual engine loads. Based on the obtained values, actual exhaust emissions from the powertrain of the helicopter during the pre-flight were determined. The here-discussed evaluation constitutes a part of a larger work aimed at the evaluation of negative impact of operation of transport helicopters upon the natural environment. The work is also connected with the development of a universal test facilitating the determination of exhaust emissions generated by helicopters.

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FLIGHT TIME LIMITATIONS SCHEME PROTECTION FOR CIVIL AVIATION PILOTS, A COMPARISON IN SHORT HAUL AND MEDIUM HAUL FLIGHT OPERATION.

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Abstract – *The aim of this study was to investigate the effect of fatigue on performance in short haul and medium haul flights, identifying the most fatigue affected stage of flight (pre-flight, top of descent, post-flight) and to identify differences in protection between the UK FTLs and other International FTLs. 32 pilots participated, they were required to complete a Samn-Perelli (SP) questionnaire and a 5 minute Psychomotor Vigilance task (PVT) before and after flight and also at the top of descent for medium haul flights (MHF). Repeated measures analysis of variance (ANOVA), correlation and T-test were conducted on the data. There was no significant effect (p>0.05) found under the different FTLs on flight stage and different measures of fatigue (SP, PVT reaction time, PVT lapses) for both MHF and SHF. The UK CAP 371 in comparison to other FTL's did not yield significantly different fatigue ratings (p>0.05). Results also revealed a non-significant main effect of the difference in SHF and MHF. There was no significant difference in the fatigue measures obtained at top of descent in comparison to post flight MHF. There was significance in the data that subjective fatigue (Samn-Perelli) was a predictor of the objective fatigue (PVT & PVT lapses) for both MHF and SHF. These findings highlight the difficulty in investigating the highly individual effect of fatigue in relation to FTLs protection and design.*

Key words – fatigue, FTL, FTLprotection, MHF, SHF, performance.

Introduction

Fatigue has gradually become recognized as a factor that has a significant impact in increasing the risk of human error (Ferguson et al, 2005). With the growth in the aviation industry fuelled by the demands of today's society, the need for twenty four hour operation in order to satisfy this consumer demand, has led to the interest in fatigue research to expand. Industries that require a round-the-clock operational capability are prone to fatigue related accidents and further research will be of significant value. In airline operations, where shift work, time zone changes and irregular work patterns are present, pilots have been identified of having a increased risk of fatigue and associated error rate; an environment that is challenging at both physiological and psychological levels (Eriksen & Akerstedt, 2006), this raises concerns about the maintenance of "satisfactory" levels of flight safety (Samel et al, 1997). National Aviation Authorities such as the United Kingdom's Civil Aviation Authority (UK CAA), have Flight Time Limitation schemes (FTLs). The UK CAA scheme is Civil Aviation Publication (CAP) 371, and it is titled "The Avoidance of Fatigue In Aircrews" (© Civil Aviation Authority 2004). FTLs define the maximum duty hours, flying hours and commander's discretion to deviate from these hours. The problem for current aircrew is that companies are now planning flight operations up to the maximum that the FTLs allow; this was not the purpose when CAP371 was written.

There are number of accidents where time of day and irregular working hours were identified as possible causal and contributing factors in major catastrophes; e.g. the Challenger space shuttle disaster (1986), Chernobyl (1986), Three Mile Island nuclear power station disaster (1979) (Wright & McGown, 2001) . Prior sleep deficit, due to circadian disruption is common in the aviation industry; this is just another factor contributing to an increasing risk of accidents (Green et al, 2005). These well know accidents demonstrate the risks that work related fatigue presents to safety and the reduction in human performance. With the expansion of technology and associated increased reliability, air transport operations flourish, increased range that enable direct ultra-long haul flights(18hrs or more), numerous night flying, mixed early starts, time zone changes etc requires new regulation to ensure that flight safety is maintained. The recent regulatory requirement for Fatigue Risk Management Systems (FRMS), that is defined by the International Civil Aviation Organization (ICAO) as "*A data driven means of continuously monitoring and managing fatigue related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate level of alertness*"(ICAO FRMS Annex 6 2011), whilst this is a theoretical leap forward, the actual cost and difficulties for operators to achieve this, the lack of simple validated tools, lead to difficulties in effective implementation at airline level.

There are numerous studies illustrating that fatigue is responsible for many aircraft accidents (Wright & McGown, 2001), thus to reduce this risk, the question arises, what are the main causal factors for aviation/transport fatigue? Both physiological and psychological factors are identified; the physiological factors contributing to fatigue are well known and identified, namely sleep disruption, irregular sleep wake pattern and Circadian rhythm and other contributing factors e.g. time of day, duty period. Psychological effects cannot be separated from the physiological, many are linked stressors, behavioral, environmental and emotional factors are linked often to the physiological factors, further disruptions in an individual's life often lead to a covert stress prior to commencement of a duty pattern (e.g. being away from base during an anniversary, child's birthday, etc)(Matthews et al, 2004).

Defining Fatigue

Fatigue is complex in origin; it refers to a state where one is unable to maintain expected force (Radovic & Malmgren, 1998), it can be defined in terms of quality and variation in or of performance; it is not just a decrease of attentional resource (Matthews et al, 2004). Fatigue usually includes three components; the physical component, mental components and the sleep component. The most relevant components are most probably, mental fatigue and sleepiness (Keclund & Akerstedt, 2004) and "*can be regarded as a consequence of severe or sustained stress and are important mediators of the relation between stress and performance*" (Keclund & Akerstedt, 2004).

Fatigue in Aviation

In aviation, the research interest in fatigue has increased with the growth of accidents attributed to human error, despite an overall reduction in accidents, the UK Civil Aviation Authority (UK CAA CAP 720) research claims that 65% of accidents in air transportation are due to flight crew errors, many are traced back to a decrease in performance due to deprivation of sleep (not only on long-haul flights).

The unsociable working hours and continuous twenty four hour operation schedules result in a disruption of the circadian rhythm and cumulative sleep loss (Rosekind et al, 1997) that result in fatigue with a negative impact on performance.

There are three distinctive influences on fatigue, identified from the psychological point of view; the task induced fatigue, sleep deprivation and time of day (disruption to circadian rhythms) (Matthews et al, 2004).

Performance in general is affected by the time of day that the task is performed (Green et al, 2005); simple tasks such as reaction times, visual search speeds and vigilance, require low working memory, improve during the morning to early afternoon hours and decline in the evening, reaching the lowest levels of performance at 4 am in the morning. (Green et al, 2005). Individuals tend to show differences in their preferred time of day, some are so called "owls"(evening types), some are "larks"(morning types) (Matthews et al, 2004), the subjective arousal of an evening type is higher in the evening and for morning type it is in the morning. This is reflected in their performance; however this effect seems to vary with the tasks and associated processing demands (Matthews et al, 2004).

Night duties are especially fatigue prone, as they often combine circadian disruption with prolonged duty leading to psychomotor impairment and reducing the ability to respond to changing circumstances (Akerstedt et al, 2003). Research (UK CAA aircrew fatigue 2005/4) suggested that 22 hours of sleep deprivation could be compared to a 0.085% of blood-alcohol level (in the UK, legally drunk).This relation was derived from a model where performance decrease is associated with alertness and alertness, with alcohol intoxication (UK CAA aircrew fatigue 2005/4). Similar effects were obtained from research by Lamond and Dawson (1999), where moderate levels of fatigue resulted in performance that was comparable to performance under alcohol intoxication. This highlights that decision making in state of cognitive impairment is highly prone to misjudgment of the situation (Green et al, 2005) and that the consequences of fatigue are still underestimated (Maruff et al, 2005).

The Circadian rhythm, or circadian clock, controls the timing of physiological activity (thermoregulation, digestion, immune function) (Rosekind et al, 1996) and performance, alertness and mood. The lowest activity point of the circadian clock for human functioning is circa 3am to 5am, the second low point occurs at circa 3pm to 5pm and this is also associated with decreased performance.

Finally, sleep deficiency or sleep loss is recognized as a major cause of industrial accidents (Swan et al, 2006) and the key factor contributing to fatigue (Dinges et al , 1994).Sleep loss is accumulative, and this is often seen in the case with shift work, early rising, night work or time zone shifts; further a reduction of sleep to only 5 hours per day for 5 days, is the equivalent for fatigue and performance to the loss of one full night's sleep (Akerstedt et al 2003). Reduction in sleep time is especially likely when sleep is taken during the day, where many environmental factors (e.g. stress, noise, sleeping position) contributing to the disturbance of both quality and quantity of sleep (Akerstedt et al., 2003).

Fatigue Symptoms and Effects on Performance

Fatigue caused by sleep loss, physical or mental work or both can decrease human performance (Caldwell & Leduc 1998). Petrie and Dawson (1999)(as cited in Caldwell, 2005) described cognitive slowness, reduced concentration, irritability, lethargy and sleepiness as a common symptoms of pilots fatigue. The sleep deficiency that is related to shift patterns manifests in reduced cognitive abilities, vigilance and slower reactions (Caldwell & Leduc 1998). The consequence of visual fatigue is reduced or impaired performance (cognitive and psychomotor) (Antunano & Mohler, 1988).

Aircrew performance is closely connected to safety and fatigue reduces reaction time and the ability to concentrate. Performance changes result from fatigue (experiment conducted in a sleep laboratory in Farnborough) (UK CAA aircrew fatigue 2005/4), actual fatigue can be predicted by measurement of performance. The results show the changes in performance after a period of 16 hours and 24 hours of wakefulness (commencing at 7 am). One example of the effect on performance is in a memory recall task, after 16 hours of wakefulness, errors increased to 8.8% and after 24 hours to 15.5% (with a baseline 5%). Further, complex tasks e.g. multi-attribute task (MAT) battery test, the response times increased from the normal, with a 25% increase after 16 hours and over 70% after 24 hours. This illustrates the relationship of long duty hours and impaired performance or impact of fatigue on tasks (CAA aircrew and fatigue research, 2005).

As the number of fatigue related accidents increases, this clearly preventable cause needs to be addressed through research and incorporated in international rules to increase safety for crew and passengers. Reports from a survey of 739 pilots (Petrilli et al, 2006) revealed that pilots are most affected by night flights and jet lag which is consistent with other studies (e.g. Samel et al,1997, Petrilli et al, 2006). Ericksen and Akerstedt (2006) conducted a small study of 14 pilots flying trans-Atlantic routes, with a comparison of sleepiness on westward bound, morning and evening flights, using the Wrist Actigraph and Karolinska Sleepiness Scale (KSS), they concluded that evening flights resulted in higher levels of sleepiness than morning flights; the most probable cause is the proximity in time to the circadian trough of alertness (Ericksen & Akerstedt, 2006). To prove that fatigue is linked to accidents in aviation, Goode (2004) assessed 121 accidents from 1979 until 1999, which were classified as human factor accidents, in order to demonstrate the empirical relation of aviation accidents and cockpit crew schedules and fatigue. The analysis concluded that the probability of an accident does increase with lengthy duty hours, where 20% of accidents happened in the 10th or more hour of consecutive duty (10% of pilots' duty assessed was in the 10th hour or greater duty period). After the 13 hour of consecutive duty, 5% of accidents occurred (although at that time only 1% of pilots' duty was longer than 13 hours). Further, he suggested the limitation of duty hours as possible solution and risk reducing factor in commercial aviation accidents (Goode, 2004).

FTL's basic principle

The main objective of FTL's is to control the flight duty and rest time, ensuring sufficient rest prior to every flight in order to prevent fatigue and ensure safe operation. The increased frequency of flying, number of take offs and landings, time of day all require consideration, as well as the minimum rest between duties that a crew member requires without being exposed to cumulative fatigue (UK CAA CAP371). Factors vary between airlines and depend on the regulatory authority, as they also take into account commercial requirements of the company, and therefore the fatigue levels will differ in intensity in between various airlines.

Many countries operate under the guidance of the UK CAA CAP 371, this has been long established and has been the aviation "Gold" standard; this dictates the maximum limits an individual can work. Thus some airlines set the maximum limit as their goal and whilst others a lower limit (Weir, 2002).

The aviation industry point out that they consistently operate within the constraints of these regulations and are therefore legal and safe. Variations in other Countries from the UK CAP371 rule of an annual legal limit of 900 flying hours do occur, this number could reach as much as 1200 hours per annum in airlines operating under the FAA "regional" rule, FAR 135.265(a) (Williamson, 2002), which raises a question mark whether the rules are working sufficiently well in order to prevent pilots flying when unfit due to fatigue. Dinges et al, 1996 (as cited in Caldwell, 2005), suggested that industry practices are currently not incorporating concerns of fatigue into their regulations effectively, thus increasing this avoidable air safety risk.

Short Haul Flights (SHF), Medium Haul Flights (MHF) and Long Haul Flights(LHF).

In the recent years an increased number of studies have focused on long haul flights (LHF), mainly because of rapid growth in intercontinental flying and the association with a circadian rhythm disruption and cumulative sleep loss, recognized as contributing factors in fatigue. This may have taken away the focus from SHF and MHF; these operations face many similar, but also markedly different challenges for aircrew in comparison with LHF. SHF operations involve a mix of overnight duties, early starts, late night finishes, all combined with more sectors (one sector is one take off and landing), all are stressors. However the long overnight operation is not as common as in LHF, therefore assumptions arose that the sleep disruption would not be as severe (Loh et al, 2004). There has been little aviation research on SHF, but the work to date would indicate that this assumption is not entirely correct (Loh et al, 2004). According to SHF research, work related fatigue is caused by scheduling issues e.g. number of sectors, early morning starts, consecutive days work etc. (Spencer and Robertson, 2002). Spencer and Robertson (2002) also linked fatigue in SHF to the time of day of the duty period. In a six day schedule, fatigue increased with the number of consecutive days and also fatigue impairment increased with the number of sectors worked; the difference between flying one sector compared to four sectors being the equivalent of working an extra 2.77 hours . Further factors connected with SHF identified was the inherent hassle, the pressure of ground staff, aircraft preparation, during time restricted turn rounds, that has a consequent effect on performance (Spencer and Robertson, 2002). In comparison, LHF the accumulation of fatigue seems to be mainly related to insufficient sleep and continued sleep disturbances (Spencer and Robertson, 1999). The most significantly elevated fatigue levels on LHF are on the return phase, possibly when the recuperative value of sleep in the in flight bunk facilities was less than on the initial outward leg (Spencer & Robertson, 1999).

Measurement of fatigue

The simplest way to measure fatigue objectively is by measuring how long you take to react to a given signal (Green et al, 2005). A standard test used worldwide in research on human performance is the hand-held (Palm®) Psychomotor vigilance task (PVT) that is recognized and accepted as a reliable measure, assessing functional consequences of fatigue (Lamond et al, 2005).The PVT version for Personal Data Assistant (PDA) was developed by Walter Reed Army institute of Research (Thorne et al, 2005). The participant rests his finger on the button and responds to a stimulus (Bulls-eye target) appearing on the display as fast as possible, the stimulus appears for 5 minutes at random intervals. In this research average response times (RT) and number of lapses (response greater than 500 milliseconds) were chosen for analysis. Lapses in vigilance and increase in RT are identified with a reduction in performance (Doran et al, 2001).

Subjective fatigue is an individual's own perception of their fatigue and can be measured on a self reported questionnaire such as the Samn-Perelli (SP), a seven point Likert scale.

The aims of this study are to investigate the effect of fatigue on the performance of aircrew in short haul (flight time less than 2 hours) and medium haul flights (flight time 2 to 5 hours), to identify the most fatigue prone stage of the flight (i.e. pre-flight/ top of descent / post flight), examining both subjective fatigue levels (using the Samn-Perreli 7point scale) and objective fatigue (using the Palm® PVT) on pilots operating under the UK CAA CAP 371 and comparing with other FTLs.

Finally, does the current and recognised as the "Gold" standard of FTLs, UK CAA CAP371, afford more protection in comparison with other national regulations

Design

A Mixed design experiment was conducted. This design would consist of two within subject variables, the Flight Stage with three levels (pre-flight, top of descent and post-flight) and Test with three levels (Samn-Perelli, PVT response time, PVT lapses) and two between subjects variable (Flight Time Limitation scheme), with two levels (CAP 371 or other International FTLs) and flight sector with two variables (SHF and MHF).

Participants

Participants comprised of thirty two adults, 23 captains and 9 first officers, 30 male and 2 female pilots, of mixed nationalities, random sample, with an age range from 30 to 55 years (mean age 41.84 SD = 6.33).

Statistical analysis

The data was analyzed using SPSS software (Version 15.0: SPSS Inc., Chicago, Illinois, USA). Two measures were analyzed from the Palm® PVT test (measure of objective fatigue), the mean response times (RT) and number of lapses (response time greater than 500 milliseconds). The objective fatigue was assessed using repeated measures mixed model Analysis of Variance (ANOVA); the data obtained from the Samn-Perelli (SP) questionnaire was also subjected to a repeated measures mixed model Analysis of Variance (ANOVA). Where necessary (if violation of sphericity), the Greenhouse-Geisser procedure was applied to provide a correction to the degrees of freedom, for all ANOVA analyses.

The match of the subjective (self estimated fatigue rating, Samn-Perelli 7 point scale) and objective fatigue (palm PVT test) was further subjected to analysis using a regression analysis to determine their relation.

A paired sample T-test was conducted on the top of descent and post flight data in MHF to determine the most fatigue prone point of the flight and a independent T-test to determine the most fatigue prone sector (SHF or MHF).

RESULTS

All effects are reported as significant at $p<0.05$.

Mixed design ANOVA SHF data.

Repeated measures effect with corrected F values - SHF

As the data violated the sphericity assumption, the Greenhouse Geisser correction was applied. There was no significant interaction between the different FTL's (CAP371 and non CAP371) and the different tests (SP, PVT, PVT lapses) (F (1.014, 14.198) =0.043 p>0.05) . There was also no significant interaction between the different FTL's (CAP371 and other FTLs) and the different flight stage (pre-flight, post-flight)(F(1.000,14.000)=0.000, p> 0.05).

The three way interaction between the Flight time limitation, different tests and flight stage was not significant (F (1.024,14.341)=0.008,p>0.05, indicating that the flight stage and the different tests on SHF did not depend on the flight time limitation rule (CAP 371 or other FTLs).

There are no significant effects of the type of test (SP, PVT) used, the time of flight testing (pre-flight, post-flight) and the interaction of these two variables on SHF.

The pre-flight response times on SHF were lower under the CAP371 (M=244.81, SE=36.93) and higher under other FTL's (M=248.85, SE=31.08), the pre-flight lapses were higher under the CAP371 rule on SHF (M=1.38,SE=1.51)in comparison to other FTL's (M=1.25,SE=1.39).

The post-flight response times on SHF were lower under the CAP371(M=318,44,SE=54.73) than under the other FTL's rule (M=321.42,SE=34.73).The post-flight lapses on SHF under the CAP371 were also lower (M=7.37,SE=10.61)than under the other FTL's rules (M=7.75,SE=4.43)

Contrast for Repeated measures variables - SHF

TEST AND FTL INTERACTION SHF/ Samn-Perelli x PVT

The first interaction looks at level 1(PVT test) compared to level 3 (Samn-Perelli test) under the different FTL rules. This contrast is not significant (F(1,14) = 0.039, p>0.05).

TEST AND FTL INTERACTION SHF/ Samn-Perelli x PVT lapses

The second interaction looks at the level 2 (PVT lapses) compared to level 3(SP test) under different FTL's rules. This contrast is not significant (F(1,14)=0.001,p>0.05).

FLIGHT STAGE AND FTL on SHF

Pre-flight testing and post-flight testing were compared under the different FTLs. There was no significant contrast (F (1, 14) =0.000, p>0.05.

TEST, FLIGHT STAGE AND FTL on SHF

The first interaction compares the level 1(PVT) versus level 3(Samn Perelli test) at pre-flight test (level 1) and post-flight test (level 2) under different FTL's. The contrast is non-significant (F(1,14) = 0.008, p>0.05)

The interaction of level 2 (PVT lapses) and Level 3 (SP test) on pre-flight test (level 1) and post-flight test(level 2) under different FTL's is also insignificant(F(1,14) = 0.008, p>0.05).

Mixed design ANOVA MHF data.

Repeated measures effect with corrected F values - MHF

The data violated the sphericity assumption; the Greenhouse-Geisser correction was applied to test and flight stage data. There was no significant interaction between the different FTLs (CAP371 and other FTLs) and the different tests (SP, PVT, PVT lapses) (F (1.101, 14.015) =0.058 p>0.05). There was also no significant interaction between the different FTLs (CAP371 and other FTLs) and the different flight stage (pre-flight, top-of-descent, post-flight)(F(1.206,16.885)=0.033, p> 0.05)

The three way interaction between the Flight time limitation, different tests and flight stage was not significant ($F(1.207,16.903)=0.023, p>0.05$, indicating that the flight stage and the different tests on MHF did not depend on the flight time limitation rule (Cap371 or other FTL).

The pre-flight response times on MHF were higher under the CAP371 (M=272.68, SE=60.37) and lower under other FTL's (M=267.66, SE=43.56), the pre-flight lapses were higher under the CAP371 rule on MHF (M=1.63, SE=2.26) in comparison to other FTL's (M=1.38, SE=1.99).

The top of descent response times on MHF were higher under the CAP371 (M=319.31, SE=41.50) and lower under other FTL's (M=313.13, SE=40.36), the top of descent lapses were lower under the CAP371 rule on MHF (M=3.75, SE=2.91) in comparison to other FTL's (M=4.13,SE=2.10).

The post-flight response times on MHF were higher under the CAP371 (M=315.88, SE=43.36) than under the other FTL's rule (M=313.30,SE=42.07).The post-flight lapses on MHF under the CAP371 were lower (M=4.00,SE=3.85)than under the other FTL's rules (M=4.75,SE=2.96)

Contrast for Repeated measures variables - MHF

TEST AND FTL INTERACTION MHF/ PVT vs. Samn-Perelli

The first interaction looks at level 1(PVT test) compared to level 3 (Samn-Perelli test) under the different FTL rules. This contrast is not significant ($F(1,14) = 0.054, p>0.05$).

TEST AND FTL INTERACTION MHF/ PVT lapses vs. Samn-Perelli

The second interaction term looks at the level 2(PVT lapses) compared to level 3(SP test) under different FTL's rules. This contrast is non significant ($F(1,14)=0.019,p>0.05$).

FLIGHT STAGE AND FTL on MHF/ pre-flight vs. post-flight

Pre-flight testing and post-flight testing were compared under the different FTL's. There was no significant contrast ($F(1, 14)=0.043, p>0.05$).Meaning that the rating responses were very similar in pre flight and post flight ratings under both FTLs.

FLIGHT STAGE AND FTL on MHF/ top-of-descent vs. post-flight

There was no significant contrast ($F(1, 14)=0.184, p>0.05$) on top of descent and post flight rating under the different FTL's.

TEST, FLIGHT STAGE AND FTL on MHF

The first interaction compares the level 1(PVT) versus level 3 (Samn-Perelli test) on pre-flight test (level 1) and post-flight test (level 3) under different FTL's. The contrast is non significant ($F(1, 14) = 0.021, p>0.05$)

The interaction of level 1(PVT) and Level 3(SP test) on Top of descent test (level 2) and post-flight test (level 3) under different FTL's is also not significant($F(1,14) = 0.143, p>0.05$).

The interaction of level 2(PVT lapses) and Level 3(SP test) on pre-flight test(level 1) and post-flight test(level 3) under different FTL's was not significant ($F(1,14) = 0.925, p>0.05$).

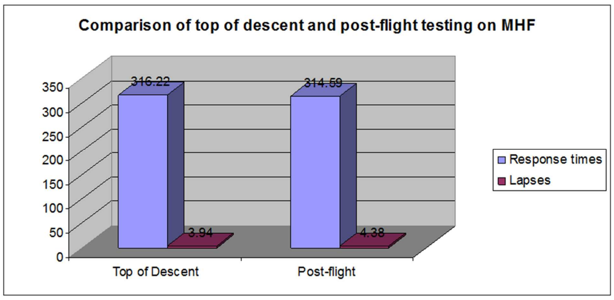
The interaction of level 2(PVT lapses) and Level 3(SP test) on top of descent test (level 2) and post-flight test (level 3) under different FTL's is also not significant ($F(1,14) = 0.036, p>0.05$).

Top of descent fatigue on MHF in comparison to post-flight fatigue on MHF

A paired sample T-test was conducted on the top of descent and post flight data MHF. On average, participants results from the PVT at the top of descent generated greater response times (M=3.16, SE=-39.67),in comparison to post flight response times (M=314.58,SE=41.26), however the difference was not significant ($t(15)0.365,p>0.05$.

Participants experienced less top of descent lapses (M=3.94, SE=2.46) in comparison to post-flight (M=4.37) ($t(15)=-0.665, p>0.05$) **(Figure 1),** however this difference was not significant.

Figure 1: The graph shows the PVT lapses and response times at top of descent and post-flight on MHF.



Subjective and objective fatigue – correlation

The relationship between the self rated fatigue (Samn-Perelli 7-point scale questionnaire) on SHF and MHF and the objective fatigue (Psychomotor Vigilance Task) was investigating using Pearson correlation coefficient.

There was a significant strong relationship between the Samn-Perelli pre-flight fatigue ratings and the pre-flight objective fatigue from PVT-response times on SHF($r=0.831, n=16, p<0.05$), also the pre-flight fatigue ratings and pre-flight PVT lapses did yield a significant relation ($r=0.883, n=16,p<0.05$).

This suggests that the Samn-Perelli questionnaire in SHF was a predictor of the PVT results in pre-flight fatigue.

However, on SHF there was non significant relationship between the Samn-Perelli post-flight fatigue and the post-flight objective fatigue ($r=0.113, n=16, p>0.05$) and post-flight self rate fatigue and post-flight lapses($r=-0.191, n=16, p>0.05$).

The relationship between the self rated fatigue (Samn-Perelli 7-point scale questionnaire) on MHF and the objective fatigue (psychomotor vigilance task) was also investigating using Pearson correlation coefficient.

Results revealed a significant relationship between the pre-flight subjective fatigue (Samn-Perelli) and pre-flight objective fatigue ($r=0.574$, $n=16$, $p<0.05$) and pre-flight subjective fatigue and pre-flight lapses from PVT data($r=0.661$, $n=16$, $p<0.05$).

The relationship between the subjective fatigue on top of descent and objective fatigue on top of descent was also significant($r=0.499$, $n=16$, $p<0.05$).

The subjective fatigue on top of descent and objective results from PVT lapses on top of descent revealed a non-significant relationship ($r=0.199$, $n=16$, $p>0.05$).

The subjective post-flight fatigue and objective post-flight fatigue, the correlation between the variables was significant ($r=0.775$, $n=16$, $p<0.05$).The relationship between the subjective fatigue ratings and PVT post flight lapses did yield significant correlation; there was a strong positive correlation between the variables with large effect size (Cohen, 1988)($r=0.875$, $n=16$, $p<0.05$)

Fatigue ratings on SHF and MHF.

The comparison of objective fatigue on SHF and MHF was investigated using an independent T-Test.

The pre-flight Response Times (RT) on MHF ($M=270.17$,$SE=50.94$) were greater than the pre-flight RT on SHF($M=246.83$,$SE=33.04$)this difference was not significant $t(30)=-1.538$,$p>0.05$

The pre-flight lapses on MHF ($M=1.50$, $SE=2.07$) were also greater than the pre-flight lapses on SHF ($M=1.31$,$SE=1.40$),this difference was not significant $t(30)=-0.301$,$p>0.05$.

The post-flight Response Times (RT) on MHF ($M=314.59$, $SE=41.29$) were smaller than the pre-flight RT on SHF (319.93, $SE=44.31$) this difference was also not significant $t(30)= 0.353$,$p>0.05$. The post-flight lapses on MHF ($M=4.37$, $SE=33.4$) were also smaller than the post-flight lapses on SHF ($M=7.56$, $SE=7.86$) this difference was not significant $t(30)=1.493$,$p>0.05$.

Figure 2: The Graph shows the objective fatigue (PVT-response times) on pre-flight and post flight on SHF and MHF.

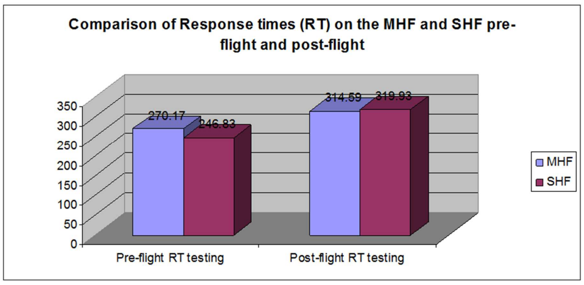
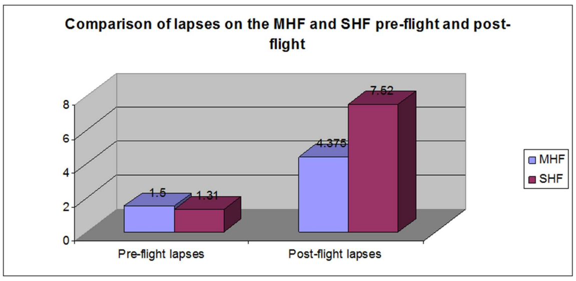


Figure 3: The Graph shows the objective fatigue (PVT-lapses) on pre-flight and post flight on SHF and MHF.



Conclusion

"The Air Navigation Order requires that a crew member shall not fly, and an operator shall not require him to fly, if either has reason to believe that he is suffering, or is likely to suffer while flying, from such fatigue as may endanger the safety of the aircraft or of its occupants." This is a quote from the UK CAA CAP 371, subtitled "The Avoidance of Fatigue in Aircrews". The UK CAA is a recognised pioneer in fatigue regulation and has been a leader in research into the field of fatigue. Further these regulations are recognised to be the most fatigue preventative regulation currently in use in civil aviation, the "Gold" standard compared to other Flight Time Limitation schemes (FTLs). Is this protection measurable and can a pilot accurately judge his real fatigue, subjective versus objective?

1.) CAP371/NON CAP371 which has generated higher fatigue ratings?

The findings of the present study were not able to identify evidence of a significant difference between the UK CAA CAP 371 FTLs rule and others FTLs in either SHF or MHF.

Although not significant, in SHF the average response times pre-flight and post-flight were higher under other FTLs compared to with CAP 371, with fewer lapses post-flight. In MHF pre-flight, the reverse was seen, as the data shows that CAP 371 generated slower response times and more lapses in comparison to other FTL rules.

At the top of descent and post-flight on CAP 371 governed pilots, the lapses were lower than other FTLs, but response times were higher. As lapses have been identified as the most useful measure of performance from PVT device results (Powel et al, 1998), then based on lapses (non-significant) CAP371 cannot be identified as the most protective from fatigue. These results should not be viewed as surprising, it is difficult to create any scheme that can cover all individuals and flight circumstances that contribute to fatigue, e.g. the different pace at which individuals get tired and their performance deteriorate (Williams, 2007) or the individual peak performance time (e.g. the owls and larks theory) (Mathews et al, 2000) and the individual different coping strategies. Further, the amount of hassle that is present on arrival, especially on multi-sector (multiple take off and landings) SHF is, according to Spencer (2002), a contributing factor. Nor to forget that it is the individual, that is responsible for his own rest before each flight. Variables of duty pattern, prior rest, outside stressors, age, environmental factors (temperature, humidity) all have an effect that is hard to assess e.g. the CAP 371 participants where operating in a Country with high humidity, circa 85% and temperature range from day to night of 47-35 degrees Celsius in comparison with more temperate climate operators.

2.) SHF/MHF which is more tiring?

MHF appeared to be more tiring at the pre-flight stage in response times and also in the lapses than the SHF. This may be a factor that was outside the boundaries of this research but it was noted that the report time for duty was in the 0300 to 0600 local time band, this is known to be at a circadian low. Nevertheless the SHF is more tiring at the end of the flight, observable in terms of both lapses and response times; statistically these results were not significant. Further differences in pre-flight and post-flight fatigue may also arise from work related fatigue that is the result of scheduling factors (Spencer & Robertson, 2002); again the analysis of an individual’s schedule was outside the remit of this study. As according to Powell et al (2007) the number of sectors and duty length are the most important determinants of fatigue in SHF, this is in line with this assumption arising from the presented data.

3.) Comparison of top of descent and landing fatigue on MHF

No study so far identified, has compared the top of descent with post flight fatigue, the findings of this study reveals that mean response times at the top of descent is slightly longer than post-flight, this effect may be explained by some form of post workload arousal; prior to descent the crew have been under relatively low workload and arousal, which rapidly increases in the descent cumulating in landing, taxi in to parking(often described as very stressful) and shutdown . It was established that the later stages of flight (descent, landing etc) are more risk prone and may effect performance in a greater way in comparison to the earlier stages (take off, early cruise) of flight, (Petrilli, et al, 2006), leading to increased pilot awareness of fatigue and potential arousal. The identification of the stage of flight that is the most fatigue prone could have an effect on the future fatigue testing, allowing the incorporation of alertness measures (already proposed by one major airline to Airbus Industries), with the associated decrease in human error. The data obtained from this study however is inconclusive, the PVT lapses in alertness, that are explained as a micro sleep (Stern & Brown, 2005) and are an indicative sign of impairment, are not significantly higher at the top of descent in comparison to post flight lapses.

Interestingly, the numbers of lapses at the top of descent under the CAP371 rule were less in comparison to the post flight lapses (average of 3.75 lapses TOD and 4.00 post flight). Under different Flight Time Limitations, the number of lapses increased to a mean of 4.26 at TOD and a mean of 4.75 at post flight testing. The converse was true for the PVT response times, which may underline the need to gather more data, potentially follow a group of pilots over a complete roster period to see the “bigger picture” as opposed to the “snapshot” approach normal to research within this field.

As commented, the fatigue level seems to increase prior to descent and decrease on arrival which could be explained by elevated arousal levels as the task demands are high (Matthews et al, 2000). This should be an area for future research, to follow and identify individuals that show signs of fatigue before the top of descent and do not appear fatigued post landing; how long does this increased performance last? Would it be dangerous for the individual to drive home and for pilots on multiple sectors, what if any effect is there on the next sector?

4.) Does subjective fatigue indicate correctly the objective fatigue?

What is the relationship between subjective and objective fatigue in aircrew, are pilots better equipped to recognize fatigue as per the requirement of the regulations?

The data obtained in this study indicate that the subjective fatigue was a significantly reliable predictor of the objective fatigue in pre-flight testing for both SHF and MHF, this is inconsistent with the previous research that found subjective fatigue not to be a reliable predictor of objective fatigue (Bonnet, 2000, Matthews et al, 2004). The post-flight correlation in SHF (both RT and lapses) as well as the subjective fatigue in MHF at top of descent was not significant in correlation with PVT lapses, which may indicate an inconsistency in results; this could be interpreted as that self-rated fatigue is not a reliable predictor of objective fatigue. Further, the pre-flight correlation of the self-rated fatigue and response times and lapses could be interpreted as individuals that are fresh at the start of their flight duty and their ability to assess their fatigue levels more accurately are greater, in flight tiredness may effect judgement of this as indicated in the top of descent testing MHF group. The ability of the MHF group to judge performance and fatigue decreases with duty time, at the top of descent the subjective fatigue measure was less than the objective effect on reaction time. Nevertheless, the MHF post-flight correlation yielded significant findings, validating self rated fatigue with the objective measure, but as we have concluded before, SHF are more fatiguing than MHF, this may explain the significant results on the post-flight MHF correlation. Subjective levels of fatigue may be affected by the pilot’s expectation (Matthews et al 2004); at the end of a flight they would expect to be more tired, although this effect was not identified in this study.

All flights operated under the protection of their national FTL scheme, but it was observed that pilots experienced a large number of recorded lapses indicative of degraded performance. The question is, how would a FRMS approach improve this? Pilots cannot be expected to accurately measure their performance or fatigue levels accurately at all times. The development of alertness measures, perhaps a variant of the current Palm® PVT, with an individual database based on that person’s baseline normal performance, measuring both lapses and reaction time in comparison to the baseline; for use prior to flight and during flight, could generate an acceptable area and a “amber” zone when performance would be impaired. Many airlines are showing interest in some form of alertness measure either laptop based or part of the onboard aircraft equipment and thus future research must work to fill this gap.

ACKNOWLEDGEMENTS

I would like to thank Dr. David Thorne of the Walter Reed Army Institute of Research for supplying the Walter Reed Palm-held Psychomotor Vigilance Task.

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MEASURING SAFETY LEVEL BEFORE INCIDENT OR ACCIDENT IN CURRENT CIVIL AVIATION

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Abstract *– Aviation safety is very publicly discussed topic. Each and every person has own attitude towards safety of air transport. But general attitude of common people is that "safe" operation is when there is no accident. It was for a long time the only way how to measure safety when there was just reactive approach and the only safety indicator was number of accidents per certain period (accidents ratio). But it is quite useless while aviation reached ultra-safe status and accidents are so rare events that it would be ludicrous to label aviation company as absolutely safe just because of the fact that statistic shows zero accidents per few years.*

New modern approach to safety provides new indicators that may be used before any undesirable outcome of air transport actually happens. It is very essential to be able to measure safety level on operational basis in order to improve it. When just the reactive approach was used, the only way to improve safety was after accident had happened.

This article should give basic overview of proactive risk assessment methods that might be used in aviation industry. Proactive indicators are very crucial to be able to determine safety level of organization in order to monitor and predict safety trends and especially measure impact of operational changes, new procedures or regulations. Nowadays there are only a few companies where safety culture and other proactive indicators are used with traditional reactive indicators concurrently. It would be very inappropriate in current so called ultra-safe aviation to improve safety only reactively on the expense of accidents or even human lives.

Key words – Aviation safety, measuring safety, safety level, proactivity, expert system, AHP method, FUZZY.

INTRODUCTION

Aviation safety is very complex and inexact part of aviation industry. It is key objective of every aviation company to prevent accidents in order to keep company's reputation, prevent pecuniary loss and above all human injuries and casualties.

But it is very hard to measure safety level when almost no accident actually happens. Main reason for measuring safety level shouldn't be an announcement designated for public that some company has the best possible safety level. Objective of safety measuring is to collect and analyse data for trend monitoring and to be able to translate them into meaningful information for senior management. As (Shyur, 2008) states that, „commercial aviation is a complex mosaic of many varied, yet interrelated human, technical, environmental, and organizational factors that affect safety and system performance. The possible influencing factors should be included while assessing risk. "

Safety manager is probably the weakest link in hazard identification, because when hazard is not correctly identified it might be missed out and potential risk would not be mitigated. According to (Hadjimichael, 2009) "flight operations are extremely complex, involving many components: human, mechanical, technological, and environmental. Consequently, the risks associated with flight operations are equally complex and diverse". Therefore it is very tricky for safety manager or any safety personnel to responsibly identify all key affecting factors that determine safety level. It is very well known that the best knowledge of potential threats has your colleague sitting across from you. Therefore safety culture is also very useful to be able to fully evaluate safety risks and eventually assess safety level. Safety climate – safety attitudes – safety thinking should be implemented in employees' value system as one of the priorities.

PROACTIVE/REACTIVE

Safety is according to many definitions a system characteristic of risk management that excludes unacceptable risks. In other words safety might be perceived as process of risks mitigation.

It is very crucial to label safety as process, because labeling it as state would be completely improper. Safety must be defined in organizations as process because it is continuous action of maintaining and even improving safety level. This is done by safety amendments of e.g. safety regulations, operating procedures, training and other.

Aviation safety attitude is divided in two main very specific levels; proactive and reactive approach:

Reactive approach – is very well known and was used with great achievements. Reactivity is mostly about response to accident or any event that have already happened. That means there must be some undesired outcome of system – the safety must actually fail, and that finally triggers the reaction and possible safety consequences. Reactive actions were very well beneficial to aviation safety in the past when accidents were caused mostly by single failure particularly of technical system.

Proactive approach – gives us on the other hand possibility to actually prevent the potential subsequent accident by mitigating or even avoiding causes that might lead to accident. Example of proactive action to eliminate prospective error is according to (Flight Safety Foundation, 2003) "use of checklists, which itemize a small set of weighted risk factors, and are completed by the flight crew before departure. (qtd. in Shyur, 2008)"

Other well-known proactive tool to measure safety (safety indicator) is Digital flight data recorder (DFDR) data analysis. DFDR analyzis is proactive because it collects data and provides safety level outcome on operational basis. According to (Hadjimichael, 2009) data that are "generated by the aircraft during routine flight operations, is analyzed in order to reveal situations that may require corrective action, to enable early intervention to correct adverse safety trends before they can lead to accidents."

DETERMINATION OF SAFETY LEVEL BEFORE INCIDENT/ACCIDENT

Current safety level of organization is not that useful information for safety manager as safety level trend. In order to evaluate such trend, safety level must be measured repeatedly with same methodology. There must be established accurate methodology to keep results consistent. It would be very useful to measure safety level before and after every significant implementation of new procedures or regulations. Consistent data are useful especially in order to properly evaluate safety trend in particular organization. Identical methodology across whole sector of aviation industry is not needed and it might be even misleading because each company is unique and has different safety procedures.

As it was stated above, it is tricky to identify all risks, but another even harder task is to quantify the risk. This article should give basic overview of risk assessment and quantification of safety methods – safety benchmarking. Aviation industry is too extensive in order to generalize any measurements techniques. In a simplified way aviation industry benchmarking may be divided into:

- Maintenance organization
- Airline
- ATC
- Airport

Each group consist of First line employees – pilots, maintenance workers, ATCs as well as engineering stuff and management that significantly influences lethal factors of safety barriers.

Suitable method to proactively measure safety level is to use safety culture survey that measures safety climate – attitude towards safety in company. As (Evans, 2007) states; "safety climate – may be especially useful in identifying key factors that contribute to safety performance and provide a method by which organizations can benchmark safety perceptions."

RISK ASSESSMENT

It is said that aviation is the safest mean of transport and it is quite true. Nowadays aviation encounters very few accidents and risks are low, but there might be really serious consequences when accident ultimately happens. Therefore aviation is described as low-risk, high-hazard system just as nuclear power industry or healthcare.

Aviation safety reached such high safety level, that it is almost completely resistant to single failure accidents – caused by human or mechanical mishap. Present day accidents are caused by bunch of mishaps, failures, violations and errors. These prerequisites for accident may be divided in two categories; latent that might be dwelling in system for a long time and active which is usually just the trigger for chain of events that leads to accident. On that account it is important to perceive accident as concurrence of many variables.

Aviation risk assessment uses reactive data from accidents, incidents or ordinary operational errors and proactive for example safety indicators, audits or surveys. According to (Edkins, 1998) these proactive indicators are „airline safety culture, staff risk perception of aviation safety hazards, willingness of staff to report safety hazards, action taken on identified safety hazards and staff comments about safety management within the airline."

RISK MODELING

Modeling in aviation safety is used for simplifying real situations that might occur during aircraft operation. It is a description of system that uses special language particularly UML - Unified Modeling Language.

Model of aviation system is very useful in order to calculate compound risks and determine possible hazardous actions. According to (Hadjimichael, 2009) "Risk modeling approaches are typically aggregations of the collected knowledge resulting from accident and incident analysis, theoretical and empirical studies (e.g., effects of fatigue on human performance), and human experience." Creating and analyzing model of potential hazards is proactive action that also uses reactive knowledge and should be greatly used in day to day work of safety manager, especially when new procedures or regulations are implemented. In order to create fully realistic model, risks must be completely identified and expertly analyzed to be able to set it up qualitatively and quantitatively. "The most well-known probabilistic approach considers the probability and severity of a set of outcomes. Risk is defined as the product of likelihood and severity." (Hadjimichael, 2009)

CASUAL MODELS

Causal models are intended to describe aviation system as closely as possible. It is specific because of the aiming on relationships between various components of the system. (Ale, 2006) states that, "causal modeling is considered to be a powerful tool in supporting the insight into the interdependencies between the constituent parts of complex systems."

This model is especially useful to describe relationship between high management decisions and first line employees, because this is often ignored. Relations should be such realistic that it would be possible to simulate particular situations like downsizing or change of processes. Causal model is used for measure failures and interactions qualitatively so there must be some way to quantify it for example by fuzzy method (VI).

(Ale, 2006) declares that next necessary task is „development of a causal model for air transport safety. This model would, at least in principle, be better equipped to account for airport specific circumstances and measures than the risk assessment model currently in use, which is based on selected historical data." Causal model combines data from reactive knowledge with proactive indicators and other circumstances. It uses probability trees of assessed risks to specific actions or situations that can be calculated to evaluate final risk of situation. According to (Netjasov, Janic, 2008) causal models may be divided as follows:

1. Determination of safety level by probability of risk of failure

- "Fault tree analysis"

Describes possible risks or hazards of system by logical operators. In general this analysis supposes that it is possible to determine probability of consequent accident by summing probability of contributing factors.

"For the quantification of a fault tree, data are required for initiating or base events. These data have to be complete. Missing data can be obtained by expert judgment." (Ale, 2006)

- "Common cause analysis"

Describes sequences of events that lead to possible accident of aircraft. This method divides causes of component failure into specific zones of aircraft.

- "Event tree analysis"

Describes sequences of events that lead to single hazard.

2. Determination of safety level by assigning safety level of procedures

- Bow-tie analysis

Describes causal model in the form of Fault tree analysis and consequence model in the form of Event tree analysis. This method is combination of Fault tree analysis and Event tree analysis

- TOPAZ accident risk assessment

Describes operation model by Petri nets using scenario analysis. This method analysis model by Monte Carlo simulation technique.

- Bayesian Belief Networks

Describes complete system scenario with logical structure. This method describes complete case studies with wide range of failures both qualitatively and quantitatively.

AHP METHOD

Analytic hierarchy process (AHP) is technique of multi-criteria decision making. It is based on decomposing of problem and analyzing it in logical hierarchy model. This model is very useful, because it does not clearly determine solution but it unveils causes and consequences of actions. It is also rather easy to evaluate risks and calculate possible scenarios. Both of these characteristics are very suitable techniques in order to improving of safety level. As (Shyur, 2008) precisely states, "developing an analytic method that moves beyond the essential identification of risk factors to assess the safety performance and discover the potential hazards of airlines is indispensable."

This model gives possibility of simulating different influences on every element and the effect on overall steadiness of system.

EXPERT SYSTEM

It is very hard for single safety manager to fully and eruditely describe such complex system as aviation. Therefore there must be other input of knowledge to properly set significance of measured factors. (Hadjimichael, 2009) states that risk model created by expert system "is knowledge-driven and nonprobabilistic (...) It is primarily based on the knowledge derived through extensive discussions (knowledge elicitation sessions) with subject matter experts. Furthermore, the emphasis is on representing the process of the flight operation (in terms of risks factors), rather than the outcome."

Expert system may be very well used to prepare safety culture survey. It usually contains more phases that are according to (Evans, 2007) as follows:

1. "Safety themes recognized in previous studies (management commitment to safety, communication, rules and procedures, shifts and schedules, safety training, equipment and maintenance"
2. "Ranking of themes by experts (scale assessing)"
3. "Trial sampling on small group of respondents"

Initially there must be group of expert that analyzes possible threats or topics of questionnaire that is afterwards completed by small sample of respondents in order to assess scaling system of selected topics and answers.

Output of Expert system may be for example identification of safety indicators or possible safety hazards. (Evans, 2007) in his paper gives example of possible identified themes that may be included in safety survey:

- "Management commitment and safety communication"
    - Open communication about safety
    - Safety is one of the top priorities for employees as well as top management
- "Safety training"
    - Adequacy of safety training and proper regularity of revision training
- "Equipment and maintenance"
    - Proper maintenance following authorized regulations and sufficient resource allocation

FUZZY

As it was mentioned above it is very hard to quantify proactive safety indicators. To be able to measure safety level there must be specific statistical way to calculate it. Because there are not any safety units or positive points to value safety attitudes, processes or how closely are regulations followed it is necessary to find some method how to convert day to day operations into statistical values. (Hadjimichael, 2009) concludes that problem of quantification safety is “particularly challenging in domains where undesired events are extremely rare, and the causal factors are difficult to quantify and non-linearly related. One such domain is aviation safety.”

Fuzzy is a way how to convert and measure not specific values by comparing them with each other and creating artificial values from that comparison. Fuzzy is usually used along with expert system for proactive risk assessment. According to (Hadjimichael, 2009) “fuzzy expert system is an ideal method for the representation and application of knowledge in a domain such as aviation safety, in which knowledge may be highly subjective and empirical, resulting from years of experience, accident investigations, psychological studies, simulations, and modeling.“

CONCLUSION

Safety level in current civil aviation is very high; therefore it is much harder to improve it even further. In the past safety level was measured reactively, that means that safety must have failed in order to pronounce company as unsafe.

Aviation safety went through quite long and thorny evolution and finally reached the status of ultra-safe system. Safety level is now very hard to measure so it is hard to label company as safe or not until something undesirable actually happens.

In order to increase safety level, it must be measured and measuring of safety in modern civil aviation organizations should be done proactively. But it is very hard to comprehensively measure safety level because it is not exact. Therefore aviation companies, civil aviation authorities or supranational authorities should develop such tools that would follow current safety trends of increasing and measuring safety without any mishaps needed.

This article propounds basic overview of some methods that are used to convert inexact world of aviation safety into statistically countable model of risks and hazards. These models should be as simple but as realistic as possible in order to be able to simulate potential scenarios and proactively oversee safety level.

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This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS12/165/OHK2/2T/16.

START OF THE HELICOPTER PILOT EDUCATION AT THE CTU

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Abstract – *In the paper a detailed information concerning the whole Professional Pilot branch study track and its study curricula are fully described as well as the overall information about the whole extend of the education and research provided by the Department of Air Transport is given. Performed an analysis of the number of holders of licenses pilots and helicopters, in cooperation with DSA found that in the next five years is not enough pilots for the air rescue service. The results of the analysis are the following graphs and demonstrate the lack of helicopter pilots under 45 years of age.*

Keywords – ATO, Bachelor Proffesional Pilot Study Branch, Flying Training Organization, Theoretical Pilot Training, Practical Pilot Training, ATPL(A/H), JAR FCL.

INTRODUCTION

The Faculty of Transportation Sciences belongs to one of six faculties situated on CTU – The Czech Technical University in Prague, the oldest Technical University in Central Europe, founded 18th January 1707. First education focused on the transportation was provided by eminent scientist and engineer, Professor Franz Josef von Gerstner, in the period 1806 -1832. His work focused on applied mechanics, hydrodynamics and river transportation as well as railway transportation. He helped to build the first iron works and first steam engine in Czech lands. In 1807, he suggested the construction of a horse driven railway between České Budějovice and Linz. This railway was later actually built between 1827 and 1829 by his son František Antonín Gerstner. In the period 1841 -1851 Christian Johann Doppler, Professor of mathematics and practical geometry, had been working at Prague Polytechnic. In 1842 Professor Doppler formulated his well-known principle concerning the frequency shift of waves due to the relative velocity of the source and the observer.

First aeronautical engineering courses started at the CTU on 10 May, 1910, provided by Professor Viktor Felber, with lectures focused on aerodynamics and flight mechanics. Later in thirties of the last century, new aeronautical engineering program was created with courses focused on Aero-engines, Aircraft instruments and control and Aircraft design. After the Second World War the courses continued till 1950 when according to a political decision of the communist regime the aeronautical engineering courses were moved from CTU in Prague to the Military Academy in Brno.

But, in the year 1975 the aeronautical engineering education was founded at the CTU in Prague again and was provided at Faculties of Mechanical Engineering (courses of Aircraft Design and Aircraft Engines Design) and at the Faculty of Electrical Engineering (courses of Radio-navigation and Avionics)

Till the 1993 four Aeronautical Engineering Program Branches were provided at the Faculty of Mechanical Engineering: Aircraft Design, Aircraft Engines Design, Aeronautical Production Systems and Technologies and Air Transport. After splitting of Czechoslovakia the Air Transport branch was moved to the newly founded Faculty of Transportation Sciences.

During the period from 1974 till 1993 almost 1000 students graduated at the Faculty of Mechanical Engineering. Many of them have been active pilots and some of them are still working for CSA Company.

Faculty of Transportation Sciences was founded in 1952, originally as a part of CTU. Later reformed into Independent University of railways, began its activity in Prague-Karlin from 1953 with four faculties: of civil engineering; mechanical engineering; electrical engineering; and the faculty of transportation science. In 1960/61 it was moved to Žilina and changed the name to the University of Transport and Telecommunications. After splitting of ČSFR the Faculty of Transportation Sciences was established as a part of CTU in Prague, education started in 1993/94.

Faculty of Transportation Sciences received an accreditation for engineering studies on 5. May 1993. Legal status was accredited by Academic senate of CTU on 9 June 1993. In the academic year 1993/94 at the Faculty almost 200 students started their full-time studies, in following academic year 1995/96 new bachelor studies were opened in the faculty part in the town Děčín.

DEPARTMENT OF AIR TRANSPORT

Department of Air Transport was established on March 1, 2002 as part of the Transportation Faculty. Primary mission of the Department is the education and training of highly qualified professionals in the field of civil aviation in Czech Republic. Currently, in Czech Republic the Department of Air Transport provides unique education and schooling in the areas of operational-technical and operational-economical civil aviation studies.

In compliance with the Bologna Agreement, studies in civil aviation, as well as the rest of the CTU studies, follow the standardized three-level structured studying scheme.

Department of Air Transportation provides highly specialized environment for lecturing expert studies within the “Operations and Management of Air Transport” PhD and master studies and within the “Air Transport”, “Professional Pilot”, and “Technology of Maintenance” bachelor studies.

Department of Air Transportation is certified to provide for theoretical air crew education (flight training organization certification of Civil Aviation Authority (CAA) CZ/FTO-010) and to provide for education, training, and examinations of aircraft maintenance personnel (aircraft maintenance training organization certification of Civil Aviation Authority (CAA) CZ.147.0004). Both certifications meet European standards and requirements.

Department provides for practical trainings for pilot courses and courses of aircraft maintenance technology as well.

Also, there is a wide range of specialized projects in which students of “Air Transport” bachelor and master studies may participate in:

Modern Trends in Airport Design (Development)
Systems of Air Traffic Control and Assurance
European Approach to Aircraft Maintenance
Quality Assurance in Civil Aviation
Air Transport Operations and Economics

Current research initiatives are headed towards enhancement of safety and quality of civil aviation and towards designing such modules for training and education of pilots, engineers, and other aviation specialists that would meet the European standards and criteria.

Flight Planning and Performance Laboratory (LPPL)

As part of the highly specialized educational and training environment, a laboratory of flight planning and performance was designed at the Department of Air Transportation in 2004-2005. Laboratory mainly supports the educational process of professional airline pilots obtaining their training in accordance with JAR-FCL 1.
Laboratory serves its purpose not only in the schooling itself, it also provides room for application of knowledge obtained in several other courses: Mechanics of Flight, Avionics, Meteorology, Navigation, Radiotelephony and Communications, etc.

Knowledge and skills obtained in the Laboratory will be accepted by the Civil Aviation Authority as part of the ATPL(A) ground training requirements.

Teaching methodology:
At first, students complete the training in Laboratory of Radiotelephony where they receive the basic skills and knowledge in aviation radio-communications. Further on, skills are developed in flight simulator where, in the course of time, students gain the ability to fly, navigate, and communicate.

In the advanced level, after acquiring standard level of skills and proficiency, non-standard and emergency situations (such as obstacles on RWY, in-flight engine failure, etc.) handling is trained.

ATR Simulator

In cooperation with CSA Czech Airlines, it is possible to provide the flight training to DAT Professional Pilot students in multi-engine turboprop ATR simulator under the supervision of experienced aircraft captains. Students have the chance to try to handle either normal or non-normal and emergency procedures.

Observer flights

According to the agreement of cooperation between the Faculty of Transportation Sciences and CSA airline company professional pilot trainees have a possibility to attend on selected regular CSA flights in the cockpit as observers.

Cooperating Training Organizations

Education and training of aircraft maintenance personnel is performed in cooperation with SPS and SOU Odolena Voda and with other organizations approved by CAA under Part 145 such as CSA Czech Airlines, Aeroservis, DSA, ABS-Jet, etc.

International Academic Cooperation and Scholarship Possibilities

Faculty of Transportation Sciences of the CTU in Prague cooperates with many international universities and organizations. Most popular options, selected by our students, are the one-or two-semester courses at foreign universities cooperating under student exchange programs. These programs (known as SOCRATES/Erasmus) are financially supported by the European Union.

Erasmus, as a part of SOCRATES educational program, is mainly designed for higher or university education. This program enables mutual cooperation between all types of higher education institutes.

CTU became a full-member of the Pegasus Network EU aerospace universities in 2006. Primarily, Pegasus is oriented towards continuous support of education by organizing European-wide conferences where students are provided the possibility to present their works and achievements. The best ones are awarded. Department of Air Transportation plays a significant role in this program.

Department of Air Transportation also cooperates within the CESAer project. Part of this project is the reciprocal exchange of PhD- and master-studies students within the Canada-EU project which is aimed at cosmic technologies and aircraft construction studies. Between 2005 and 2008, there will be 56 students in total (7 from each university) participating in this project. Within CESAer project, the following universities are cooperating: University of Glasgow, Delft Technical University, Technical University Munich and CTU Prague on the European side; and University of Toronto, Ryerson University Toronto, Carleton University Ottawa and Concordia University Montreal on the Canadian side.

Conferences and Workshops

Providing the possibility for our students to participate in scientific and research conferences and workshops is one of the cornerstones of educational principles respected at the Department of Air Transport. Students may elect to participate as active speakers or simply by helping in event organization.
DAT in cooperation with Department of Air Transport of the Zilina University in Zilina and Department of Aerospace Engineering of the Brno University of Technology holds scientific conferences on New Trends in Civil Aviation.

Actual Student body at the DAT

In academic year 2010/11 almost 200 freshmen applied for studies in three bachelor branches (Professional Pilot, Technology of Aircraft Maintenance and Air Transport) and one master branch (Traffic and Management of Air Transport). Quality of education is supervised by following authorities: Accreditation Commission of the Czech Ministry of Education, Youth and Sports, CAA, EASA, JAA.

In three study grades of three bachelor branches assured by DAT there is more than 400 undergraduate students.

In two study grades of master branch assured by DAT there is over 100 graduate students.

In doctoral studies assured by DAT there is more than 20 Ph.D. students

Total student body at DAT is actually 520 students.

STUDY BRANCHES AT DAT

Bachelor branches

Three study bachelor branches are provided by the Department of Air Transport. These study branches are newly accredited in the common bachelor study program Techniques and Technology of Transport and Communication. The length of studies is 3 academic years that is 6 semesters with total number of ECTS credits 360 (European Credit Transfer System). The studies in the study program are concluded by a State Exam from 3 study subjects and by a defense of the bachelor graduation theses in front of the State Examining Body.

- **Professional Pilot Branch**

For the Professional Pilot training as a theoretical integrated training ATPL (frozen) according to the European Regulation JAR FCL1 for the pilot training JAR FCL1 the DAT received also the approval granted by the CAA and EASA and holds this approval as a Flying Training Organization of the No. CZ FTO 010.

Professional Pilot Branch education has three major parts. In the beginning there is a common track with others branches of the bachelor study program comprising of fundamental scientific and general transportation courses oozed through a gradual start of special subjects for pilots in the duration of first three semesters.

Consequential second part of the study track is fully involved to the pilot training according to the European Regulations JAR FCL1.

In parallel to the theoretical training students complete a practical training in flight in Flight training organization (FTO) certificated for integrated practical training with them DAT has signed agreement of cooperation. At present they are these companies: F-Air Benešov, Bemoair Benešov, Delta System Air Hradec Králové. Costs of the practical training of the order of one million Czech Crowns are fully covered by the trainees. Students in the Professional Pilot branch receive after successful graduation a bachelor diploma and after successful passing of appropriate exams at CAA also a license of ATPL (frozen).

- **Technology of Aircraft Maintenance branch**

Department of Air Transport holds also an approval as a Maintenance Training Organization granted by EASA and CAA for education and practical training of professionals for posts of certificatory mechanics and workmen of technical control. The granted approval has a Reference No. CZ.147.0004.

The main goal of this program is to give the University degree in civil aviation and give theoretical knowledge in accordance with Part 66.

This bachelor branch has subsequent specializations:
B1 – Line maintenance - mechanical
B1.1 – Aeroplanes Turbine
B1.2 – Aeroplanes Piston
B2 – Line maintenance - avionic

Similarly as the Professional Pilot branch study track the Technology of Aircraft Maintenance branch study track comprises of the common trunk with other bachelor branches in first three semesters together with some special subjects and also with special practical training in workshops belonging to partner vocational school at Aero Vodochody Company.

After successful graduation students receive a bachelor diploma. Graduates will receive a basic knowledge and practical knowledge according to Part 66 and Part 147. DAT as approved MTO is authorized by the CAA and also by EASA to examine trainees and grant them respective professional licences which are recognized by all EU member countries.

- **Air Transport branch**

The studies in the branch are provided in several projects chosen by students:

- Project „Modern trends in airport's developments "
- Project „ Aeronautical telecommunication and ATC"
- Project „Quality in civil aviation "
- Project „ European approach to aircraft maintenance "

B. Master Branch

- **Traffic and Management of Air Transport branch**

One study Master branch "Traffic and Management of Air Transport" is provided by the Department of Air Transport. The length of studies is 2 academic years that is 4 semesters with total number of ECTS credits 240.

The studies in the branch are provided in several projects chosen by students:

- Project „Modern trends in airport's developments "
- Project „Systems of control and security of air traffic"
- Project „Quality in civil aviation "
- Project „Management and economy of air transport "

Study program is concluded by a State Exam from 3 study subjects and by a defense of the diploma graduation theses in front of the State Examining Body.

The Master (Engineering) programs at the Faculty of Transportation Sciences are accredited by the Czech Accreditation Commission and also by the European Federation of National Engineering Societies in Brussels.

The study master branch "Traffic and Management of Air Transport" is also recognized by the PEGASUS Network of the EU Aerospace Universities.

PROFESSIONAL PILOT STUDY TRACK CURRICULA

The study scheme in the Professional Pilot branch comprises all courses prescribed and accredited by the Czech national accreditation body and also fulfill the requirements of the JAR FCL 1 regulations. So the total number of ECTS credits is 360 and the total number of teaching hours is 2324 from them 1358 teaching hours are devoted to theoretical training in subjects focused on prescribed learning objectives. These prescribed learning objectives by JAR FCL 1 regulations are completed by more theoretical parts which are required by the university level standards.

Theoretical studies are divided into 6 semesters. The theoretical training according to JAR FCL 1 regulations starts at the beginning in first semester by initial course while in the beginning of the studies general engineering courses as well as scientific background courses are predominantly. In second and third semester the proportion of the professional pilot courses gradually grows and in fifth and sixth semester there are only prescribed professional pilot courses taught.

The study plan for the Professional Pilot branch by JAR FCL 1 regulations is:

The Study Plan for the Professional Pilot Branch by JAR FC 1 regulations:

Code	*Course*	*Sem.)***	*Hours/ week)**	*ECTS*
21UVP	Introduction to Aviation Personel Training Theory	1	2+1	6
18TTED	Technical Documentations	1	2+1	2
21N	Navigation	2	4+0	4
21PSL	Operations Procedures and Requirements	2	2+1	3
21PVY1	Pilot Training – Excercise 1	2	0+1	2
21TPIL	Pilots´s Training Theory	2	4+4	7
21PLL1	Flight training operations 1	3	2+1	4
14ZAET	Elektrotechnics	3	2+1	2
21RFS	Radiotelephony and Communication	3	1+2	4
21RN	Radionavigation	3	2+2	5
21 LR	Radio Engineering in Aviation	4	2+0	2
21CNV	Fligh Navigation Excercises	4	0+2	2
21LL1	Aircraft 1	4	2+1	3
21LPVL	IFR, Night and Multiengine Aircraft Flying	4	2+0	3
21MGI	Meteorology	4	4+2	7
21PJE1	Aircraft Instruments 1	4	2+1	2
21PLL2	Flight training operations 2	4	2+1	4
21PVY2	Pilot Training – Excercise 2	4	0+1	2
21ZLE1	Principles of Flights 1	4	2+1	3
21LLTE	Aerodromes	4	2+1	4
21DTL	Aviation Datalink Communication	5	2+0	2
21LICL	Human Factors in Aviation	5	2+0	4
21LTA2	Aircraft 2	5	2+1	2
21PJE2	Aircraft Instruments 2	5	2+1	3
21PLL3	Flight training operations 3	5	2+1	7
21PPJ	IFR Flights Procedures	5	2+1	3

The Study Plan for the Professional Pilot Branch by JAR FC 1 regulations:				
Code	***Course***	***Sem.)*****	***Hours/ week)****	***ECTS***
21ZLE2	Principles of Flights 2	5	2+1	4
21LCP	Human Factor for Pilots	6	2+0	4
21LPS	Air Operations and Regulations	6	3+1	6
21LRY	Aircrafr Engines	6	2+1	2
21MCC	MCC – Multicrew Cooperation	6	2+0	4
21PVY3	Pilot Training - Excercise 3	6	0+1	3

)* - study hour (45min.)
)** semester (14 weeks)

Performed an analysis of the number of holders of licenses pilots and helicopters, in cooperation with DSA found that in the next five years is not enough pilots for the air rescue service. The results of the analysis are the following graphs and demonstrate the lack of helicopter pilots under 45 years of age.

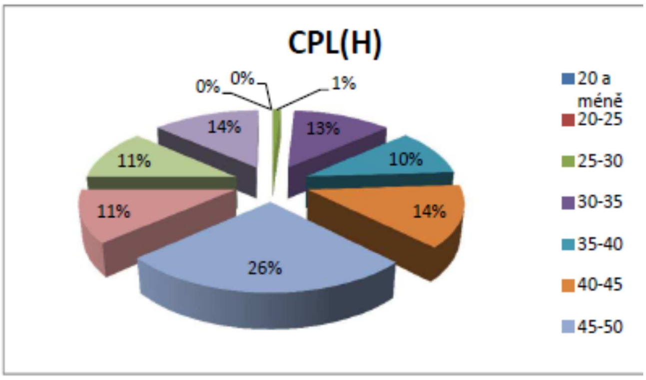

Figure 1

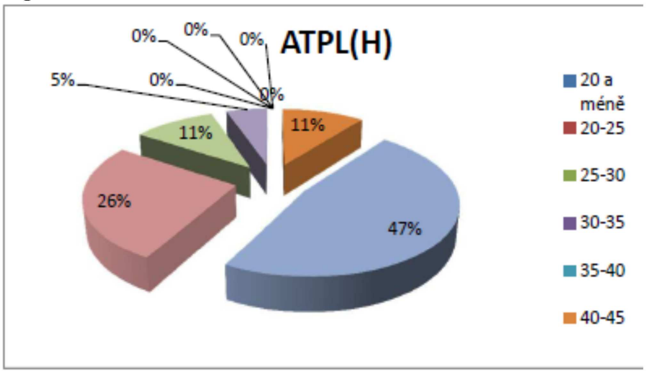

Figure 2

As the air rescue service in accordance with Regulation of the European Parliament and Council Regulation (EC) No 1899/2006 (EU-OPS) commercial air traffic, pilots must meet age limits specified in this Regulation.

As the Czech Technical University by the end of 2012 to transfer his authorization for pilot training in accordance with Regulation (EU) No 1178/2011 and we will be in this transfer request to extend the authorization for integrated training ATPL (H). Courses will be conducted in "Professional Pilot" and within this field project established integrated training ATPL (H). The total number of hours of theoretical instruction remains the same, just different subjects will be taught separately. Practical training will be delivered by DSA, as at the airport in Hradec Kralove.

CONCLUSION

Department of Air Transport of the Faculty of Transportation Sciences of the Czech Technical University in Prague is the only academic institution in the Czech Republic offering a professional pilot training as a integrated course according to JAR FCL1 regulations as a university bachelor study branch awarding beside the academic title Bachelor also a license ATPL (frozen). From the foundation of the Faculty of Transportation Sciences in 1993 till now more than 230 graduates at the CTU in Prague received a professional pilot license. The majority of them are now flying as captains, co-pilots and also in the positions of instructors and inspectors at CSA, Travel Service and others airlines worldwide. Some of them continued their studies in consequential master as well as in doctoral branches “Traffic and Management of Air Transport” of studies provided by DAT and hold academic titles of Engineer “Ing.” and Doctor of Philosophy “Ph.D.”.

Extension education in training helicopter pilots to solve the current problem of industries and CTU will increase the prestige of education. Effective cooperation between universities and industry can overcome obstacles and achieve quality results.

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CONFLICT RISK ASSESSMENT MODEL FOR AIRSPACE OPERATIONAL AND CURRENT DAY PLANNING

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Abstract - *This paper presents a framework for airspace planning and design based on a conflict risk assessment developed for the purpose of preventing aircraft conflicts and collisions. It also represents a continuation of previous works on development of: a) conflict risk assessment model for airspace strategic planning, which was intended to facilitate comparisons and sensitivity analyses of different airspace designs and organizational scenarios under different traffic flow levels; and b) conflict risk assessment model developed for airspace tactical planning which was intended for comparison of different alternative flight scheduling scenarios for a given airspace sectorization. Apart from developed framework, the aim of this paper is also to present a conflict risk assessment model developed for the purpose of airspace operational and current day planning. The model is intended to support air traffic managers decision-making in real-time during process of dynamic sectorization (i.e. making decision about necessary sectors grouping or collapsing for a given set of sectors determined at tactical planning levels) through evaluation of conflict risk and air traffic controllers task load. The model is based on the assumption that conflict between aircraft pair exists when either horizontal or vertical separation minima are violated. Additionally, it was assumed that risk values are stochastic. The developed model allows for the estimation of the number of conflicts and the conflict probability, and their distribution on considered airspace, i.e. at intersections or along airways as well as air traffic controller task load. A simple illustration of the model application shows that in addition to airspace geometry, the total conflict risk and task load also depends on traffic demand, aircraft speed, spatial and temporal distribution of traffic in the airspace as well as the applied separation minima.*

Keywords - Risk Assessment, Risk Probability, Dynamic Sectorization, Aviation Safety, Air Traffic Management.

I. INTRODUCTION

Air Transport is generally growing despite constraints such as the global economic crisis, with a further increase with an average annual rate of about 4 – 5% [1, 2] expected. The increase of the air traffic in Europe 2050 is forecasted in the European Commission (EC) document “Flightpath 2050” [2] to be an almost threefold increase relative to the year 2011 (25 million commercial flights in 2050 relative to 9.4 million expected in 2011). At the same time, an increased level of safety is required through both an 80% reduction in the accident rate for specific operations, and through a significant decrease of human error [2]. Similar objectives have been defined in the USA [3]. Objectives mentioned in the previous documents are conflicting and present a significant challenge for the research and scientific community since an increase in traffic should not lead to a decrease in safety. According to “Vision 2020” [4], developments of new operational concepts in the air traffic system are expected as well as development of safety measures and system safety performance indicators.

Physically, and operationally, the air transport system is a rather complex system with the main components - airlines, airports and air traffic control services – all interacting in and across different hierarchical levels, which constitutes a very complicated, highly distributed network of human operators, procedures and technical/technological systems. In particular, the risk of accidents and the related safety in such a complex system is crucially influenced by interactions between the various components and elements [5, 6]. This implies that the provision of a satisfactory level of safety, i.e., in the airspace context a low risk of an accident, is more than just assuring that each of the components and the elements functions safely [7]. Due to such an inherent complexity and the severe consequences of accidents, risk and safety have always been considered as issues of the greatest importance for the contemporary air transport system [8]. Consequently, these characteristics have been a matter of continuous research from different aspects and perspectives ranging from the purely technical/technological to the strictly institutional. In general, the former have dealt with the design of safe aircraft and with other system facilities and equipment. The later have implied setting up adequate regulations for system design and operations [5, 6].

The system infrastructure – airports and the Air Traffic Control/Management (ATC/ATM) system, although in many cases acting as temporal “bottlenecks”, are expected to be able to support such growth safely, efficiently and effectively. This research is concentrated on the ATC/ATM system, i.e., on airspace planning. Ultimately, unconstrained airspace capacity, given as the maximum number of aircraft going through any given geometrical airspace in a given time period [9], depends on the traffic flows on certain, or all of, the airways, as well as the applied aircraft separation minima. One of the possibilities to increase airspace capacity is to reduce the separation minima [10, 11, 12].

An increase in airspace capacity is a prerequisite for satisfying the growing demand for air traffic, but it also affects safety of aircraft operations. This is why it is necessary to develop models that will help assess the safety of such a change and to find the balance between an increase in capacity and any unwanted decrease in safety at different planning levels. A review of these types of models is given in [5, 6].

The aim of the research described in this paper is to develop a framework for airspace planning at the operational and current day level as the natural continuation of research presented in [13, 14]. A further aim was to develop a risk assessment model for airspace planning purposes as a first step towards implementing the proposed framework, considering airspace organization at the operational and current day planning level. Namely, the aim of this research is to develop a tool (a risk assessment model) that could be used by air traffic managers in real time in order to support their decision making process about necessary dynamic sectorization (i.e. during airspace planning process) based on a conflict risk assessment.

Data regarding weakly and/or daily traffic, i.e., flight schedules with designated aircraft types, are used as traffic demand indicators. The supply side is represented by airspace geometry (number and length of airways as well as airway tracks) which was determined as most appropriate from a safety point of view at the tactical planning level. At the operational and current day level we were concerned with the exposure of air traffic controllers (ATCo) to conflict situations and task load which depend on dynamic sectorization.

The paper is organized as follows. Section 2 provides a description of the proposed framework for the airspace planning and design based on conflict risk assessment. Section 3 explains the development of a conflict risk assessment model for airspace operational and current day planning. Section 4 illustrates the application of the developed model in case of a hypothetic en-route sector and flight schedule example. Section 5 draws conclusions and presents further research directions.

II. FRAMEWORK FOR THE AIRSPACE PLANNING AND DESIGN BASED ON CONFLICT RISK ASSESSMENT

The basic idea of the research presented in this paper is that different planning levels in ATC/ATM require different models for risk assessment. Their main purpose is to support decision-making processes during system planning and development, through evaluation of risk and safety of proposed changes (either in the existing or new system).

Generally, during airspace planning and design process, airspace designers follow different criteria, such as capacity increase, reduction of air traffic controller's (ATCo) task load, etc. Here, an additional step is introduced – risk and safety assessment, performed by safety analysts who usually follow risk reduction criteria (Figure 1.), and provide useful feedback (both positive and/or negative) to airspace designers regarding the safety issues of their solutions [7].

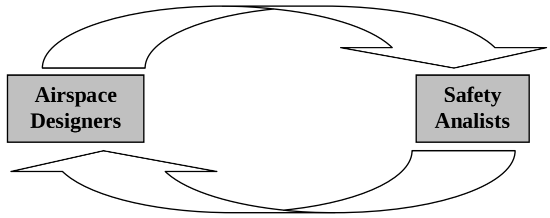


Figure 1 *- Iterative process for airspace design and planning (compiled from [7])*

A risk assessment modelling framework containing three planning levels (strategic, tactical and operational) is proposed in the research presented in this paper. The proposed framework is designed to be complementary with ICAO CRM's (which could be used at the operational level of the proposed framework) and is not its replacement. The main differences between the proposed approach and the ICAO CRM are the following:

- The proposed framework considers the risk of conflict while the ICAO approach considers the risk of collision;
- The proposed approach considers airspace designs for a given separation minima based on conflict risk, while CRM uses collision risk for determination of a separation minima which then allows an increase of airspace capacity;
- The proposed approach considers the forbidden volume around aircraft while CRM considers the size of the aircraft; and
- The proposed approach uses distance-based separation minima, while CRM uses both distance- and time-based.

The framework is intended for use by the safety analysts presented in Figure 1. For each of the three planning levels (Figure 2), necessary (not exhaustive) inputs are listed and possible types of models are proposed.

Conflict risk assessment models for airspace strategic and tactical planning level are developed and presented in work of Netjasov [13, 14]. An example of risk assessment model for airspace operational planning level is presented in work of [15, 16, 17].

The research presented in this paper considers airspace organization at the operational and current day planning level (e.g. from current day up to a week in advance), which represents the transition between third and fourth level of a proposed framework (Figure 2). For that purpose data about weekly and/or daily traffic, i.e., schedules with designated aircraft types, are used as traffic demand indicators.

The supply side is represented by airspace geometry (number and length of airways as well as airway tracks, sector borders, etc.) which was determined as most appropriate from a safety point of view at the tactical planning level. The influence of Humans – operators is considered at this level through the ATCo task load.

The main purpose of the research presented in this paper is to support decision-making processes during dynamic sectorization[14] (for a given set of available sectors determined at tactical planning levels) through evaluation of conflict risk and ATCo task load.

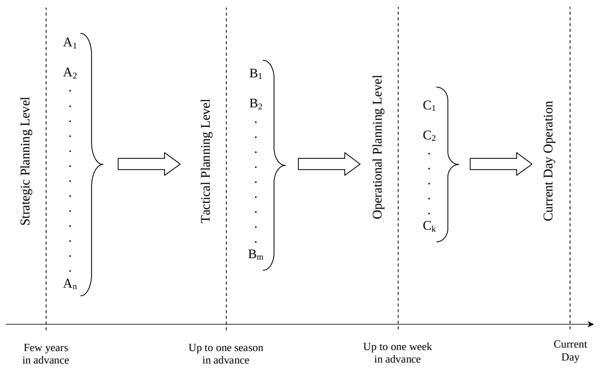


Figure 2 *- Planning levels in Risk assessment modelling framework*

III. Conflict Risk Assessment Model for Airspace Operational and Current Day Planning

Objectives and Assumptions

The main objective of this research is to develop a model (tool) for conflict risk assessment, which could be used for estimating numbers of conflicts as well as risk and ATCo task load in certain airspace, with the aim to help decision makers (air traffic managers) to decide about possible sectorization. The main starting point is that risk depends on airspace geometry (static element) and the air traffic using it (dynamic element).

The following assumptions are introduced in developing the method for safety assessment [13, 14]:

- If there is no traffic, there is no risk;
- Risk values are not constant;
- Risk values are stochastic;
- Risk values positively correlate to traffic demand and negatively to airspace volume;
- One aircraft at an airway can be simultaneously in conflict with only one aircraft from another airway.

The main inputs for developing the method for safety assessment are [13, 14]:

- Airspace geometry and characteristics (number and length of the airways, number of intersecting points, available flight levels, etc.);
- Traffic characteristics (distribution of traffic flows, proportion of level flights vs. climb/descent flights, share of specific aircraft category in total traffic volume);
- Human operator issues are considered through the estimated ATCo task load.

From the mentioned objectives and assumptions it should be emphasized that the main difference between approach taken in this research and those from previous works [13, 14] is in fact that risk is here assumed to be stochastic and that developed conflict risk assessment model should serve as a decision supporting tool.

Development of the Model

The model presented in this paper is of a macroscopic nature. It looks at a given portion of the airspace (en-route sector or terminal manoeuvring area - TMA) and focuses on the geometry of the airways. Also, it uses data from filed flight plans, such as entry time and entry point into the airspace and chosen airway.

Critical Section length and duration

A conflict situation is a situation when two aircraft come closer than a specified minimum distance both in horizontal and vertical plane. In order to determine whether or not, conflict situations exist, a cylinder-shaped “forbidden volume” (“protected zone” in [18, 19]) is defined around the aircraft, the dimensions of which are determined by the minimum horizontal Smin and vertical separation Hmin.

A potential conflict situation exists between two aircraft if one of them enters the other’s forbidden volume. Conflicts could be of crossing or overtaking type, depending on the aircraft trajectory relations both in horizontal and vertical plane.

Let us consider the situation when two aircraft are flying on the same level and their trajectories *i* and *j* are intersecting in the horizontal plane, with intersection angle α. Let the speed of aircraft be V_h. A “critical section” was defined as portion of trajectory *j* in which aircraft should not be at the same time, if other aircraft is in intersection point *O* flying on trajectory *i*, in order to prevent occurrence of conflict. The length of the “critical section” depends on the plane on which the potential conflict has occurred (horizontal or vertical), on the flight phase combination (level flight, climb, descent), crossing geometry, aircraft speed and applied separation minima (S_{min} and H_{min}).

In [13] it was shown that critical section length d_h in the horizontal plane can be calculated using the following expression:

$$d_h = \frac{2 \cdot S_{min}}{\sin \alpha}$$

An aircraft will traverse the critical section length in some average critical time τ_h. In the case when both aircraft are flying at the same level (horizontal plane) critical time τ_h can be estimated as follows (similar reasoning is applied also in the vertical plane) [13]:

$$\tau_h = \frac{d_h}{V_h} = \frac{2 \cdot S_{\min}}{V_h \cdot \sin \alpha}$$

[14] Air traffic managers working in real time environment are monitoring the work of their air traffic controllers and development of traffic situations. If traffic rises during certain period of time, air traffic managers are making decision based on estimated risk and task load values to divide airspace in bigger number of smaller sectors. In opposite, if the traffic is declining, they will combine smaller sectors into bigger one. This process is known as dynamic sectorization.

Conflict probability

Relative to the conflict probability determination approach presented in [13], here a somewhat simpler approach was accepted. During one hour, aircraft flying on trajectory i enter airspace in moment t_i^{in}. In moment x aircraft enters into critical part of the trajectory and flies through it τ_i time units (an hour is used here as time unit). Same is applicable for aircraft on trajectory j.

Assuming that traffic flows are independent, conflicts will appear when both aircraft are simultaneously inside critical parts of their own trajectories (Figure 3). Conflict probability P_c is represented by shaded surface P_c on Figure 3 and could be calculated by the following expresion:

$$P_c = (A_1 - A_2 - A_3) / A_1$$

where: $A_1 = 1$, $A_2 = ½ \cdot (1 - \tau_j)^2$, $A3 = ½ \cdot (1 - \tau_i)^2$, and A1, A2, A3 are areas (Figure 3).

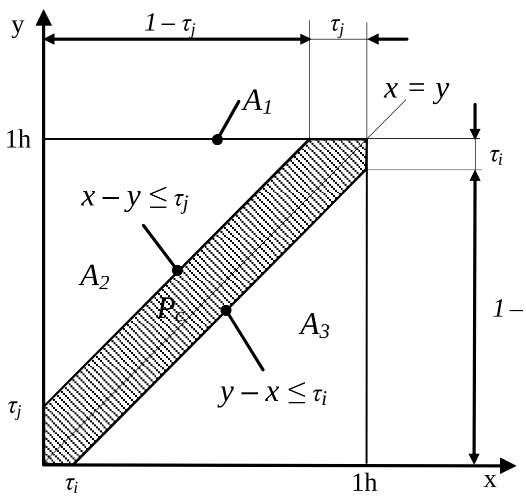


Figure 3 *- Determination of P_c*

This approach could be equaly used for determination of P_c in the horizontal P_c^h and the vertical plane P_c^v [13]. Total conflict probability is defined as a product of conflict probability in the horizontal and the vertical plane:

$$P_c = P_c^h \cdot P_c^v$$

Model 1 - Deterministic Risk of Conflict

In the situation when an aircraft flying on trajectory i occupy the critical length of trajectory j, a potential for the occurrence of a conflict situation with the aircraft flying on trajectory j exists. This potential is higher if the traffic flow on trajectory j is higher. The situation is worsened when we take into account the traffic flows on both trajectories. For the known average maximum traffic flows on both trajectories Q_i^{max} and Q_j^{max} we can estimate the average maximum number of crossing conflicts per hour N_c^{max} for the given intersection point, at given FL [13]:

$$N_c^{max} = min\ (Q_i^{max}, Q_j^{max}) \cdot P_c$$

The product of traffic flows in expression for N_c^{max} represents the maximum number of aircraft pairs (one aircraft belongs to flow i, the other to flow j) which could enter into a crossing conflict situation.

In this research, the risk is considered as a combination of the probability (or frequency of occurrence) and the magnitude of consequences (or severity) of a hazardous event [20]. According to that definition it is assumed that the average number of crossing conflicts per hour N_c (where $0 \le N_c \le N_c^{\max}$) represents the risk of conflict.

This model enables determination of the lowest and highest risk values based on conservative (more risk) approach (0 when there is no traffic and $N_c^{\max}$ when maximum traffic flow appears)[15]. Between those to figures there is no other information.

Model 2 - Stochastic Risk of Conflict

This model allows for estimation of the conflict risk by performing the simulation of traffic in the given sector. Namely, repeating the simulation, it is possible to estimate conflict frequency $E(N_c)$ which is used for calculation of risk N_c. Calculated risk belongs to the risk range calculated with the Model 1 and it could be determined by the following expression:

$$N_c = E(N_c) \cdot P_c$$

Risk is now represented as a discrete stochastic variable where its values belong to the given risk range with certain probability (relative frequency):

$$N_c = \begin{pmatrix} 0 & \cdots & N_{c_i} & \cdots & N_c^{\max} \\ p_1 & \cdots & p_i & \cdots & p_{E(N_c)} \end{pmatrix}$$

were: $\sum_{i=1}^{E(N_c)} p_i = 1$ and $0 \le E(N_c) \le min\ (Q_i^{max}, Q_j^{max})$

Model 2 - ATCo Task Load Estimation

In this research, having in mind that main gool of the research was to provide decision support tool with the aim to help decision makers (air traffic managers) to decide about possible sectorization, the ATCo task load is calculated following the next steps:

- Step 1: ATCo tasks are devided into four sub-task types: beckground, transition, reccuring and conflict tasks [23],
- Step 2: For each sub-task types, an average sub-task load in seconds was estimated as a function of number of aircratf entering, exiting, simultaneously present in the sector, and number of conflicts discovered by simulation in 15 minutes time intervals,
- Step 3: To estimate ATCo task load caused by the specific sub-task type we multiple the frequency of specific sub-task type with the average task load for that task,
- Step 4: Estimate total ATCo task load (as percentage of time devoted by the ATCo to aircraft and conflict handling during one hour) by sumarising all sub-task type task loads.

ATCo task load is estimated by the same simulation used for the conflict risk estimation. Actually, every task is triggered in the simulation by the certain event (aircraft entry into sector or exit from the sector, conflict appearance, etc.) and holds some specific predefined time value (average task load).

[15] Risk is additive according to [21] and [22]

IV. Illustration of the Model Application

In order to illustrate the developed model a hypothetic en-route sector was considered [13]. The sector (Figure 4) contains two uni-directional and one bi-directional airway as well as four flight levels (e.g. FL320, 330, 340, 350).

Total traffic flow through the given sector is Q = 28 aircraft/hour of which $Q_1 = Q_2$ = 10 aircraft/hour on both airway AWY1 and AWY2, respectively, and Q_3 = 8 aircraft/hour on AWY3, of which half is in the eastbound direction and other half in the westbound direction. The airways are mutually dependant creating two intersection points $O_{1,3}$ and $O_{2,3}$ (Figure 4).

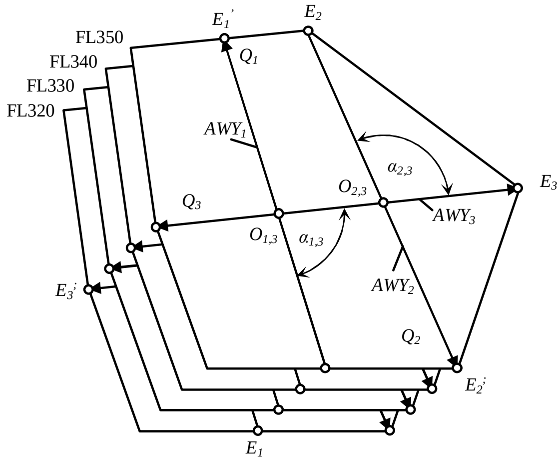


Figure 4 *- Sector geometry*

The lengths of the airways are: 180 NM, 195 NM and 210 NM respectively for airways AWY_1, AWY_2 and AWY_3. Average aircraft ground speeds are 450 kt on AWY_1 and AWY_2, and 400 kt on AWY_3. The distribution of aircraft on FLs, in each airway, is given in Table 1.

Table 1 *- Distribution of aircraft on FL's*

	FL320	FL330	FL340	FL350
AWY_1	0	50%	0	50%
AWY_2	50%	0	50%	0
AWY_3	30%	30%	20%	20%

A simulation model was developed in ARENA for the purpose of estimating the number of conflicts. Based on traffic flows presented above, airspace entry times for aircraft from all trajectories were determined. In order to determine entry times, firstly the aircraft inter-arrival times were determined using Poisson distribution in case of AWY_1 and AWY_2 and Uniform distribution in case of AWY_3.

Simulations were repeated 700 times for each of the following AWY_3 traffic flows: 4, 8 and 12 aircraft/hour, and separation minima: 3, 5 and 10 NM.

On Figure 5, for different traffic flows (and for separation of 10 NM, figure up) and separation values (and flow of 12 aircraft/hour, figure down), distributions of number of conflicts determined by the simulation are shown.

On Figure 6 hourly numbers of conflicts were shown. It is evident that risk values are spread within the range of values, i.e. between zero and maximum risk value (case with 12 aircraft per hour has been shown).

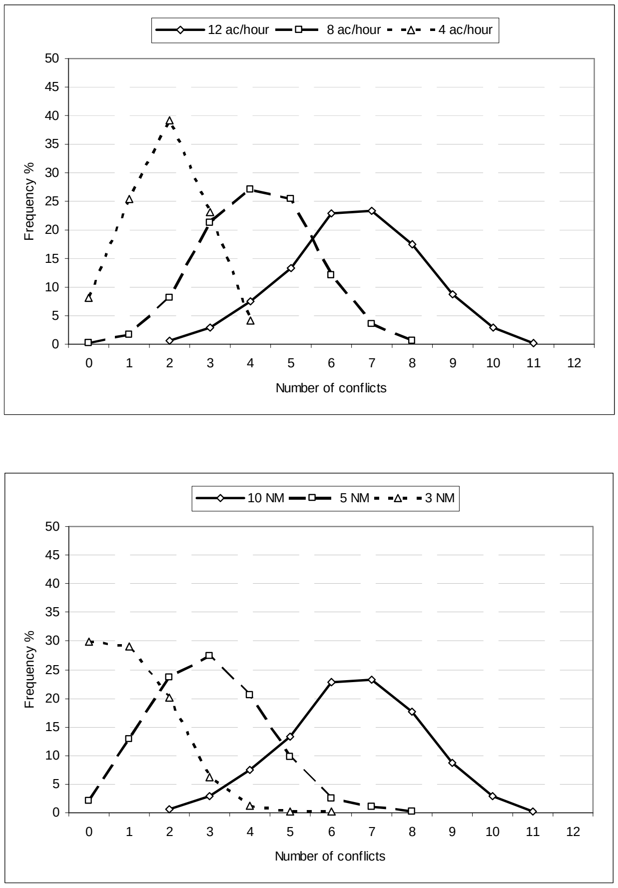


Figure 5 *- Frequency of number of conflicts*

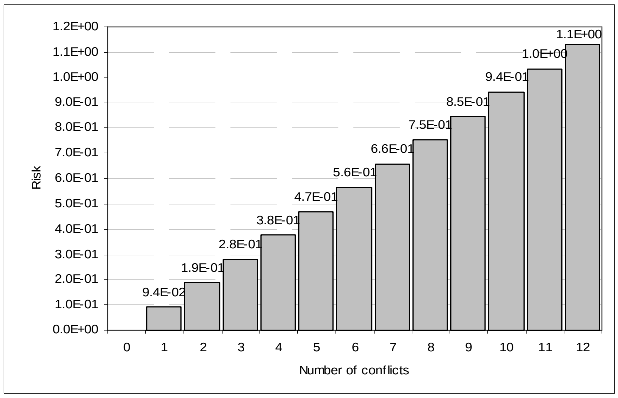
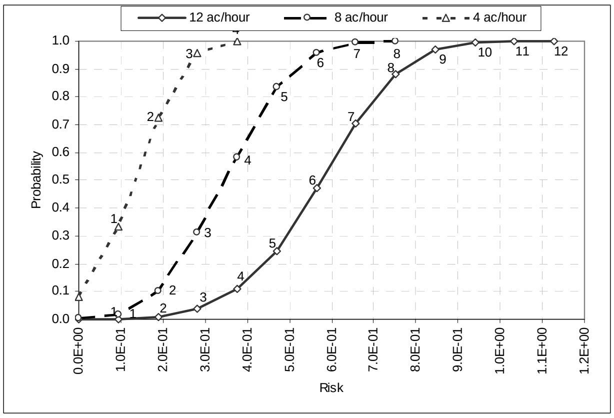


Figure 6 *- Hourly number of conflicts (risk) for the given sector dependent on traffic flow on AWY3 (12 ac/hour)*

Calculated risk values should be understood as relative, i.e. intended for comparison between numerous schedule scenarios, not for comparison with Target Level of Safety (TLS) given by international regulations [24, 25].

Further analysis was performed combining risk (Figure 6) with frequency of certain number of conflicts (Figure 5) a probability density functions and cumulative density of risk values are obtained (Figure 7). From the Figure 7 it can be seen that average risk values are higher in the case of larger traffic flows (Figure 7 up) and in case of larger separation applied (Figure 7 down). Numbers attached to the probability cumulative curves on Figure 7 are presenting estimated number of conflicts.



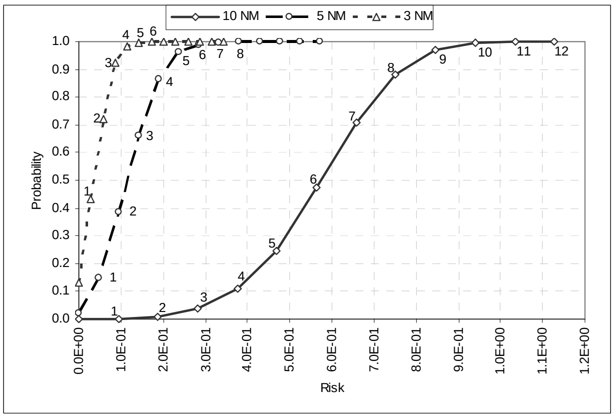


Figure 7 *- Cumulative probability of risk values*

Task load values are dependant on number of aircraft in the system as well as on the number of conflict situations. The task load figures given as percentage of time devoted to aircraft and conflict handling by the ATCo, are presented on Figure 8. It is evident that increasing traffic volume is causing increased ATCo task load. In case of no conflict situations, there is still a task load due to the fact that ATCo still has to handle traffic, i.e. to perform certain tasks such as e.g.: communication, transfer, coordination, etc. Also, logically, with increase of number of conflicts an ATCo task load is also raising.

Figures 6, 7 and 8 could serve air traffic managers to decide about performing the dynamic sectorization, i.e. airspace management. Namely, for some estimated number of conflicts, applied separation minima and known traffic flow, air traffic managers could easily read from those figures, an estimated risk value, a probability of risk value as well as an estimated ATCo task load.

Based on those information managers could decide to perform or not sectorization. Of course, it could be expected that different managers will behave differently. That means that some of them will accept the risk with certain probability and will not perform sectorization, while other one will not accept this risk and will perform sectorization.

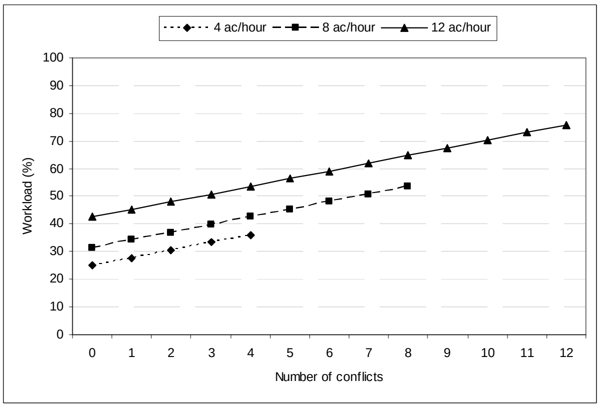


Figure 8 *- Task load for the given sector dependent and hourly number of conflicts (risk) and traffic flow on AWY3*

V. CONCLUSION

This paper presents a framework for airspace planning and design based on a conflict risk assessment developed for the purpose of preventing aircraft conflicts and collisions. The proposed framework is designed to be complementary with ICAO Collision Risk Models and is hierarchical by nature, containing three planning levels: strategic, tactical and operational.

In this paper an extension of previously developed framework was made. Risk assessment model for the purpose of air traffic manager's decision making about performing sectorization at certain moment are presented. The model are combining approaches presented in [13, 14] and are assuming that risk could be stochastic variable. Based on this fact decision makers could decide whether or not will take the risk with certain probability and task load and will or not perform dynamic sectorization at operational or current day level.

The proposed model is based on following assumptions: a) If there is no traffic, there is no risk; b) Risk values are not constant; c) Risk values are stochastic, d) Risk values positively correlate with traffic demand and negatively with airspace volume, and e) One aircraft at an airway can be simultaneously in conflict with only one aircraft from another airway.

Based on above mentioned assumptions, the developed model allows for the estimation of the number of conflicts, the conflict probability, and their distribution in sectors, i.e. intersections or along airways. Also, the model allows for the determination of the ATCo task load for the given airspace and traffic load. The model is intended for use both in en-route as well as in TMA airspace.

The illustration of the model application shows that in addition to airspace geometry (airways length and airways crossing angles) conflict risk in the given airspace also depends on traffic flows, average flow speeds, average aircraft inter-arrival times as well as applied separation minima. Also, it was proposed that risk values, when determined during planning process, should be considered as probabilistic rather than deterministic variable and that are sensitive to traffic demand

and separation minimum changes. Finally, it was shown that results of the model could be used by the air traffic managers in order to help them decide about necessary sectors grouping or collapsing (dynamic sectorization).

Further research will consider application of the developed model in real life and large scale cases as well as investigation of air traffic manager behaviour during decision making process.

Acknowledgements

This research was conducted with support from the project "A support to sustainable development of the Republic of Serbia's air transport system" (Project Number 36033) commissioned by the Ministry of Education and Science of the Republic of Serbia, under the 2011-2014 research programme in technological development.

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NON PUNITIVE REPORTING TO FIND WEAK POINTS IN THE SAFETY SYSTEM

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Abstract *– Safety is the highest quality feature of an airline. Therefore, an efficient and modern safety management is of great importance to recognize and to eliminate any vulnerability in the system. A very effective way of finding vulnerabilities is the "non punitive reporting" which has already been successfully used for many years in the cockpit and the cabin of the airlines. The advantages of the "non punitive reporting" must also be used in the maintenance and the ground operation to increase the safety of work routine. In particular through the use of the new generation aircraft with their high quota of fibre composite material this step appears inevitable since damage to this material is not necessarily visible. In 2012 Lufthansa implemented such a "non punitive reporting" system for the ground operation and maintenance to find undetected weak points in the safety system.*

Key words – Accident, Confidential safety report, Cost reduction, Error probability, Flight safety, Ground handling, Human factor, Lufthansa, Maintenance, Non punitive, Safety management, Standard operating procedure, Training concept, Working error.

INTRODUCTION

One of the in the last decades well-developed transportation means is the air transport. The importance of air transport in the area of freight is recognizable by the fact that less than 1 percent of the world trade weight is transported with aircraft but its' value is estimated at 40 percent. This means that aircraft as transportation means is used in particular for high-quality goods. Also the transportation of people in the aviation sector has now reached a number of four billion passengers annually. In the transport of valuable goods, and especially the transport of people, the most important quality characteristic for the customer is still the safety. The precise knowledge about the causes and the background that are affecting the safety of an airline therefore is an essential knowledge for economic survival because it reduces the accident rate, provides a positive public image and ensures economic success. For these reasons it is of great importance to detect and eliminate weaknesses in the safety system. A particularly promising tool for the detection of weak spots in the safety is the "non punitive reporting".

NON PUNITIVE REPORTING TO IMPROVE THE SAFETY AND TO REDUCE COSTS

Many years ago the airline industry decided that safety is more likely to be improved by allowing staff to admit their mistakes without fear of retribution than it would be by instilling the fear of punishment in them. This principal is so effective that for cockpit and cabin crews the system has now been adopted in most parts of the world under different names like: Confidential Safety Report (CSR), Cabin Quality Report (CQR), Flight Safety Report System (FLYSIS), Cockpit Flight Report (FR), and so on. The system doesn't mean that individuals can act negligently with impunity. It does mean that training and operating procedures can be improved in ways that might not seem immediately obvious, as well as allowing best practice to spread throughout the industry. Flight data monitoring will tell an airline what happened when there is an incident with an aircraft but it cannot always explain why. This information has to come from the person involved in the incident and that is why the "no blame" culture of the airline industry is so important. It is in the interest of the "share your experience" concept that almost all events are reported which could endanger flight safety. Another goal is that "non punitive reporting" leads to better training methods and improved standard operating procedures and these can enhance the economic performance of the airline besides the increase of safety.

The advantages of the "non punitive reporting" for safety-related areas in the flight operations of an airline are obvious. Therefore the consistent implementation of this system in areas such as maintenance will significantly contribute to improve the safety level. Thus, at the Flight Safety Foundation Congresses several presentations dealt with the interrelationship of safety and maintenance, already. According Airbus in about 50% of the cases of all U.S. Hull Losses from 1995 to 2000 errors of maintenance were involved in the accident or were at least "contributing factors". As a solution approach it was therefore demanded that the maintenance and overhaul companies have to introduce a maintenance safety management system analogous to the one at the flight operation with the following components:

- Non punitive reporting for all types of working errors
- Reactive and proactive analysis of errors and a prevention plan to avoid them
- Human factors training for the maintenance staff

Human Factors are relevant because time pressure and stress are the main attendant circumstances of error in maintenance. Professor Bupp, at the institute for ergonomics at the technical university of Munich has determined the following table for “Mean Time Between Failures” (MTBF) for people in various demanding tasks:

***Table 1** – Task–related error probability and MTBF*

Category	Task-related error probability	MTBF
Simple and frequently performed tasks at low stress	10^{-3}	~30 min
Complex, frequently performed tasks in a familiar situation with no time pressure	10^{-2}	~5 min
Complex tasks in unfamiliar situations with high stress and / or less time	10^{-1}	<30 sec

The statement of Prof. Bubb shows impressively the importance of stable concepts (known as SOPs) mainly for dealing with complex situations under time pressure. When proper procedures are not consistently implemented or not practiced on a sufficient scale, the number of defects per time increase to an unacceptable level. The table shows that as soon as actions are required that take place under stress and time pressure in an unusual situation, the error rate is extremely high. Therefore, it is normally not possible to think up something new or to be innovative in a time critical situation. This general statement is true for all people during execution of a task so well for the pilots and flight attendants as well for the ground staff of an airline. Unfortunately time pressure and stress during aircraft handling and maintenance actions are meanwhile part of a normal working environment with the corresponding accumulation of work errors. Here, the "non-punitive reporting" can lead to a significant improvement in safety levels. Information about incidents that otherwise would not have been reported will be made available to all. In the case of accumulation of the same work errors, weak points in the safety system can be detected in a much faster and more reliable way and countermeasures can be developed such as improved standard operating procedures (SOP’s) or improved training. Especially in the maintenance the principle of "share your experience" involves a large unused potential of learning from mistakes. With the increasing quota of fibre composite materials in the new generation aircraft like the Boeing B787 or the Airbus A350, the "non-punitive reporting" becomes more and more important since composite damage is not necessarily visible any more as well as the repairs of composites are time consuming and effortful and thus expensive.

To be sure to get all recognized damages reported an employee on the apron like a loader or technician must not be afraid of punishments or drawbacks because of a damage caused by him. Otherwise a lot of damage remains undetected with the corresponding disadvantages for the safety of people, equipment and operation.

INCIDENT AND ACCIDENT AVOIDANCE BY NON PUNITIVE REPORTING

Due to the increased workload and stress during normal work routine of the ground staff the detection of weak points in the safety system of the maintenance and ground handling gets more and more important to maintain a safe aircraft operation. By time optimized processes during the aircraft ground handling working errors and damages to the aircraft are becoming more frequent. Turn around times of less than 30 minutes for an aircraft like the Airbus A320 or the Boeing 737 are usual today and therefore aircraft damage by any kind of ground equipment at the airport will increase. During ground service between flights a great number of ground equipment must operate close to the aircraft. Up to 21 pieces of ground equipment are used to service a wide body aircraft during turn around and frequently the aircraft is rammed by ground service vehicles. This leads to damages such as simple paint scratches up to severe damage and any damage in aviation affecting the flight safety must be carefully investigated. Visible damage may look harmless but still carries the risk of severe internal damage with the loss of strength and therefore the loss of function. A good example of the seriousness of not reported and therefore not assessed damage was the depressurization incident on Alaska Airlines flight 536 on December 26, 2005. The MD-83 headed from Seattle to Burbank, California, experienced a loss of cabin pressure shortly after takeoff. Emergency oxygen masks were deployed in the cabin and the aircraft returned to Sea-Tac Airport to make an emergency landing. Fortunately no fatalities or serious injuries were reported. According to the NTSB, a baggage handler admitted to failing to immediately report bumping the plane at the gate with baggage handling equipment. The dent created by bumping the aircraft became a 1-foot (30 cm) gash when the aircraft reached its cruising altitude. The crucial question of why the baggage handler did not report the damage, however, has not been investigated by the investigating authority. It is very possible that the lack of a non punitive safety system for the ground staff as it is available for the cockpit and cabin staff of the airlines, already, have been the cause. This example also shows that the introduction of confidential report systems is essential to be sure that safety related incidents like damages inflicted by staff are reported and the real cause of working errors are found to develop appropriate avoidance strategies.

COST REDUCTION BY NON PUNITIVE REPORTING

As already mentioned besides the main goal to improve the safety, the economic advantage of having a system like the “non punitive reporting” to reduce the error and damage rate has a significant influence to reduce costs of an airline. The passenger boarding bridges, the cargo belt loader, the catering trucks and the fuelling trucks are the vehicles involved most frequently in damaging an aircraft on the ramp. Also any other vehicles or equipment can damage the aircraft due to improper use or lack of attention or just working errors. The annual cost of ramp damage to airport structures, aircraft and ground service equipment for the global airline industry are estimated at losses of USD 3 billion. The costs are equivalent to the value of 15 aircraft like the Boeing 747-400. Statistically any airline operating more than 100 aircraft has to have one of the aircraft in the maintenance hangar daily for ramp damage repairs. As a guideline the airlines calculate with USD 450 per minute as average aircraft delay cost due to ramp damage. The number of events that can damage aircraft or injure people on the ramp is innumerable. Trucks, tractors and other service vehicles can collide with the fuselages, the wings or other structural aircraft parts, inflicting serious structural damage which may go undetected. The direct cost of a ramp damage incident can be up to USD 75,000 and the indirect costs can be up to USD 230,000 for narrow body aircraft. For wide body aircraft the indirect cost can even reach USD 425,000.

Figure 1 *– Typical ground handling damage*

But also during maintenance inspection or repair working errors or even damages with impact on the safety can occur. According a NASA study the maintenance error as a factor in fatal aviation accidents in the meantime has climbed to the second place. The maintenance errors can be statistically summarized as follows:

- Deviations from procedures
- Lack of communication especially at shift changes
- Documentation errors
- Failure of the management in the organization and supervision

Here the use of an effective “non punitive reporting” system will help to identify the problems and to develop solutions to reduce the number of maintenance errors.

CONFIDENTIAL REPORTING SYSTEM FOR GROUND STAFF AT LUFTHANSA

In 2012 in order to better identify weak points in the maintenance and ground handling Lufthansa has introduced the "Confidential Safety Report Ground" (CSR-Ground) which is a non punitive reporting system. Here the ground handling and maintenance staff can write absolutely confidential reports on flight safety relevant occurrences, similar to the system for the cockpit and cabin crew. The confidence of the employees in the reporting system is critical to success therefore all reports sent to the Safety Department are strictly confidential. It is absolutely necessary that the employees do not have any fear to be punished for any working errors. Therefore nothing that allows conclusions about the individuals involved will be forwarded to other departments. The primary goal is to locate potential threats to the flight operations, not to search for employees who have made mistakes. This is achieved by the fact that the Lufthansa Safety Department has no disciplinary function, is independent of other departments and is connected directly to the board of directors. The involved employees decide for themselves whether they report attributed or anonymous and if the departments concerned may be informed by the Safety Department as well as only employees decide if they agree with an anonymous publication of the described incident. Exclusively issues concerned to the flight safety will be reported with the CSR-Ground, i.e. incidents that may cause danger to human and material. This can include defects or errors in existing methods, instructions or documentation, as well as own misbehaviour and the misbehaviour of other. Since the confidential reporting system is totally new for the ground staff, it will take some time until the employees have confidence in the system. In the cockpit and the cabin where the system is already established it provides important data to improve the flight safety. In 2011 nearly 250 confidential safety reports were reported at Lufthansa, about 150 from the pilots and about 100 from the flight attendants.

CONCLUSION

For the operators it is of great importance to get all information about damages as well as to get all information about working errors influencing the reliability and operational safety. As already mentioned this it is not to punish the employee but to analyse the incident and the work processes. With this damage information it would be possible to further develop strategies to avoid damages, to optimize the processes and to increase safety. To get the required information the maintenance companies as well as the insurance companies are using data acquisition computers to store the damage information but the information about the background must come from the involved employee. Today errors are easily revealed by the evaluation systems but the questions about the backgrounds are not sufficiently pursued through all levels. The information from the ground staff obtained by the newly introduced "Confidential Safety Report Ground” can now be used to better detect safety gaps in the aircraft operation and to improve the quality in the areas of selection, training, standards and checking and therefore to improve the flight safety and to reduce costs for the airline. Thoughtful and constantly monitored efficient training concepts with standard operating Procedures (SOP) for the ground staff analogous to those of the pilots and flight attendants can minimize the increasing probability of work errors and damages in the work environment of further time optimized ground processes.

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PRINCIPLES OF ECONOMIC OPTIMIZATION FOR IMPLEMENTATION OF SAFETY MANAGEMENT SYSTEM

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Abstract - *Implementation of Safety Management System (SMS) for air operators brings some economic costs. Under the principles of implementation the range of SMS need to be as wide as it is necessary in regard with a size of aviation organization and its operating characteristics. This paper deals with the principles of economic optimization in building SMS based on selection of appropriate tools to ensure the safety and established supporting technologies. It introduces basic economic models based on ratio indicators to evaluate the effectiveness. According to experience from other industries describes the experience with the introduction of tools to ensure the safety and use of related technologies. At the end, the article describes the benefits of these industries that have chosen to implement the SMS.*

Key Words – Safety Management System, Implementation, Safety, General Aviation, Economical Indicators.

I. INTRODUCTION

Today, air transport operators from member states of ICAO are required to introduce its own safety system based on SMS (Safety Management System). SMS is a package of tools which focuses on processes and operational procedures and enabling the improvement of safety. Continuously ongoing hazard identification, risk analysis and consequently their management allows different instruments to reduce these risks to our desired level.

The main reason why ICAO prescribes the implementation of SMS is need to further reduce the number of events which could affect safety. If SMS is used correctly, we can use it to detect the potential occurrence of hazardous incident even at an early stage and prevent its full realization.

Implementation of this system costs a certain amount of resources and in the current conditions of air transport it is difficult to quantify its return. Therefore, we use information from other fields of human activities, such as nuclear energy, where safety managers have more experience with the implementation of SMS to the normal operation, yet it is also a sector with very high emphasis on safety similar to air transport. In determining the total economic benefits of the implementation of SMS we must include in income the cost of a possible accident, which was prevented by the SMS. With this feature it will mean in most cases, that consideration about to implement or not to implement will rise to "black numbers" and the aircraft operator's attitude will support SMS implementation. We can easily find out the importance of SMS by consulting the organization's accounts and analysis of the cost of removal of accidents during the period (for example 5 years). Also, we consider the positive impact of SMS on a company's credibility among the general public as did the introduction of SMS in nuclear energy [3].

II. Why Implement the SMS by Air Operators

Safety in air transport was based on a reactive approach; it means that the safety precautions were made on the base of the results of accidents investigations. Thanks to gradual development in this area the safety in air transport came to a very high level and could also be quantified as the probability of one accident per 10 million flights. Further reducing the occurrence of hazardous events, respectively increasing the safety with this procedure is no longer possible and therefore a new proactive approach was introduced. This approach was named Safety Management System and its principle is to focus on processes and use this to detect potential startup of hazardous events before they occur. Recently, the vast majority of accidents were caused by human and organizational factors. But we can not say that the only cause of these accidents was the negligence or incompetence to perform the activity. Assumption to these failures was often placed far before there was a failure of the individual. We can reveal this if we look at all processes systematically, as a string of individual events. And a properly functioning Safety Management System will help us with it if we will actively use the right tools to increase the level of safety.

III. ECONOMICAL ASPECTS

Implementation of a new application in service brings naturally its own costs. When implementing the SMS we should take into consideration investment costs of implementing the system and then the annual costs of proper operation.

Investment costs involve the purchase of software, basic training of responsible staff and distribution of information material to all employees. Operating costs include the costs to ensure the smooth function of the system. Therefore contain the wage rate of employees, costs to restore software licenses, regular retraining of employees, etc. The highest cost item is the payment for the software where its price range is from the hundreds of thousands to millions CZK and then the wage costs per employee [6]. Due to this fact, it is necessary to develop a suitable model of SMS, which will provide full functionality using the selected tools and also will be affordable for any small operator. Despite this fact, some aircraft operators, especially smaller ones with not too large budget can be very restrained to the SMS introduction. But the implementation of SMS can be easier for small operators than in large company. Due to the small number of employees someone from existing staff may hold the position of safety manager. This one employee will be only widening the scope of his operations. Also introducing a model of open communication across the organization will be easy as well. Finally, it should be noted that the implementation of SMS and its keeping in the proper operation can bring a much lower cost than the cost of one accident or other event affecting the safety what could be prevented thanks to properly functioning SMS [6]. In the following sections we introduce the direct and indirect costs associated with the occurrence of accidents or other incidents affecting the safety of air traffic.

Direct costs

These costs are easily quantifiable and are directly linked, as the name suggests, with the occurrence of accidents. These costs may be included in the amount of removal of damaged aircraft from the accident site, repair the damaged aircraft or its write-off if the aircraft is beyond repair, etc.

Indirect costs

Indirect costs, as opposed to direct, are not so easily measurable and can even occur with delay after the accidents. These costs can sometimes be several times higher than direct costs and sometimes can have devastating effects on the entire organization.

Among the indirect costs can be included the loss of reputation. In the aviation this can mean, for example, an outflow of students from flight schools which will have more accidents, or organization can look less credible if they will not implement the SMS as opposed to a company that has implemented this system. Return of the lost position in the market means also big spending, both financial and time. Another cost may be increase in charges for insurance, because insurance companies follow the safety of the organization. If the organization has increases rate of events affecting the safety which cause harm to the property the insurance company will subsequently increase the rates of insurance.

Into indirect costs can be further calculated training as well. This cost is reflected, if the organization lost the plane to which was trained a significant number of service personnel. These staff will need to be retrained for a new type of aircraft and the cost of training can be very high.

Finally, the indirect costs include rent of any aircraft to substitute the airplane which is repaired and other similar costs.

The following table lists examples of direct and indirect costs incurred after the crash of a small twin-engine aircraft.

Table 1 *- Examples of direct and indirect costs of plane crash [5]*

Event	Direct Costs	Indirect costs
Taxiing aircraft hit the parked aircaft	4 000 USD for repair	19 000 USD for aircraft rent during the repair of damaged one
Take off with applied brakes	5 000 USD for repair	5 000 USD for rent of another aircraft
Landing with landing gear up	20 000 USD for repair	16 000 USD rent of another airplane and remove the crashed one from the crash site

The previous table shows that the costs of liquidation of even a minor accident are relatively high.

IV. Economic Indicators

Different economic indicators serve for the assessment of costs resulting from the implementation of new processes and technologies. The first, in this article we want to introduce, is ROI (Return of Investment Index) [2].

$$ROI = \frac{Payment - Investment}{Investment}$$

This indicator can serve as a benchmark for determining a decision if some safety improvement will be applied and in some ways can be used to evaluate the return on investment for implementation of SMS as mentioned above - the costs caused by loss of market position compared to the costs which are related with the implementation of SMS.

In the following example, we use this formula to show the calculation of return on investment to corrective action to the incident, which resulted in serious damage to the aircraft. In the context of monitoring the effects of organizational factors of safety the rules for the submission of information and their sharing have not been properly defined and the airline had to pay about 3 millions CZK due to this repetitive incident. On the implementation of the safety system the company had to incur direct costs around 1.2 million CZK. This cost includes fees for special software, initial training of the person responsible, etc. The annual operation of this system would cost about 1.7 million CZK [6]. The ROI of Implementation the corrective measure is calculated below:

$$ROI = \frac{3000000 - 2900000}{2900000} = 3{,}4\%$$

This is the return in the first year of operation. As time goes, the return on investment in the system increases and for larger damages, which are very costly, can be the needed financial amount to liquidate this incident much higher than many years of operation of SMS. Thus we can proceed to any investment in corrective action.

For the actual implementation of SMS there is possible to see the difference between the resources invested in this system and resources saved ie resources needed to liquidate the possible crash etc, as the interest rate. To determine the costs that would have to be spend on the liquidation of realized risk is possible to use various methods to estimate future development based on operators past periods or at the overall prognosis in the civil aviation sector.

Such proposals on the return on investment shall be submitted to the representatives of top management, which decides on the allocation of financial resources. Management usually requires the return on such expended funds about 10%. If the SMS will be introduced with an appropriate combination of tools for its applicability, with this amount of return can be calculated as the time horizon of 5 years.

We can use the following formula to determine the maximum amount of funds which we will decide to invest with the required rate of return where "*n*" is the number of years, "*R*" are saved funds distributed to the appropriate number of years and "*i*" is used for the desired return on investment:

$$P = \left(\left(R \frac{1}{1+i} + R \right) \frac{1}{1+i} + R \right) \frac{1}{1+i} + R =$$

$$= \frac{R}{1+i} + \frac{R}{(1+i)^2} + \ldots + \frac{R}{(1+i)^n} =$$

$$= R \left(1 - \frac{1}{(1+i)^n} \right) / i$$

Example of this formula follows. In previous years we have established that for repairs was spend approximately CZK 250 000 per year and there is a possibility to use the elimination process of mitigation of damages. The return is required in the next 4 years and the level of return is fixed at 10%. If we consider that the mitigation process will operate with 100% efficiency, we consider the avoided costs amount to 4 * 250 000 CZK. The calculation is therefore as follows:

$$P = R \left(1 - \frac{1}{(1+i)^n} \right) / i =$$

$$250000 * \left(1 - \frac{1}{(1+0{,}1)^4} \right) / 0{,}1 \cong 792000 K\check{c}$$

This amount can we present to top management as a requirement for the introduction of corrective measures. This calculation would be valid only if a corrective measure will be 100% effective. But in reality we have to consider that even after setting the corrective actions there will be influence of other circumstances that lead to the occurrence of these events. In this case, we consider only a certain percentage of the amount saved - eg 70%. The calculation is as follows:

$$P = R \left(1 - \frac{1}{(1+i)^n} \right) / i =$$

$$175000 * \left(1 - \frac{1}{(1+0{,}1)^4} \right) / 0{,}1 \cong 554000 K\check{c}$$

This is again the amount which may be required for the implementation of corrective measures with given parameters.

V. Experience with SMS Implementation in Other Industries

As mentioned in the introduction, there is not much experience with the implementation of SMS in Air Transport to be able to bring relevant conclusions. For experience with the implementation of SMS, we have to look to other disciplines such as nuclear energy or chemical industry.

Common experience with the implementation of SMS in these disciplines are mostly positive, such as safety in nuclear power plants rapidly grew after the implementation of SMS and adding emphasis on organizational factors of operation. A similar progression can be observed in the chemical industry [3].

Based on studies performed at the University of Parma (Italy) companies that have adopted a functioning SMS have fewer events affecting the safety and also the introduction of SMS reflected positively on the economic situation of the companies. The introduction of SMS in these companies mean more or less cost savings by reducing the allocated resources associated with the liquidation of events with safety implications [1].

VI. Conclusion

This article should introduce the basic outlook on the implementation of SMS in economic terms. It presented two possible calculations. First for return on investment and the second to determine the maximum amount of funds expended for the implementation of corrective measures. These are simply quantified data to saving money primarily arising from reducing the harm during operation. These damages do not come only from accident but occur also, in no small measure, with various incidents for example at the airport movement area, during taxiing, towing aircraft to / from the hangar, etc. Damage caused by these incidents can climb up to the amounts of ten millions CZK or above and the implementation of a well-functioning system can prevent the company from these incidents [6]. With the implementation of SMS are also related some indirect benefits such as improvement of market position through improved safety, good image building which in effect has a positive economic impact to company as a whole. In the General Aviation in the Czech conditions, this can be a form of competition eg between individual pilot schools, aero clubs, on how many pilots (or future pilots) will want to fly on their airports, fly with their aircrafts.

This all indicates that the introduction of SMS with well-chosen tools adapted to these conditions of general aviation can be a good investment for future growth and prosperity of General Aviation on the Czech and Slovak sky.

Acknowledgments

This article was created thanks to work on the project advertised in the student grant competition SGS12/165/OHK2/2T/16 named “Nástroje pro zlepšení provozní bezpečnosti a zvýšení ochrany před protiprávními činy malých mezinárodních letišť”.

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STABILIZED APPROACH TRENDS

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Abstract *– Professional pilots are under large pressure from many sides these days. There are requirements from operators on using continuous descend techniques to save fuel. Civil aviation authority has many demands on performance and large airports all over the world fight for lowering the noise level.*

Key words – stabilized approach, continuous descent, final approach segment, go around.

INTRODUCTION

According to latest trends pilots are pressed from their employer to save the aviation fuel. To do so they have to use the newest procedure in aviation and still study new techniques. One of the methods is continuous descent which is method for saving the fuel where pilots in coordination with air traffic control flying the best vertical profile during their descent.

Bad part of this action is increasing number in unstabilized approach which is opposite side of the coin.

CRITERIA FOR STABILIZED APPROACH

Let's take a look on criteria which are considered as a good crew performance technique concerning stabilized approach.

Maintaining a stable speed, descend rate, and vertical/ lateral flight path in landing configuration is commonly referred to as the stabilized approach concept. Any significant deviation from planned flight path, airspeed, or descent rate should be announced. The decision to execute a go-around is no indication of poor performance. And that is a result from a long term statistic.

RECOMMENDED ELEMENTS OF A STABILIZED APPROACH

The following recommendations are consistent with criteria developed by the Flight Safety Foundation.

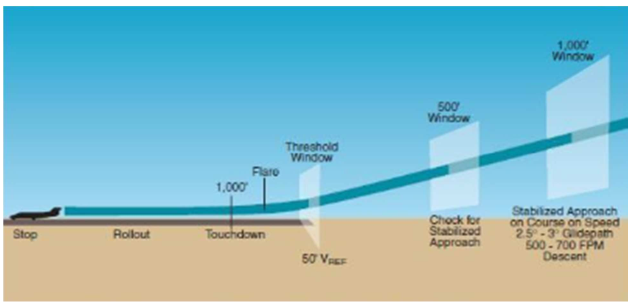

Figure 1 *– Stabilized approach*

All approaches should be stabilized by 1000 feet above ground level in instrument meteorological conditions any by 500 feet above ground level in visual meteorological conditions. An approach is considered stabilized when all of the following criteria are met:

a) the airplane is on the correct flight path,
b) only small changes in heading and pitch are required to maintain the correct flight path,
c) the airplane should be at approach speed, deviation of 10 knots to 5 knot are acceptable if the airspeed is trending towards approach speed,
d) the airplane is in the correct landing configuration,
e) sink rate is no greater than 1000 feet per minute, if an approach requires a sink rate greater than 1000 feet per minute, a special briefing should be conducted,
f) thrust setting is appropriate for the airplane configuration,
g) all briefings and checklists have been conducted.

SPECIAL TYPE OF APPROACHES

Special types of approaches are stabilized if they also fulfill the following:

a) instrument landing system approach should be flown within one dot of the glide slope and localizer,
b) during a circling approach, wings should be level on final when the airplane reaches 300 feet above ground level.

Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.

UNSTABILIZED APPROACH

An unstabilized approach is the biggest single cause of tail strike. Flight crews should stabilize all approach variables – on centerline, on approach path, on speed, and in the final landing configuration – by the time the airplane descends through 1000 feet above ground level. This is not always possible. Under normal conditions, if the airplane descends through 1000 feet above field elevation in instrument meteorological condition, or 500 feet above field level in visual meteorological condition, with these approach variables not stabilized, a go-around should be considered.

Flight recorder data show that flight crews who continue with an ustabilized condition below 500 feet seldom stabilize the approach. When the airplane arrives in the flare, it often has either excessive or insufficient airspeed. The result is a tendency toward large thrust and pitch corrections in the flare, often culminating in a vigorous pitch change at touchdown resulting in tail strike shortly thereafter. If the pitch is increased rapidly when touchdown occurs as ground spoilers deploy, the spoilers add additional nose up pitch force, reducing pitch authority, which increases the possibility of tail strike. Conversely, if the airplane is slow, increasing the pitch attitude in the flare does not effectively reduce the sink rate, and in some cases, may increase it.

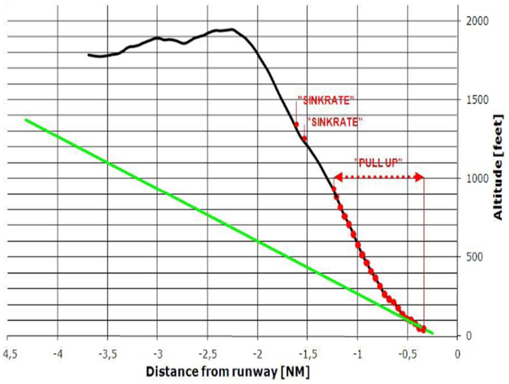

***Figure 2** – Unstabilized approach*

A firm touchdown on the main gear is often preferable to a soft touchdown with the nose rising rapidly. In this case, the momentary addition of thrust may aid in preventing the tail strike. In addition, unstabilized approaches can result in landing long or a runway over run.

The second most common cause of a landing tail strike is an extended flare, with a loss in airspeed that results in a rapid loss of altitude, (a dropped-in touchdown). This condition is often precipitated by a desire to achieve an extremely smooth/soft landing. A very smooth/soft touchdown is not essential, nor even desired, particularly if the runway is wet.

Trimming the stabilizer in the flare may contribute to a tail strike . The pilot flying may easily lose the feel of the elevator while the trim is running. Too much trim can raise the nose, even when this reaction is not desired. The pitch up can cause a balloon, followed either by dropping in or pitching over and landing in a three-point attitude. Flight crews should trim the airplane during the approach, but not in the flare.

Other condition is when airplane is placed in a sideslip attitude to compensate for the wind effects, this cross-control maneuver reduces lift, increases drag, and may increase the rate of descent. If the airplane then descends into a turbulent surface layer, particularly if the wind is shifting toward the tail, the stage is set for tail strike. The combined effects of high closure rate, shifting winds with the potential for a quartering tail wind, can result in a sudden drop in wind velocity commonly found below 100 feet.

***Figure 3** – Crosswind landing*

Combining this with turbulence can make the timing of the flare very difficult. The pilot flying can best handle the situation by using additional thrust, if needed, and by using an appropriate pitch change to keep the descent rate stable until initiation of the flare. Flight crew should clearly understand the criteria for initiating a go-around and plan to use this time-honored avoidance maneuver when needed.

CONCLUSION

An approach that becomes unstabilized below 1000 feet above ground level in instrument meteorological condition or 500 feet above ground level in visual meteorological condition requires an immediate go-around. The condition should be maintained throughout the rest of the approach for it to be considered a stabilized approach. If the above criteria cannot be established and maintained until approaching the flare, initiate of a go- around should be needed.

Above mentioned conclusion should be in all pilots mind and any pressure to go behind the limits should be refused from their side. Daily operations show that if pilots continue in unstabilized approach safety is deteriorated and as an example tail strike can occur.

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PERSPECTIVES OF ELECTRIC POWERED AIRPLANE

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Abstract *– This paper compares electric propulsion based on batteries and hydrogen fuel cells as major energy source in terms of efficiency, operational characteristics and feasibility for propulsion of the light sport aircraft. Both technologies are compared on an experimental electrically powered aircraft VUT 051 RAY, which is developed by Brno University of Technology with contribution of JIHLAVAN Airplanes Company. Environmental issues have rising importance in aviation. The paper presents activities done also in light airplanes and general aviation aircraft.*

Key words – electric, battery, fuel cell, VUT 051 RAY.

INTRODUCTION

In the growing need for more environmentally friendly and efficient travel, researchers, technologists, and inventors are pushing the limits of our current technology. Environmental taxes and laws restricting emissions and pollution are beginning to drive the design of our future transportation vehicles. Powering an aircraft with an electrical power system is not new. Several attempts were made in the early days of aviation to incorporate electrical power into aircraft. The first was fully controllable airship La France, whose propeller was driven by an electric motor. However, the main difficulty rested with the storage of electrical energy in bulky and heavy batteries. Even now, batteries are still too heavy to be used in general aviation aircraft as the main power source, except for aircraft with very short operating time like gliders. One aeronautical field in which electrical propulsion has become established over the past 20 years is for model aircraft flying. Progressive miniaturization of electrical and electronic components has shown the advantages of the technology. We must also point out a number of large aircraft designed and flown using solar panels as an energy source. References to the Pathfinder, Solar Challenger and phenomenal Solar Impulse demonstrate ability of new technology of propulsion. Also, the automotive industry has again become interested in electrical propulsion for environmental reasons. The search for clean power systems has led to the development of alternatives to the traditional lead–acid batteries. Developments in the automotive industry is also followed by aviation. Several companies have displayed prototype aircraft using fuel cells (FC) or batteries.

The article deals with the assessment of both types of energy sources and their mutual suitability for light **aircraft propulsion**. **Aim of this paper is not a detailed technical description of the aircraft propulsion system, but an objective evaluation of the advantages and problems of various energy sources for electric propulsion**.

Institute of Aerospace Engineering, Brno University of Technology (BUT) with contribution of JIHLAVAN Airplanes Company deal with this problematics by developing experimental aircraft VUT 051 RAY. The project aims on creation of functional base for design and development of electric powered airplane. VUT 051 airplane should verify integration of an electric drive system for small aircraft. The concept is based on existing VUT 001 Marabu experimental aircraft, which was also developed and built by BUT. The aircraft underwent comprehensive flight measurements, and its structure enables adaptation to electric propulsion. VUT 051 RAY is not the first aircraft with electric propulsion. Over the past few years, a number of aircraft with electric propulsion were presented. These aircraft were powered by batteries as well as from the fuel cells. The list of projects of electric aircraft with their basic performance characteristics is provided in Table 1. Goal of VUT 051 RAY project is to prepare suitable (and practical) technical solution for future light electric powered airplanes. Difference from similar projects is the creation of operationally usable electric aircraft concept.

Table 1 – A list of recent project of electric aircrafts

Airplane	No. of seat	Wingspan [m]	Wing area [m²]	Mtow [kg]	Engine take-of performance [kW]	Endurance [hr]	Battery capacity [kWh]	Battery Weight [kg]	First flight
Electraflyer C	1	8,38	7	283	13,5	1-1,5	5,6	31	06/2008
Yuneec e430	2	13,8	9	430	40	2	13,32	83,5	06/2009
Apis EA2	1	15	12,2	370	40	0,26	8	55	08/2010
Electra one	1	8,6	6,4	300	16	3	3	100	03/2011
LZ Design FES	1	15	9,06	453	25	1	3,6	27	03/2011
e-VIVA	2	17	14,2	472,5	40	1,3	8,2	75	04/2011
Electrolight 2	1	15	11,7	315	19	1,5	5,55	34	12/2011
DynAero Lafayette III	1(2)	6,63	8,15	450	40	Not declare	17kW PEM FC + Li-ion	50+78 FC system	05/2004
HK36 Super Dimona	1(2)	16,3	15,3	700	54	0,33	25kW PEM FC +25kW Li-ion	Not declare	04/2008
SkySpark fuel cell	1 (2)	7,5	10	450	65	2	60kW PEM FC + Li-ion	Not declare	05/2009
Antares DLR H2	1	20	12,6	750	42	4,2	25 kW PEM FC + Li-ion	Not declare	07/2009
ENFICA - FC	1(2)	9,9	11,85	550	40	0,18	20 kW PEM FC +20 kW Li-ion	Not declare	05/2010

Table 1 documents the development of electrically powered aircraft. Aircraft powered by batteries as Yuneec 430, Electraflyer C, ElectraOne are already commercially available on the market. Hydrogen powered airplanes represent only experimental prototypes. In terms of performance, both groups have comparable results. Battery technology has currently fast development and battery parameters are improving with each generation. However, the achieved performance does not allow longer flights. To achieve the same performance fifteen times better performance of batteries compared with gasoline is still needed. Energy density and power density of energy source represent an important parameter when selecting a suitable source of electric energy. The hydrogen fuel cell can increase the amount of stored energy by increasing the volume of the tank. This increase of a stored energy has a nonlinear dependence as a battery. Overview of technology options for each source is indicated in Figure 1.

The fuel cell itself has in contrast with battery very good parameters. In practice, however, these parameters are lower due to the installation of additional equipment necessary for operation of the FC. Also the operational characteristics of FC require an auxiliary battery for mobile applications.

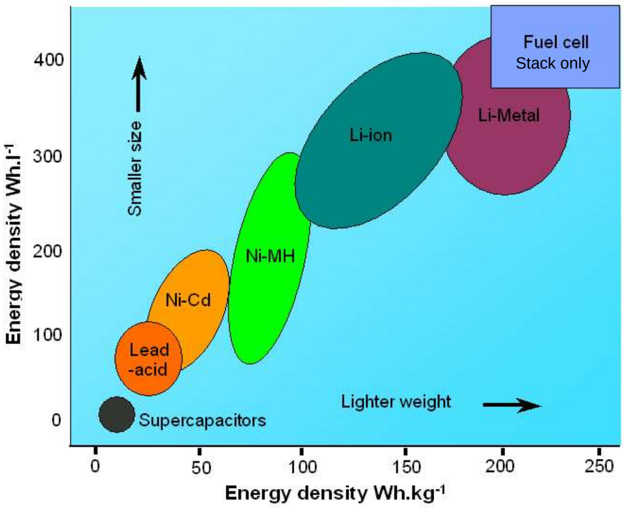

Figure 1 – Specific energy and specific volume of rechargeable batteries and fuel cells.

CONSIDERATED PROPULSION SYSTEM

In terms of practical storage of electric energy, batteries or hydrogen in combination with fuel cell can be used. Comparison of performance in terms of efficiency, safety and operational parameters of both, fuel cell and battery system was conducted on example of VUT 051 RAY airplane. Characteristics of this experimental airplane were considered to enable direct comparison of different means, how to store electric energy. **Primary intent of the paper is not to provide information on the VUT 051 RAY, but rather to compare practical aspects of utilization of fuel cells and batteries.** The airframe for VUT 051 RAY was taken and modified form the experimental airplane VUT 001 Marabu. The aircraft has combined structure composed of glass-fibre composite fuselage (with carbon-fibre reinforcement) and metal wing and horizontal tail unit. Original VUT 001 Marabu was powered by Rotax 912 combustion engine. The airplane has small front section and power unit in pusher-propeller arrangement to enable integration of new propulsion system close to the centre of gravity.

Technical parameters of the VUT 051 RAY aircraft

Geometry:	Wingspan	9,9 m
	Length	8,1 m
	Height	2,4 m
Weights:	Max. take-off	600 kg
	Empty	390 kg
	Payload (pilot)	80 – 110 kg
Performance:	Max. design speed	260 km/h
	Econom. speed	95 km/h

Figure 1 – VUT 001 Marabu airplane for conversion on VUT 051 RAY

Electric drive chain for electric powered airplane has generally following basic components:

- Electromotor
- Engine Controller with DC/AC convertor
- Energy source

Electromotor represents in drive chain coversion of electric energy to mechanical power. Electric powered planes typically use brushless type with permanet magnets due to compromise between higher efficiency and low mass. Most projects that need to replace original piston engine Rotax 912 use electromotor with a nominal power of 40kW (50kW for take-off). Take-off power of electromor is limited mainly by cooling. For example, the engine designed for VUT 051 RAY has weight 46 kg and the best efficiency 0.94 at 2000 rpm.

Engine Controller with DC/AC convertor represents necessary component for use of the brushless motor. The inverter is changing DC current to AC. Motor speed can be controlled through changes of the frequency. Designed efficiency of this component for VUT 051 is 0.97.

Energy source An electric energy source can be selected between the hydrogen and fuel cell and batteries. The current limit for each technology are described below.

HYDROGEN FUEL CELL

Hydrogen is a synthetic fuel. Pure hydrogen does not occur in nature, for its production is necessary some energy source. Hydrogen can be produced chemically from hydrocarbon compounds or from water by electrolysis. We consider hydrogen produced by electrolysis of water in the Sustainable Energy Economy. In this context, we assume a power-plant-to-hydrogen efficiency of 70% for water make-up and electrolysis near the source of electricity. Hydrogen gas has to be compressed or liquefied to make it transportable. The efficiency of compression is about 90%, that of liquefaction about 65%. Then hydrogen will be delivered to filling stations and transferred to vehicle tanks by road or pipeline [4].

In fuel cells, gaseous hydrogen is combined with oxygen to water by the direct and continuous conversion of an externally supplied fuel and oxidant. This process is the reversal of the electrolysis of liquid water. Today exist various types of fuel cells, which use different electrolyte type and working temperature. For mobile applications are suitable fuel cells linked as Proton Exchange Membrane (PEM). They produce the most power for a given weight or volume of the fuel cell, and in addition also have good cold starts capability. Polymer Electrolyte Membrane (PEM) Fuel cell has Operating Temperature 50-100°C, typically 80°C. Table summarizes advantages and disadvantages of this FC type.

Table 2 – Properties of PEM FC

Advantages:	Disadvantages:
- Solid electrolyte reduces corrosion & electrolyte management problems - Low temperature - Quick start-up	- Expensive platinum catalysts - Sensitive to fuel impurities - Low temperature waste heat - Storage, the membrane of FC must by wet everytime

Operation, control, and monitoring of the fuel cell stack require several essential subsystems that as a whole form the balance of the plant. Thus, in addition to the stack itself, the complete fuel cell system, as shown in Figure 3, contains the following:

- Air supply. Oxidant must be supplied to the cathode at a specific pressure and flow rate. Air compressors, blowers, and filters are used for this.

- Water management. The inlet reactant gasses must be humidified, and the reaction product is water. Management of water must also consider relative amounts of the two phases. In aviation application is necessary to prevent icing of water at high altitude.

- Thermal management. Stack temperature must be monitored and controlled trough an active or passive stack cooling systems as well as a separate heat exchanger in the case of an active system.

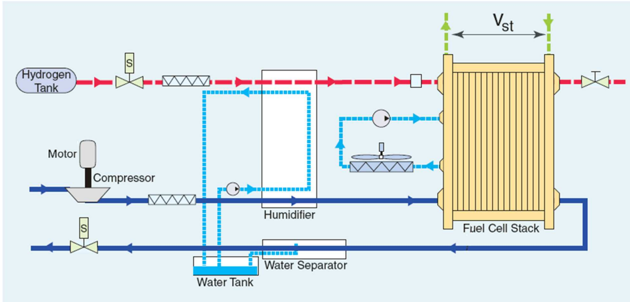

Figure 2 – Scheme of fuel cell PEM type

Hydrogen fuel cells have a high internal resistance and behave as a soft voltage source. This is different from batteries that have a low internal resistance. Batteries have better capatabilities to manage changes in loads than FC. Solutions with only FC (without batteries) have to be designed for maximum power. It requires large and heavy fuel cell stack with auxiliary unit. For example compact fuel cell system Heliocentris HyPM HD16 with 16kW power has weight 115kg. Mobile applications usually combine FC with battery as shown in table 1. For use of FC in airplanes, it is necessary to develop special light weight components of fuel cell system.

Hydrogen can be stored in the cryogenic tank or in the high pressure tank. Liquid hydrogen is not suitable for long-term storage and has not good energetic bilance, but energetic density is higher. High-pressure tanks are more suitable for mobile applications. Very high pressure is required due to low density of the hydrogen . Today’s technological limit for pressure tanks is believed to be approx. 1000 bar. Typical pressure is 200 -350 bar. For mobile applications, composite pressure tanks with pressure up to 700 bar are developed. Storage in advanced materials (within the structure or on the surface of certain materials) represent a third way. Hydrogen storage in materials offers great potential, but additional research is required to better understand the mechanism of hydrogen storage in materials under practical operating conditions.

EFFICIENCY OF FUEL CELL SYSTEM

Since fuel cells use materials that are typically burned to release their energy, the fuel cell efficiency is described as the ratio of the electric energy produced to the heat that is produced by burning the fuel. From the basic definition of efficiency:

$$\eta_{\max} = \frac{W}{Q_{in}}$$

Where W represents the “free” energy or the energy available to do useful work. For Fuel cell we can express this energy by Gibbs Free Energy or ΔG and can be also associated with the chemical energy released during the reaction occurring in the fuel cell. Q_{in} is heat energy obtained by burning fuel. This energy can be express as the calorific value. In the efficiency equation, „enthalpy formation“ h_f term is often used, and its value depends on the state of the *H2O* product. Since the two values can often be computed depending on the state of the reactant, the larger of the two values (“higher heating value”) is used (HHV). The maximum efficiency occurs under open circuit conditions (reversible) when the highest cell voltage is obtained therefore we use ΔG_o:

$$\eta_{\max} = \frac{\Delta G_0}{HHV}$$

For the hydrogen fuel cell reactions ΔG_o is 237 kJ/mol and ΔH_o is 286 kJ/mol, the maximum theoretical efficiency of the fuel cell would be 83%. According to the U.S. Department of Energy, fuel cells are generally between 40–60% energy efficient [7]. Energy efficiency depends on load of FC and on energy consumption of FC auxiliary devices. For example, at 300 kPa the compressor may consume between 15 to 30% of the stack power output, while at lower pressures it may consume as low as 2%. The cooling pump requires another 2% of the stack power output. Figure 3 illustrates distribution efficiency in energy transfer chain for Fuel Cell powered airplane.

Despite intense development, catalysts used in PEM fuel cells haven't reached the levels of performance, lifetime, or cost to be commercially viable. The main problem are suitable catalysts. The most effective catalysts in hydrogen fuel cells use platinum for both the anode and cathode.

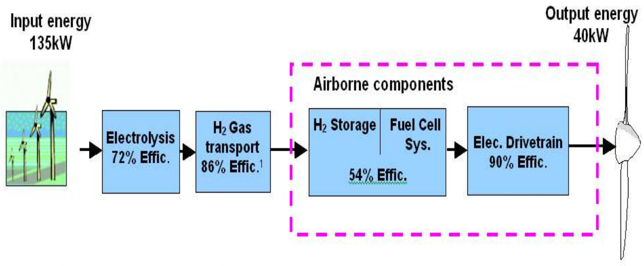

Figure 3 – Well-to-Wheel Energy Pathway for Fuel Cell powered airplane

BATTERIES

Batteries operate by converting chemical energy into electrical energy through electrochemical discharge reactions. Batteries are composed of one or more cells, each containing a positive electrode, negative electrode, separator, and electrolyte. Cells can be divided into two major classes: primary and secondary. Primary cells are not rechargeable and must be replaced once the reactants are depleted. Secondary cells are rechargeable and require a DC charging source to restore reactants to their fully charged state. Primary batteries have the highest energy density. Although the secondary (rechargeable) batteries have improved, a regular household alkaline provides 50% more power than lithium-ion, one of the highest energy-dense secondary batteries.

Advantage of secondary batteries is low internal resistance. This allows high current on demand, an attribute that is essential for traction. The lithiumbased batteries have three times higher energy density compared to other systems like nickel metal-hydride and nickel-cadmium. Therefore, Lithium-ion (Li-ion) batteries are attractive for electric aircraft applications because of their relatively high energy densities per unit mass, volume, and cost. Advantages and limitations of two main types of lithium based batteries are in table 3.

Table 3 – Properties of Li-based batteries

Advantages and Limitations of Li-ion Batteries	
Advantages	High energy density — potential for yet higher capacities. Relatively low self-discharge — self-discharge is less than half that of NiCd and NiMH. Low Maintenance — no periodic discharge is needed; no memory.
Limitations	Requires protection circuit — protection circuit limits voltage and current. Battery is safe if not provoked. Subject to aging, even if not in use — storing the battery in a cool place and at 40 percent state-of-charge reduces the aging effect. Moderate discharge current. Subject to transportation regulations — shipment of larger quantities of Li-ion batteries may be subject to regulatory control. This restriction does not apply to personal carry-on batteries. Expensive to manufacture — about 40 percent higher in cost than NiCd. Better manufacturing techniques and replacement of rare metals with lower cost alternatives will likely reduce the price. Not fully mature — changes in metal and chemical combinations affect battery test results, especially with some quick test methods.

Advantages and Limitations of Li-ion Polymer Batteries	
Advantages	Very low profile — batteries that resemble the profile of a credit card are feasible. Flexible form factor — manufacturers are not bound by standard cell formats. With high volume, any reasonable size can be produced economically. Light weight – gelled rather than liquid electrolytes enable simplified packaging, in some cases eliminating the metal shell. Improved safety — more resistant to overcharge; less chance for electrolyte leakage.
Limitations	Lower energy density and decreased cycle count compared to Li-ion — potential for improvements exist. Expensive to manufacture — once mass-produced, the Li-ion polymer has the potential for lower cost. Reduced control circuit offsets higher manufacturing costs.

Li-pol secondary batteries are currently the best energy storage devices for portable consumer electronics, in comparison with other conventional batteries, because of the high energy density as shown in Fig. 3. They were first developed and commercialized by Sony in 1990. Since market introduction, there was 3-times the increase in capacity (until today). This remarkable increase in capacity was realized through engineering improvements in the manufacturing processes and the introduction of new separator, cathode and anode materials and still exists potential for further improvement.

Major problem of Lithium-ion (Li-ion) batteries is charging process sensitivity. Exothermic chemical reaction can start in the cell when its terminal voltage is overcome. This is very dangerous due to the risk of fire. Lithium based batteries are classified as dangerous stock for air transport. Therefore batteries need special protection circuit (battery management system) for balancing voltage on each battery cell.

EFFICIENCY OF BATTERY SYSTEM

Battery efficiency is described as the ratio of the output energy produced to the input energy delivered by battery charger. Battery efficiency depends on chemical reaction in electrolyte. Short charging time causes low battery efficiency compared to longtime charging. Also time or cycle age of battery has influence on efficiency. Therefore we can assume average battery efficiency thought battery life 94%. The figure 5 shows components of battery drive chain and their efficiencies. Except airborne component of the system are illustrated necessary ground components for energy storage into batteries.

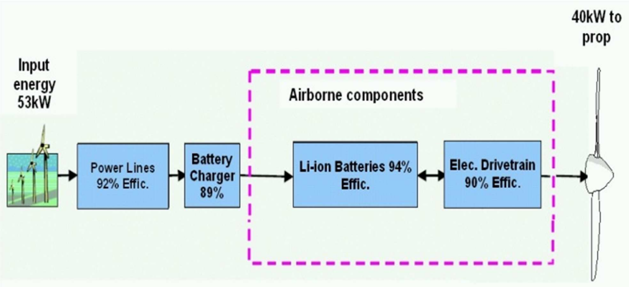

Figure 4 –Well-to-Wheel Energy Pathway for battery powered airplane

COMPARISON OF PROPULSION SYSTEMS

Table 4 shows the comparison of different propulsion systems applied to the identical airframe. The sizing of the propulsion system is limited by capacity and volume of the airframe. As fuel cell example, Ballard Velocity - 9SSL x19kW stack is considered. Prices of components are derived from prices of similar components on the market. Other information was obtained from [1] and [2]. Propeller efficiency is not included in the calculation.

The table shows that both drive systems offer comparable performance. Drive based on the fuel cell is in comparison lighter a smaler than battery another advantage of FC system is quick refueling for the next flight. Also increaing of flight time can be easily made throught increasing tanks volume. This advantages is offset by much more complicated system of FC, large pressure tank and high price. Conventional fuel cell systems also need a large number of axinuary units and a complex control system that have to work reliably both on land and at high altitudes. Furthermore would be necessary build hydrogen filling stations on airports to. The use of battery power for light aircraft has its advantages. Eliminates the installation of heavy pressure or cryogenic hydrogen tank and engine management system is much simpler. Also price for realization si much lower than in case of FC.

Table 4 also shown capatibility of electric propulsion in direct comparison with combustion engine. Flight time in case Marabu airplane is more fifteen time better than electrified version. For electric airplane are not suitable adapt conventional airframe of piston powered airplane. Electric airplanes require high efficiency airframe due to limited energy storage on board. The ideal aircraft would have sailplane-like efficiency while achieving good operating capabilities that most current sailplanes do not possess. Those operating capabilities are compactness for ground handling, good gust handling characteristics through high wing loading, high cruise speed, and short takeoff distance.

After evaluation of all these factors is better drive based on the batteries, which appears to be more advantageous for light sport aircraft. Figure 5 shows that the efficiency in such a drive is very high. This type of drive also does not require special arrangements currently infrastruktury most airports.

Table 4 – comparison of propulsion

	VUT 001 Marabu	VUT 051 RAY with Battery	VUT 051 RAY with Fuel cell
Engine take-of performance	59,6 kW	52,4 kW	52,4 kW
Continuous engine performance	58 kW	40 kW	40 kW
Storage energy on board	1689 kWh (energetic density of gasoline is 11kWh/kg, capacity of fuel tank 192 l)	33 kWh	62,6 kWh (capacity of fuel tank 1,88kg H_2 @ 350 bar)
Component weight	Engine with accessories 71,3kg Hardware 6 kg Fuel tank 5kg ***Overall 82,3kg***	Engine 48 kg Battery 150 kg Engine control and converter 8 kg Other hardware 4 kg ***Overall 210 kg***	Engine 48 kg Fuel cell stack 34 kg Fuel tank 46 kg Battery 10 kg Engine control and converter 8 kg Other hardware hardware 29kg ***Overall 175 kg***
Component Volume	Engine volume 114liter Engine accessories 25 liter Fuel tank volume 192 liter ***Overall 331 liter***	Engine 57 liter Battery 230 liter Convector 12 liter Hardware 5 liter ***Overall 304 liter***	Engine 57 liter Fuel cell stack 28,5 liter Fuel tank 78 liter Battery 80 liter Convector 12 liter Hardware 32 liter ***Overall 288 liter***
Theoretical efficiency of engine without propeller	0,306 at full power 0,366 at cont. power	Engine 0,94 Convector 0,96 Energy Distribution 0,99 ***Overall 0,902***	Engine 0,94 Convector 0,96 Energy Distribution 0,99 Fuel cell system (best case) 0,54 ***Overall =0,487***
Converted energy for propulsion	618,1 kWh	29,76 kWh	30,4 kWh
Endurance	10,66 hr	0,71 hr	0,72 hr
Costs	Engine Rotax 912: 14600 USD Engine accessories 1500 USD Fuel tank 100 USD ***Overall 16 200 USD***	Engine + controller 4000 USD Battery: 3070 cell Panasonic NCR18650A 25 000 USD Battery management system 5000 USD ***Overall 34 000 USD***	Engine + controller 4000 USD Fuel cell system: aprox. 100000 USD Storage tank: aprox. 2200 USD ***Overall 106 200 USD***

The disadvantage is a long charging time before the next flight. This can be compensate by exchange of the battery blocks. In future, in new generation of batteries can be recharge batteries in few minutes. It is also considered a further reduction in prices of batteries and incerasing of bateries capacity.

This basic comparison of technical parameters is further complemented by the of safety and operational aspect.

SAFETY ASPECT

Electromotor is optically more reliable device than combustion engine. There is no high temperature, moving parts, complicated fuel lubrication and cooling systems. Electromotor has only moving rotor with smooth rotation. Engine controller doesn't contain any moving parts and critical parts can be redundant for higher safety.

1.Another situation is for energy storage system. Combustion engine has fuel tanks with liquid gasoline. In case of emergency landing, fuel system can be damaged and fuel can create dangerous environment (vapour, pool). However, gasoline fuel system with many safety measures (at least compared to batteries or fuel cells system) was developed during over one hundred years of aviation history.

Most electric airplanes were experimental projects, where special safety aspect for every day use of the aircraft were not considered. This part therefore describes potential risks for each energy storage system.

In case of energy storage using batteries, risk exists that battery cell will fail due to overloading. Lithium based cell can explode and also toxic gases can originate. This potential hazardous situation can be solved by battery management system. System checks voltage and temperature of every cell in the battery and in case of increasing temperature or voltage, it disconnects the cell from the system. Another risk represents high voltage of the battery. For human is dangerous voltage from 120V DC. DC voltage is for human dangerous due to degradation of blood. Discharge battery has also some terminal voltage. In emergency case, there is no way, how to quickly remove energy from the battery.

Hydrogen is highly flammable gas. If fuel cell system contains leakage, hydrogen can create dangerous explosive mixture with air inside the airframe. However, if we compare hydrogen and gasoline, the hydrogen is more safe fuel. Hydrogen doesn't create flammable fuel pool. Being lighter than air, hydrogen also tends to diffuse upwards rather than accumulate near the ground. Experiment with car fuel tank confirmed the greater safety of hydrogen fuel when we consider pressure tank. Fuel cell system after disconnection hasn't any voltage and doesn't contain dangerous or toxic material (and hydrogen can be safely and quickly removed from the tank).

From this comparison, hydrogen seems to be safest energy storage system.

OPERATIONAL ASPECTS

Operation of electrically powered aircraft will be simple. Because there is no fuel, there would be no need to check drains, vents, tank selector valves, fuel pumps and fuel lines, or filters. Warm ups, engine runups, and proper mixture and manifold pressure settings would be unnecessary. Although electric motors have bearings that may require occasional lubrication, there would be no need to check or change oil. There will also be no worries about plug fouling and resultant loss of power and concerns about carburetor icing or engine damage from descending too quickly at low power settings. With the reduction in noise, passengers would find it easier to hear and converse.

Unlike the electric motorcombustion engine has another advantage form operational perspective. Refueling is very rapid, with minimal fuel loses, fuel can be easily transported. User can choose optional volume of fuel quantity for intend flight time. Difference between maximum take-off weight and weight with fuel can be used for increasing of payload. Amount of energy on-board is easy to measure. Average price of AVGAS 100LL is 1,4 UDS per liter in USA [8].

Battery based electric drive system has constant weight of the payload. For intended flight time, the user cannot choose appropriate amount of energy - battery weight. Battery has self-discharge effect, therefore the user must charge the battery before the flight. Long charging time also limits usage of the airplane for training flights. Charging can be done rapidly, however battery life will then be reduced. Amount of energy on-board is complicated to measure, there is no simple method how to estimate amount of energy on-board. It should be continuous measurement of the battery capacity and energy released. This requires an electronic system. Over the course of the typical 20- to 35-years life of an aircraft, battery replacement would be required at least every 6-8 years, as the life of most rechargeable batteries is limited to 1000 (or fewer) recharge cycles. However, this replacement battery cost should still be less than the cost of maintenance and overhaul of an engine, which is required with gasoline-powered aircraft about every 1500-2000 hours of use. Average price of the electric energy for industry in Europe is 0,1 EUR (0,122USD) per kWh according to *Europe's energy portal*. The cost of electricity required for recharging the batteries is estimated to be less than one-third of the equivalent cost of gasoline, particularly if charging occurs during off-peak hours.

Hydrogen has similar properties as gasoline. Amount of energy on-board is easy to measure by manometer on pressure tank. Weight of the hydrogen is minimal in comparison with another system components, it is about 4% weight of steel pressure tank or 7% for composite pressure tank. Hydrogen has similar operational properties as battery based system. There are, however, numerous issues to resolve, even for basic hydrogen fuel cell use. Source and storage of hydrogen, as well as the cost and complexity of the balance of plant equipment required to properly operate and cool fuel cells are but a few. Furthermore, today´s PEM FC require special storage procedure and temperature of the membrane must not be less than zero degrees Celsius. But over time the cost and complexity of fuel cells will be reduced, making them more attractive for light aircraft. Time for refueling is short and comparable with gasoline fuel. The cost of hydrogen production using electrolyse (considering only electricity costs when renewable electricity is assumed) is higher than in case of natural gas reforming technology. Electrolyzer energy requirements is 54-67 kWh to produce one kilogram of hydrogen, therefore price of hydrogen is 6,6 – 8,1 USD per kilogram. No capital, operating or maintenance costs are included. The fuel cost for the mass production and compressed hydrogen delivery is estimated 4.22 and 4.33 USD/kg for the 350-bar and 700-bar cases, respectively. It correspondent to 0,22 USD/kWh input energy [6]

Lifetime of FC system is limited mainly by pollutants in the air or in H2, which cause degradation of electrodes. Today's lifetime of PEM FC is around 2000h.

From operational aspect point of view is compressed hydrogen better energy storage system than batteries due to possibility to simply increase amount of energy on-board, but operational costs are higher. The fuel cell drive system requires production of between 2.4 and 2.6 times more input energy than a comparable battery drive system. Over overall energy distribution chain the final price is three times higher than for battery system.

Conclusion

Batteries and fuel cells provide in the current state of technology very similar results. The main advantage of FC, compared to batteries, is a non-linearity of weight gain when increasing amounts of energy needs to be stored. This advantage is compensated by weaker operating performance and lower efficiency. Today's batteries have the potential for further development and new types of batteries like Zn-Air are having the potential to completely replace FC. In addition, it is not necessary to build expensive hydrogen infrastructure in small airports. For project VUT 051 RAY was therefore selected battery-electric drive as more perspective. Similar approach can be seen for commercial electric airplanes like Electra One or Yuneec e430. Despite the current disadvantage in terms of low energy density, batteries provide electric power with simple adjustment of parameters in accordance with electric motor requirements (and without the need of complex mechanical solution as in the case of conventional internal combustion engines). Propulsion based on batteries has also better efficiency. In addition, battery power offers higher reliability and minimizes maintenance cost in comparison to FC.

To replace combustion engines by electric motors powered by batteries with similar weight and performance of overall propulsion system, tenfold higher energy density of batteries would be required, therefore the internal combustion engine will still be dominant powerplant for sport aircraft in near future. With the spread of hybrid technology for road vehicles in the future, we can expect further improvements in energy density of batteries or new battery types. RC models had undergone a similar development, where during 10 years electric power gained ascendancy over internal combustion engines.

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IMPACT OF AIRCRAFT ACCIDENT ON THE HUMAN BODY

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Abstract – *This paper is concerned with basic aspects related to the mechanics of injury of people involved in aircraft accidents. The aim is to summarize and analyse conditions influencing accident related injuries focusing on the effects of deceleration and acceleration (g-forces). The paper also discusses certain potential improvements to the construction of civil aircrafts from the perspective of limitation of injuries during accidents.*

Key words – aircraft accident; injury; g-forces.

INTRODUCTION

In case of an aircraft accident the human body is usually subject to extreme external conditions. Nevertheless, contrary to the general public opinion, the average number of passengers surviving aircraft accidents is relatively high (according to the statistics the mortality rate is approx. 30% of all passengers involved in aircraft accidents [1]).

The most common cause of aircraft accidents and related injuries is a collision with an external object on the ground or a collision with a water or ground surface. Injuries are also caused during the flight, e.g., due to meteorological conditions, fall of objects from the overhead compartments or due to fire.

DEFINITION OF AIRCRAFT ACCIDENT

According to Annex 13 of the Convention on International Civil Aviation (Chicago Convention; published under no. 147/1947 Coll., as amended) an aircraft accident is defined as (1) an occurrence associated with the operation of an aircraft (2) which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, (3) in which a person is fatally or seriously injured, the aircraft sustains damage or structural failure or the aircraft is missing or is completely inaccessible. [2]

The Czech Act no. 49/1997 Coll., on Civil Aviation, as amended, defines an aircraft accident in a similar manner and in fact contains the internationally recognized and well established definition from the Convention on International Civil Aviation.

CONDITIONS INFLUENCING HUMAN BODIES DURING AIRCRAFT ACCIDENTS

The negative conditions affecting persons involved in aircraft accidents usually include the following:

(A) Overload of a human organism caused by rapid deceleration and/or acceleration (impact of g-forces);

(B) Direct danger to the organism due to fire (temperature), loose parts of the aircraft interior or equipment;

(C) Insufficient oxygenation of the human tissues caused by decompression, fire exhausts or drowning;

(D) Psychophysiological overload of the organism due to shock, trauma etc.

EFFECTS OF G-FORCES ON HUMAN ORGANISM

Under normal conditions the human body is exposed to gravitation and centrifugal forces – gravitational acceleration. Gravitational acceleration (local gravitational field) is defined through unit g (which amounts to approx. 9.81 m/s2 at a geodetic latitude 49°) and corresponds to +1G. The g-forces (acceleration forces) and their effects on human body were first described in more detail in the beginning of the nineteenth century in connection with consciousness problems of the pilots during their acrobatic performances. Further research into g-forces and their impact on human body was initiated by the rapid development of the aviation during the Second World War [3].

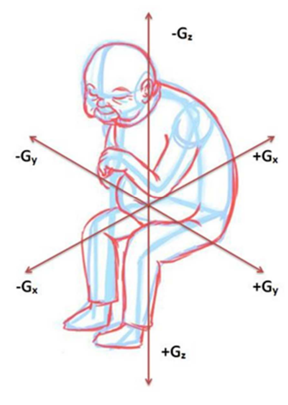

Figure 1 *G-forces affecting the human body in various axes [4]*

There are two basic types of g-forces, positive g-force (+G) and negative g-force (-G). It is, however, also necessary to distinguish the axis in which the g-force affects the human body. In this respect the standard aeromedical theory describes forward/rearward g-force (Gx), lateral left/right g-force (Gy) and vertical (head first/foot first) g-force (Gz).

Various types of g-forces can be best illustrated by their impact on the human eyeball as described in the following table:

	+G	**-G**
Axis *x*	IN	OUT
Axis *y*	LEFT	RIGHT
Axis *z*	DOWN	UP

***Table 1** G-forces and their impact on the human eyeball*

The ability of a human body to cope with g-forces depends on many factors. One of the most important is time, i.e., the length of time when the g-forces are applied. Generally, a tolerance of a human body to long-term g-forces (approx. 1 to 10 seconds; usually experienced by acrobatic and military pilots) in various axes is completely opposite to the tolerance for short-term g-forces (approx. 0.5 seconds; usually experienced during accidents).

Long-term g-forces

Acrobatic and military pilots were tested for the influence of long-term low-intensity application of g-forces. Tested aspects included reaction times, psychological and physical reactions and interconnection between parameters of g-force and loss of consciousness. Pilots proved to be most tolerant to lateral (left/right) g-forces (Gy) while the resistance to vertical (Gz) forces, in particular the negative vertical g-force, was the lowest. Under the conditions of only -2Gz the pilots experienced a strong unpleasant headache which developed to unbearable pain, acceleration of -3G Gz caused bleeding from capillaries in the eye (red vision). The g forces of -4 až -5 Gz induced for more than 6 seconds caused a complete loss of consciousness [5].

Short-term g-forces

Aircraft accidents usually induce short-term g-forces in various axes. For example, the analysis of fatal aircraft accidents shows, with respect to the pilots of the crashed aircrafts, that the impact of g-forces on a pilot's body was the most common cause of death (approx. 86% of deaths were caused by g-forces). The analysis is based on an autopsy of 559 pilots who were involved in fatal accidents of civil aircrafts [6].

Generally, short-term g-forces are best tolerated when induced in the x axis (forward/rearward ±Gx-force) while the resistance to lateral (left/right) g-forces (Gy) is the lowest (which is contrary to the tolerance of human body in case of long-term g-forces). The following table based on the evidence obtained from laboratory studies and analysis of investigations of aircraft accidents shows certain typical injuries caused during aircraft accidents and g forces which usually cause these types of injuries:

Type of injury	**G-force**
Pulmonary contusion	25G
Nose – fracture	30G
Vertebral body – compression	20 – 30G
Fracture dislocation of C1 on C2	20 – 40G
Mandible – fracture	40G
Maxilla – fracture	50G
Aorta - intimal tear	50G
Aorta – transection	80 – 100G
Pelvis – fracture	100 – 200G
Vertebral body – transection	200 – 300G
Total body fragmentation	> 350G

***Table 2** Typical injuries caused by short-term g-forces [7][8]*

Forward / rearward g-forces (Gx)

The evidence from the investigation of aircraft accidents indicates that Gx-forces (forward/rearward) occur in majority of accidents. The analysis of the evidence also provides rather precise information regarding the amount of Gx forces which are tolerable by the human body without any serious consequences. Persons seated in the flight direction (who are usually imposed to –Gx in case of an accident) are tolerable to short-term g-forces up to approx. -45G. Persons seated against the flight direction (i.e., imposed to positive Gx) should be able to cope with forces generally up to +85G. This relatively big difference is caused mainly by the fact that the heads of people seated against the flight direction are usually firmly secured by the headrests against the direction of the inertial forces. Rearward seating against the flight direction also limits a risk of spinal injury, in particular fractures of the upper cervical vertebrae (C1 and C2) usually caused by a different acceleration of a head and a fastened body. Specific injury related to the negative Gx-force is a rupture of the atria (and occasionally the ventricles) which is caused when the chin falls forward and strikes the sternum (the so called "chin-sternum-heart syndrome").

The configuration of seats currently used by commercial aircraft operators is designed so that passengers are usually seated in the direction of the flight. Obviously, it is believed (by the operators) that the majority of the population would not tolerate travelling rearward. Nevertheless, as indicated above, rearward seating provides significantly higher level of passive security in case of an accident.

The author hypothesizes that the opposition to rearward seating is mainly psychological e.g. cabin crew members who are often seated rearwards. This can also be observed with the use of rearward seats in modern high-speed trains or on board of private jets. Practical solutions to this issue could be made by further investigating the much debated concept of "blended wing body" airliner design, presented by Boeing (concept originally conceived by Northrop Grummen for military airframes). This new type of construction - aircraft body connected to wings - does not allow for windows at most passenger seats. [9] The lack of windows would therefore allow the passenger seats to be installed against the flight direction. Certain psychological discomfort would probably occur only in the critical phases of flight (in particular, during take-off) which might be, however, eliminated by projecting the view of outside the aircraft to the LCD screens situated on the sides of the fuselage.

Lateral left / right g-forces (Gy)

This type of g-force is not well tolerable by the human body. Victims of the accident are usually exposed to this type of g-forces when the aircraft hits the surface / object under moderate angle, i.e., not directly. Human organism is capable to cope with lateral g-forces up to the maximum of 12G. This value is, however, only approximation because the injuries caused by lateral g-forces are generally difficult to identify due to number of serious injuries usually caused in case of non-direct airplane crash.

Significant reduction of the amount of serious injuries caused by this type of inertial forces would be possible by installing more advanced restraint system, in particular, multi-point seatbelts for passenger use. Current commercial airliners usually provide only two-point seatbelt (in contrast to seatbelts of the cabin crew which are usually sophisticated five-point seatbelts). The problematic aspects here are the potential limitation of passenger comfort in case of multipoint seatbelts and more complicated manipulation with the seatbelt buckles (the economic impact for the operator is also a key consideration).

Vertical up / down g-forces (Gz)

Negative vertical g-force is common during rapid plane descending (high sink rate). It can be experienced in normal operating conditions during turbulence. As already mentioned above, the human body is generally very sensitive to negative vertical g-force (headache, reddened vision, loss of consciousness at approx. only -4/-5Gz) and can withstand maximum of 15G [7]. Negative vertical g-force might cause a “sudden-death-syndrome” which was identified in some fatal military aircraft accidents. Scientists believe that the deaths were caused by relatively small amounts of negative vertical g-force as a result of brain haemorrhage [3].

The Majority of aircraft manoeuvres produce positive vertical g-force. Positive vertical g-force in aircraft accidents cause typical injuries such as vertebrae compression at approx. +25G or ring fracture at the base of the skull due to force being transmitted through the spinal cord. In case of higher positive vertical g-forces, common injuries can potentially include disruption of the hip joints or ruptured aorta [7].

The Most Common Types of Injuries Suffered in Aircraft Accidents

The project HCUP (Healthcare Cost and Utilization Project) provides rare data regarding patients who were hospitalized with an aircraft accident related injury. The project took place in the US between the year 2000 and 2005. Approximately 20% of US hospitals participated in the project. In total 6080 patients were hospitalized as a result of an aircraft accident during the duration of the project. The figures equate to approx. 1000 patients on average per calendar year. The majority of patients consisted of passengers and/or crews of private aircrafts (32%) and parachutists (29%) while 75% were males aged from 20 to 59 years (71%). The average time of hospitalization of each patient was 6.3 calendar days; 120 patients died during hospitalization (approx. 2% from the total number of hospitalized patients).

The most frequent cause of death was injury to blood circulation (39%), burns (13%) and head injuries (8%). The most frequent injuries included fractures of lower limbs (27%) followed by head injuries (11%), open wounds (10%) and upper limbs fractures and internal injuries (9%) [10].

Other statistic data based on the autopsy of victims of aircraft accidents show similar results.

Approx. 80% of all passengers who died during the aircraft accident suffered from the injury of extremities, while 73,6% suffered fracture of lower limb(s) and 56,6% fracture of upper limb(s). The form and location of the fracture is one of the key elements in investigation of aircraft accidents because the mechanics of fractures and inertial forces and moments are well known and described in cases of aircraft accidents [1].

Similarly, approx. 80% of all passengers who died during the aircraft accident also suffered from various chest injuries, mostly compression of the chest, fracture of ribs and sternum which subsequently led to the fatal injury (penetration) to the heart (47,6%) or aortic ruptures (35%). Soft abdominal organs and head injuries can be identified in about 60% of fatalities. Pelvic fractures and disruptions occur in approx. 49% of all accident victims. Spinal injuries are present at approx. 45% of all victims of aircraft accidents. The most frequent are thoracic spine injuries and fractures of cervical spine (10%) [1].

Conclusion

The paper provides an analysis of external conditions which influence the human body in the event of an aircraft accident with special regard to deceleration and acceleration (g-forces). Further, study of these conditions and mechanics of injuries in aircraft accidents can lead to higher levels of safety in air transportation.

There are currently solutions available that could increase the current level of passive passenger safety in air transport. These solutions are based on the study of the aforementioned conditions and injury mechanics. They include multi-point seat belts for passengers or rearward seating (against the direction of the flight).

A potential reason why these solutions have not yet been implemented into standard commercial operations of civil air carriers could be economical (multi-point seat belts) and psychological (rearward seating).

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INAIR 2012
International Conference on Air Transport

Prepared by Martin Hromádka
Printed by EDIS-Žilina University publishers, September 2012
First edition
Circulation 200 copies

ISBN 978-80-554-0574-2
ISSN 2454-0471