FUZZY EXPERT MODEL FOR DETERMINATION OF RUNWAY IN USE CASE STUDY: AIRPORT ZURICH

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Introduction

The airport traffic control service is obliged to control and monitor departing and arriving traffic at an airport with the aim of providing safe, accurate and expeditious traffic. The traffic controllers who provide this service are located in the airport control tower. They visually monitor the airport traffic (directly through the window or by binoculars) and communicate with aircraft by radio on a specific frequency.

During their work, controllers, get information about future planned traffic (for 5 to 10 min in advance) in the form of strips (paper or electronic, containing necessary information about each flight which departure or arrival is expected), although they have direct insight into traffic at the airport. Also, via electronic display, controllers gets information about continuous changes of wind direction and speed and meteorological forecasts a few hours in advance (values of visibility, ceiling, runway visual range, amount of cloud, precipitation, etc).

One of the controller's obligations is to determine runways in use according to meteorological conditions and traffic demand. This decision provides safe aircraft operations (take-off and landings) with lower delays. Meanwhile, during the decision-making process, they also should think about utilization of available airport capacities (particularly on airports with multiple runways) and noise level around the airport.

Problem definition

At a specific moment of time, depending on meteorological conditions and planned traffic demand, the airport controller determines the runways in use trying to maximize utilization of available airport capacity (which is presented as an hourly number of operations) and minimize the noise level. Once the runway in use is determined, the controller's further work aims to provide safe and punctual traffic, until meteorological or traffic demand conditions are changed so much that a runway change is required.

If we take into account the mentioned facts, then in the case of airports with multiple runways we are faced with a very complex process of decision making. The reason for this is the large number of feasible combinations of runways in use where each combination produces a different capacity and noise level. Thus the problem could be characterized as a combinatorial. Also, which runway will be used in some specific moment of time depends on the controller's subjective judgments about the meteorological and traffic situation. Their opinions depend of personal experience, age, personality and similar parameters.

During the decision-making process, controllers have a whole spectrum of available data, of different nature and accuracy. Some of this data, although it is received in explicit form, due to the nature of the job, they realize subjectively (in linguistic form), and use in that form (e.g. a ceiling of 300ft is realized as a "low" ceiling, visibility of 8600m as "good" visibility, expected number of departures of 37 aircraft as "large" number of departures, etc.)[1]. From the other side, some data, which is explicit, is used in the same form in a process of decision making (e.g. wind direction of 340^0).

Because of the entry data nature, i.e. of subjective opinions about it, and also because of the individual differences between controllers, this paper will present a prototype of "expert" model for decision-making about runways in use based on fuzzy logic for the case of Zurich Airport. The main idea was that the model presented should serve airport controllers at this airport from 2005 when usage of new operational concepts will begin (Figure 1) (the operational concept presents a specific combination of runways in use, [2]). Using this model, controllers will be able to satisfy new airport authority goals – increase of airport usability and decrease of noise levels around the airport.

The final result of the decision making process, i.e. of application of the model, is the possible distribution of traffic on runways in use, and aircraft assignment, where, for each aircraft category, the available runway is determined.

So, the final decision contains a solution, which could provide better utilization of available airport capacities, decrease noise levels and controllers' workload.

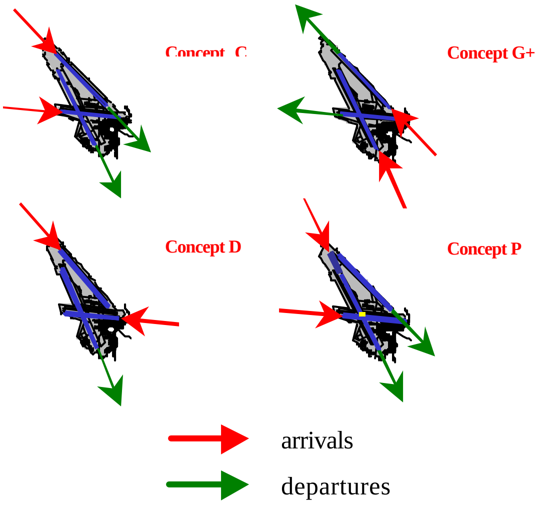

Figure 1. Overview of Available Zurich Airport Operational Concepts

Conceptual model for determination of runway in use

The process of determination of runway in use consists of several steps (Figure 2):

1. Determination of meteorological conditions depending on visibility and ceiling;

2. Determination of operational concept in use depending on meteorological conditions, wind direction and runway conditions;

3. Aircraft assignment on runways in use based on the operational concept in use and estimated number of departures and arrivals.

Entry data necessary for the decision-making process are, because of its nature and controllers opinions, divided into three groups. The first group constitutes meteorological data, which is here assumed to be lexicographic, and are presented as fuzzy variables. This data is:

- visibility (measured in km) and
- ceiling (measured in ft).

The second group presents meteorological data which is used in explicit form:

- runway condition (wet or dry) and
- wind direction.

The third group consists of planned traffic data, for which it is here assumed that they are lexicographic:

- planned hourly number of departures and
- planned hourly number of arrivals.

Because of all previously mentioned facts, the process of determination of runways in use is realized through three models:

1. ***Fuzzy model 1:*** meteorological conditions are determined depending on visibility and ceiling which are presented as a fuzzy variables;

2. ***Fuzzy model 2:*** estimated number of departures and arrivals for next hour are determined depending on planned number of departures and arrivals and absolute value of difference between their values; and

3. ***Rule base:*** the final decision about operational concept in use and traffic (aircraft) assignment on runways is determined on the basis of results from Fuzzy models 1 and 2 and additional information about wind direction and runway condition.

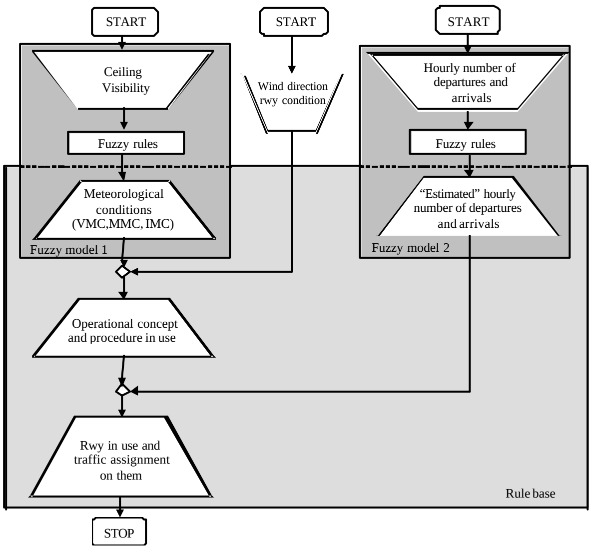

Figure 2. Conceptual Model of Determination of Runway in Use

Here it should be said that the process of decision making and characteristics of proposed fuzzy models and rule base are the product of interviews with some experienced controllers and meteorologists (experts) as well as of engineering expertise. For that reason, the expert model presents a prototype. The value of the fuzzy model parameters and combination of rules in the rule base, are also the result of engineering expertise and the specific meteorological and traffic demand condition at Zurich airport [2], [3], [4].

Fuzzy model 1

As was said before, Fuzzy model 1 serves for determination of meteorological conditions at a specific time using the fuzzy variable "Visibility" and "Ceiling". Meteorological conditions at Zurich airport could be defined as:

- visual meteorological condition – VMC;
- marginal meteorological condition – MMC;
- instrumental meteorological condition– IMC.

Visibility is presented as a fuzzy variable which contains 3 fuzzy numbers: small (from 0 to 800m), middle (from 0 to 5km) and large (from 800m) (Figure 3).

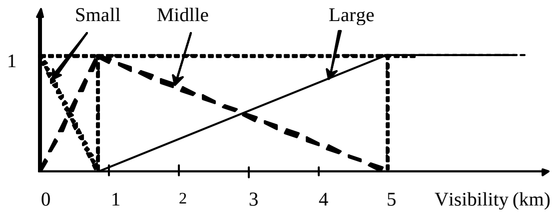

Figure 3. Fuzzy Variable "visibility"

Similarly, the ceiling is presented as a fuzzy variable which contains the following 3 fuzzy numbers: low (from 0 to 1000ft), middle (from 0 to 2000ft) high (from 1000ft) (Figure 4).

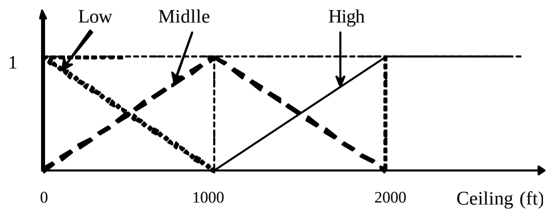

Figure 4. Fuzzy Variable "Ceiling"

The values of fuzzy number intervals are defined on the basis of meteorological recommendations and analysis of meteorological conditions at Zurich Airport, for a one year period [3]. Fuzzy numbers are presented here as triangular and non-symetrical (this assumption is based on engineering expertise).

Output from the model presents the decision about meteorological conditions which could exist at a specific time. By that reason, three output variables are presented in the form of fuzzy variables "Preference of VMC (MMC/IMC)" (Figure 5).

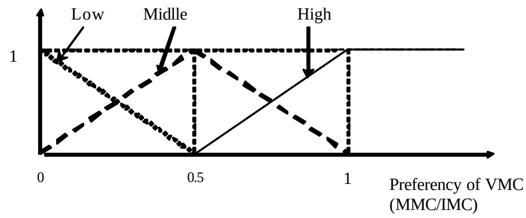

Figure 5. Fuzzy Variable "Preferency of VMC (MMC/IMC)"

Fuzzy numbers which belong to the mentioned fuzzy variables are also presented as triangular and non-symmetrical.

Fuzzy rules, which are used for determination of specific meteorological condition preference, are defined based on values of fuzzy variables "Visibility" and "Ceiling". An example of the rules for "Preference of VMC" are presented in Table 1.

A final decision about the type of meteorological conditions is made according the values of membership function to fuzzy variables "preference of VMC (MMC/IMC)" in such a way that the chosen type of meteorological condition has the highest (maximal) value of membership function for specific input variable values.

Table 1. Preference of VMC

Visibility	small	small	middle	middle
	middle	small	middle	high
	large	middle	high	high
		low	middle	high
		ceiling		

Fuzzy model 2

Fuzzy model 2 determines the estimated hourly number of departures and arrivals using fuzzy variables "Planned hourly number of departures (arrivals)" and "Absolute value of difference".

"Planned hourly number of arrivals (departures)" is presented as a fuzzy variable containing 3 fuzzy numbers: small, middle and large number of arrivals (departures). "Absolute value of difference" between the planned hourly number of departures and arrivals is presented as a fuzzy variable containing 3 fuzzy numbers: small, middle and large difference (Figures 6, 7, 8).

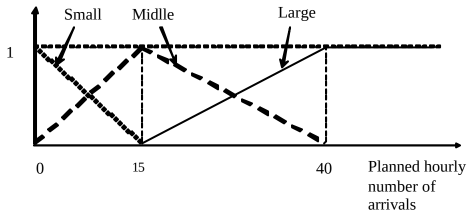

Figure 6. Fuzzy Variable "Planned Hourly Number of Arrivals"

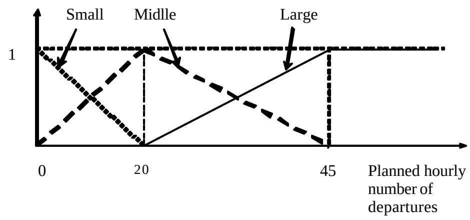

Figure 7. Fuzzy Variable "Planned Hourly Number of Departures"

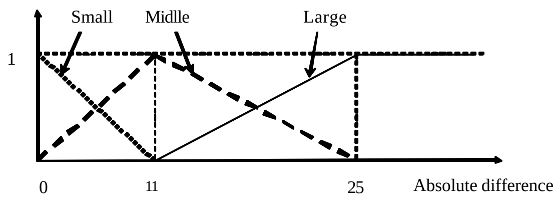

Figure 8. Fuzzy Variable "Absolute Value of Difference"

It was assumed that fuzzy numbers are triangular and non-symetric. Values of fuzzy numbers intervals are defined based on analysis of traffic planned for Zurich Airport, for a one month period [4].

The output from Fuzzy model 2 presents the linguistic "estimation" of hourly numbers of arrivals and departures. Because of that, output variables are presented in a form of fuzzy variables "preference that number of departures (arrivals) is small (middle/large)". Fuzzy numbers, which belong to the mentioned fuzzy variables, are presented as triangular and non-symmetrical (similar to Figure 5).

Fuzzy rules for determination of preference of estimated number of departures and arrivals are defined based on values of fuzzy variables "Planned hourly number of departures (arrivals)" and "Absolute value of difference" (similar to Table 1).

Final decision about the estimated number of departures (arrivals) is made according to the values of membership function of fuzzy variables "Preference that number of departures (arrivals) is small (middle/large)" in such a way that the estimated number of departures (arrivals) which has the highest (maximal) value of membership function for specific input variable values, is chosen.

Rule Base

The rule base, based on the results from Fuzzy Model 1 and using additional information about wind direction and runway conditions, gives us the operational concept in use. Also, using that result and the results from Fuzzy Model 2, the rule base can give us the final results: distribution of traffic (by aircraft category) on runways in use (traffic pattern) and distribution of different aircraft category on those runways. Rule base is completely developed on the basis of knowledge collected by interviews with experienced controllers and by engineering expertise.

The final decision contains a solution, which could provide better utilization of available airport capacities and also, decrease noise level (Figure 9).

Figure 9. contains an example for operational concept C in use. Here it can be seen that the final result depends on a combination of operational concept in use and estimated number of departures and arrivals. The result obtained for a specific combination of variables contains information about runway in use for a specific aircraft type. Aircraft are divided into three categories (depending on engine type and wake turbulence category): Turbo Prop, Medium Jet and Heavy Jet.

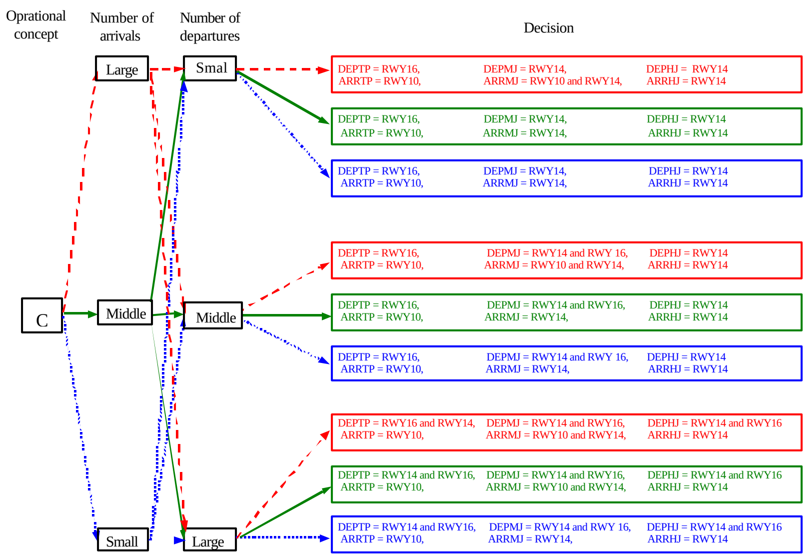

Figure 9. Traffic Distribution in Case When Operational Concept C is in Use

Programming

Programming of fuzzy models (mentioned in earlier chapters) was done using the software UNFUZZY 1.2 [5]. Using this software three programs were designed:

- ***Meteo Conditions*** based on Fuzzy Model 1, which serve for determination of meteorological conditions;
- ***Departures*** based on Fuzzy Model 2, which serve for determination of number of departures;
- ***Arrivals*** based on Fuzzy Model 2, which serve for determination of number of arrivals.

Rule Base was realised through the programme "RunwayInUse", written in programming language Borland Pascal.

Expert model is imagined as interactive, where in three steps, input data are entered by the controller. Final result presents the distribution of different aircraft category into runways in use according to rules from previous chapters (Figure 10).

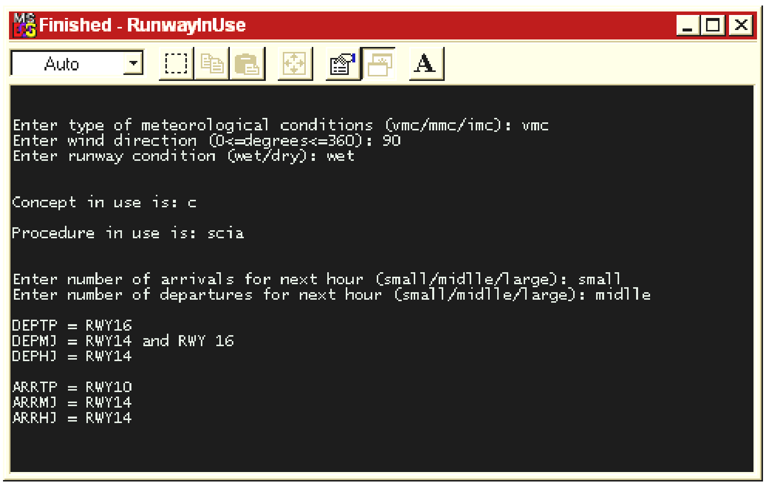

Figure 10. Window With Final Results of "RunwayInUse" Program

Conclusion

This paper deals with a real problem, which exists at airports with multiple runways – determination of runways in use and aircraft assignment on those runways. In reality, this problem is solved by airport traffic controllers. The process of determination of runway in use is realized through several steps. Most of the input data necessary for this process are fuzzy. Because of the mentioned facts, the fuzzy expert model for determination of runways in use, which could serve controllers for evaluation of their own solutions or for suggestion of new solutions, is developed.

The model is developed for Zurich Airport but could easily be applied on any other airport. Application of mentioned programs gives us the final results, which are presented in the form of runways in use and distribution of different aircraft category on those runways. These results present a solution of the mentioned problem, which simultaneously enables "maximization" of available airport capacity and "minimization" of noise level in airport vicinity. Because of all the mentioned factors, this kind of fuzzy expert model could be of benefit in reality.

At the end, it should be emphasized that the developed fuzzy expert model is prototype and is not verified yet. The reason for this is that the mentioned solutions of problems (operational concepts) have still not been implemented at Zurich Airport. Because of this, verification is, together with fine-tuning of models (adjustment of fuzzy variable type and value intervals), the goal for further research.

References

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Biography

Fedja Netjasov is Research and Teaching Assistant at the Division of Airports and Air Traffic Safety, Faculty of Transport and Traffic Engineering, University of Belgrade. He obtained his B.Sc. (Dipl. ing.) from the Faculty in 1999. He received M.Sc. from the same Faculty in July 2003. Major fields of interest are: ATM, Airports, Modelling, Transport and Traffic System Analysis.