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SUPPORT OF AIRCRAFT TAXIING OPERATIONS ON THE APRON

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Abstract

The paper presents an approach to this type of problem. Was submitted the general approach to construct the model and presented selected aspects of the application AIRS enabling decision making support on minimizing taxiing aircraft at take-off and landing operations. Taxiing operations of aircraft on the apron are the binding part of planning and air traffic control phase including the sequencing of arrivals and departures, planning of air traffic in the immediate vicinity of the airport and issues of passenger traffic in the terminals and ground handling of aircraft. The airport is presented as a model which was implemented in the form of a computer application AIRS. Application AIRS is suported to determine the optimal taxiways on schedule. The procedure for decision support in carrying out the operation of aircraft consists of: data on the types of aircraft, data staging aircraft, data about the time of use of the types of aircraft, technical and organizational parameters of the process taxiing, the structure of the apron to the process of taxiing, routing algorithms of landing aircraft, routing algorithms of taking off aircraft, algorithms for taxiing in other cases.

Keywords: *taxiing, aircraft, decision making support*

1. Introduction

The basis of the control of aerodrome traffic is the principle of priority. It is assumed that the aircraft landed or the one in the final phase of the approach takes precedence over the airplane departing. Departing aircraft should receive a permissions on the basis of readiness to take off. The exception may be the case when the amended order will allow a greater number of operations with the least average delay.

Figure 1 shows a schematic movement of aircraft over the airport area, taking into account the take-off and landing phases.

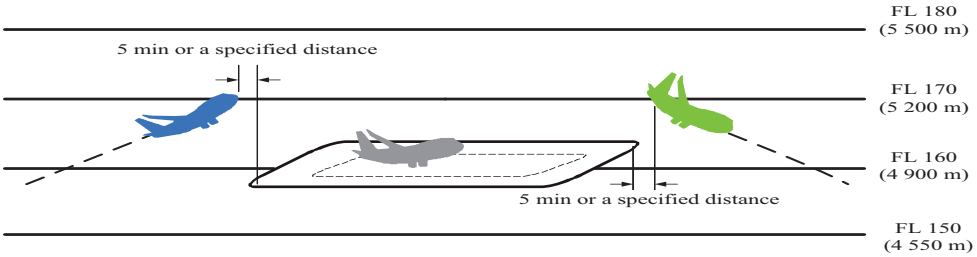


Fig. 1. The movement of aircraft over the airport area [22]

Due to the limited visibility from the cockpit, important issue of ground operations is to control the taxiing aircraft. In order to increase throughput, aircraft may receive permission to taxi on the runway in use, provided that this operation does not cause traffic delays and the danger of collision with other aircraft.

Taxiing operations of aircraft on the apron are the binding part of planning and air traffic control phase (including the sequencing of arrivals and departures, planning of air traffic in the

immediate vicinity of the airport) and issues of passenger traffic in the terminals and ground handling of aircraft. The main operations which determine airport capacity are the take-off and landing (sequencing and scheduling) on the taxiway [5, 1, 3-5], allocation of gates and parking positions for flights [8] and the movement of aircraft on the apron (taxiing).
If the taxiway is designated for reasons that are not subject the planning, the problem in the literature [20, 19] considered only the issue of scheduling of the take-off and landing operations, which are preceded by a taxiing operations. For example, in [10, 12-15, 18] shows that the algorithm of the solution of the problem selects the taxiway from a set of predefined solutions.

An important aspect of the operation of aircraft taxiing on the apron is a separation between aircraft determines the security at the airport. The need to maintain appropriate intervals and intervals of distance between aircraft due to the possibility of direct conflict between them [18, 6] or the entry into the flue gas streams or in areas of air turbulence caused by the functioning of the engine [17, 16]. The required distance between the planes is dependent on many factors, such as wind, type of aircraft and the first and the next phase of flight / taxi in which the aircraft is currently located. These are the distance ranging from 60 m to 200 m [18, 20].

Taking into account the above problem is to develop methods and tools for eliminating conflict situations, while minimizing the time of taxiing aircraft performing takeoff and landing. To accomplish this objective, it is necessary to present the airport as a model and implementation of this model in the form of a computer application.

The purpose of the efficient functioning of the airport is optimal – in the sense of accepted criteria – selection of its infrastructure to ongoing tasks, i.e. accepting and preparing aircraft serving all traffic, i.e. passenger, special transports, etc. One of the key elements of the infrastructure of the airport is the apron with of runways, taxiways, points of service. In this part of the airport operations are performed related to landing, take-off and taxiing aircraft. During these operations, depending on the traffic aircraft can reach to conflict consequences arising from the time of landing and take-offs of different types of aircraft.

2. The algorithm of the method supporting the operation of aircraft taxiing on the apron

Issues for decision support in various areas of transportation are becoming increasingly important. In order to assist decision-making in the field of operations of aircraft taxiing on the apron, identify necessary steps for individual operations and the conditions for their implementation, including various types of conflict situations (eg. Every kind of mutual exclusion). It is necessary to identify the characteristic of different types of data possible results. Overall, the apron is characterized by [11]:

- *structure* - showing the relationship between the points highlighted taxiway such as touchdown points, the points of intersection of taxiways (the so-called. Intermediate points) and points of operation of aircraft,
- *volume of traffic at the airport* - expressed as the number of planes landing and taking off in the era,
- *parameters of elements of the structure* - describe important due to the ongoing research the characteristics of the individual components,
- *organization* - understood as the consequences of schedule takeoffs and landings of aircraft at the airport and the development of the planned flight table.

By determining the structure of apron with the symbol of the ***GPL***, the load of the planes in a fixed period of time – with a symbol of ***QPL***, a set of characteristics of the elements of the structure – with a symbol of ***FGPL***, and the organization – with a symbol of the ***OPL***, the model of aircraft taxiing on the apron (***MKSnPL***) can be written as an ordered four, of the form:

$$\boldsymbol{MKSnPL} = \langle \boldsymbol{GPL}, \boldsymbol{QPL}, \boldsymbol{FGPL}, \boldsymbol{OPL} \rangle. \quad (1)$$

The description of the individual elements of a specific model of apron is determined by the

adopted model category.

The procedure for decision support in carrying out the operation of aircraft taxiing on the apron requires knowledge concerning, inter alia:

- data on the types of aircraft,
- data staging aircraft,
- data about the time of use of the types of aircraft,
- technical and organizational parameters of the process taxiing,
- the structure of the apron to the process of taxiing,
- routing algorithms of landing aircraft,
- routing algorithms of taking off aircraft,
- algorithms for taxiing in other cases,

The solution to the problem of determining a plan of movement of aircraft on the apron routes are their movements that begin in the lymph touchdown / parking, then run to each intermediate nodes and end at nodes parking / touchdown. An important aspect is the limitations of the organization of traffic on the apron among which, inter alia:

- reducing the number of aircraft that are between two distinguished points taxiway;
- assignment of aircraft to the touchdown and the staging point;
- limit on the separation time between aircraft taking off or landing;
- limit on the number of points a touchdown and staging points;
- not exceeded the maximum time for separation in conflict situations;
- the priority of taxiing aircraft maneuvering.

3. Program AIRS to support the organization of movement of aircraft on the apron

3.1. Functions and tasks of AIRS program

The procedure for the operation of aircraft taxiing was written in the form of *AIRS* program. The developed application was written in ActionScript 2.0. Is supported by the platform Flash Player. The database was created using PHP and My SQL. The application uses the Google Chrome browser and connects to the real-time database. The database contained the necessary dictionaries and software components for quick and easy job as a worker co-ordinating traffic at the airport. Applying the three-tier does not charge the computer and prevents access to the processed information to third parties. Access password is required for each person working on the job. This allows you to track every movement of the employee in the *AIRS* system.

Application *AIRS* allows:

- determining the optimal taxiways on schedule. Optimizing algorithm takes into account information such as: number of taxiways, the number of parking spaces, obstacles or weather conditions,
- optimal assignment of stopping place. Algorithm determines the appropriate technical and economical to assess the effectiveness solutions chosen parking space assignment,
- scheduling optimization based on data determined by points. 1) and 2). In addition, the program can calculate the number of infrastructure funds needed to carry out the tasks planned in the schedule for the day, which are the result of the analysis.

AIRS program functions allow loading database with data, perform calculations, and the presentation and recording the results of calculations. In addition, to create, save, print, and edit data files.

Since the main task of the program *AIRS* is to support decision-making task scheduling on the movement area, were distinguished four basic roles:

- ground controller – is responsible for maintaining the safe taxiing route for aircraft to a parking space,
- coordinator – is responsible for creating a table of scheduled flights and allocation of parking

spaces (establishment of a preliminary plan for the operation of the airport),
– dispatcher – allocates and manages each ground service and entered the real time settings, connection, substitution and withdrawal,
– administrator – adds dictionaries, etc.

In addition, the system can view the person authorized, inter alia: personnel operating aircraft and the service FALLOW ME.

The main task of the computer application is to provide a schedule *AIRS* airport operations in such a way that the delay generated during daily operation are minimal. The application is divided into five main modules.

First module is used to enter data and regulations in force at a given airport. It is available for the administrative function of software, which is designed to adapt the application to the daily work of the airport. The administrator enters data such as the number of runways, rapid exit, taxiways, stopping points, the set time of use for the operator or aircraft type (Fig. 2).

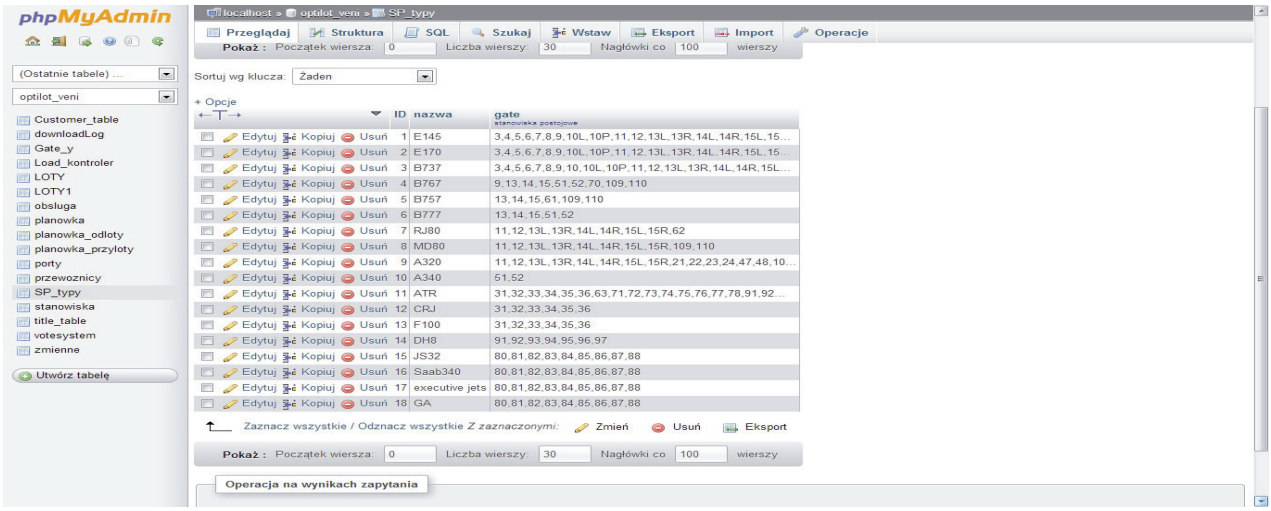


Fig. 2. The assignment of parking places for the types of aircraft (source: Printout from the AIRS program [11])

The schedule module is used to introduce of scheduled flights of aircraft scheduled 24 hours in advance. Creating a network of sequences of aircraft traffic and operations at a given airport, including the table of arrivals, departures table, scheduled tasks for companies serving the aircraft data and a map of the taxiway.

The *AIRS* program is based on four roles. The role of the controller, the coordinator (Fig. 3.), dispatcher (Fig. 4.) and administrator. Each of these users powers the system by entering data and modification of data.. The purpose of the system is therefore to generate forms based on the information collected for the system.

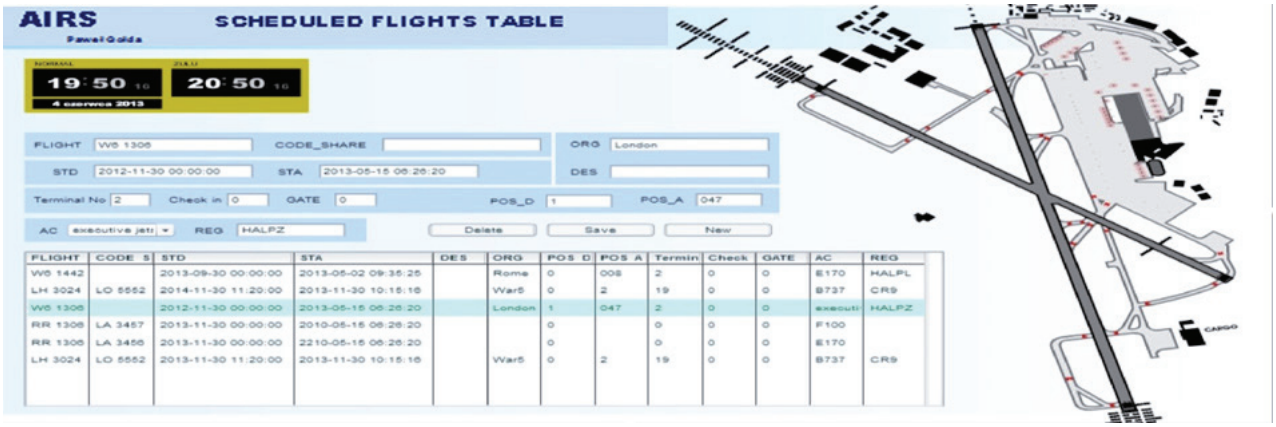


Fig. 3. Basic view of the coordinator tab (creating of planned flight table) (source: Printout from the AIRS program [11])

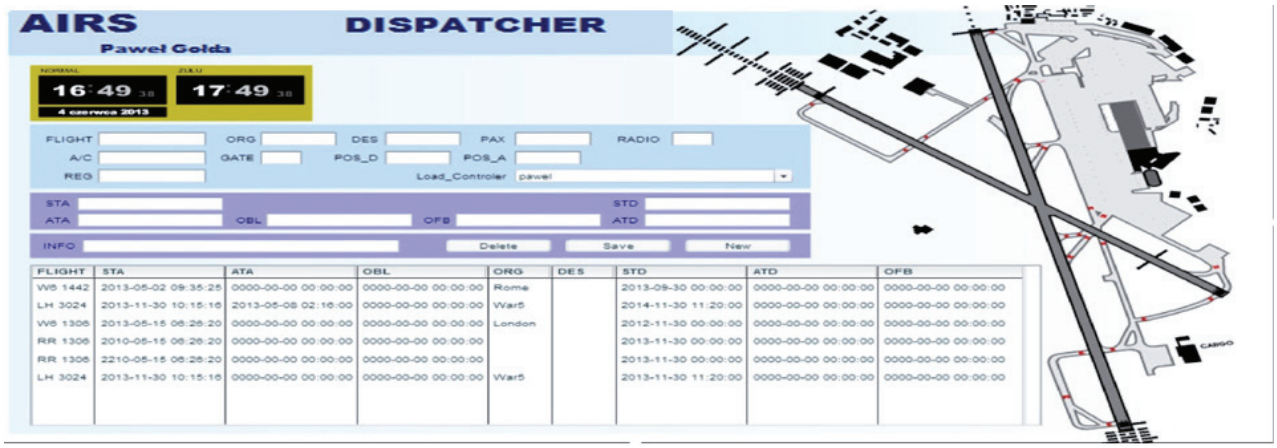
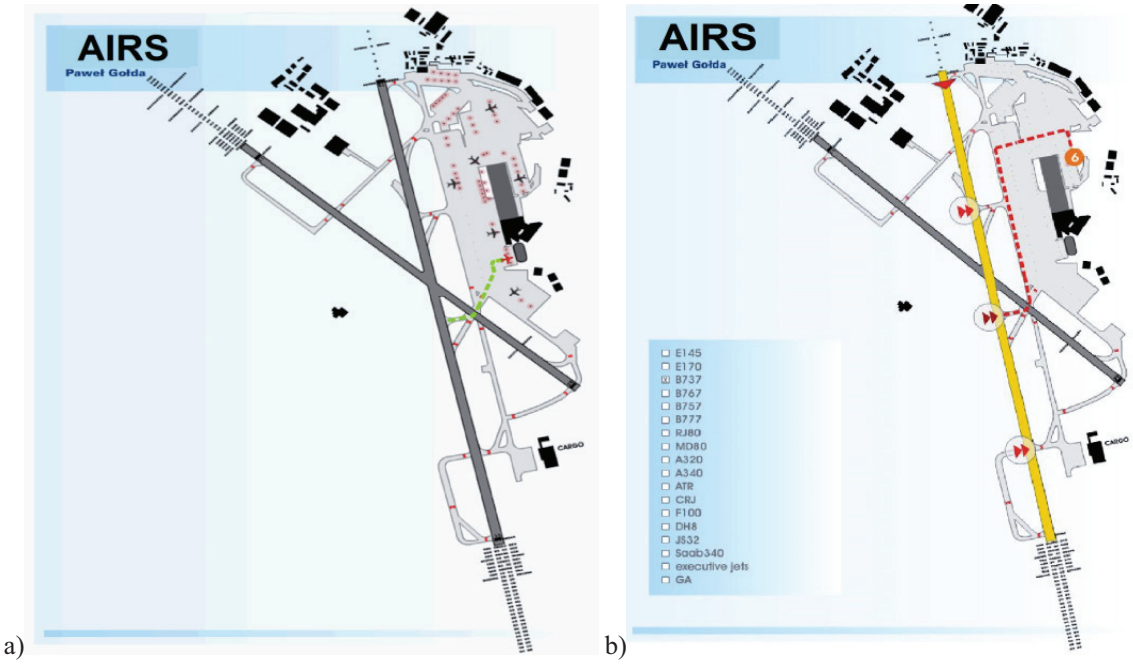


Fig. 4. Basic view of the dispatcher tab (source: Printout from the AIRS program [11])

The next modules are responsible for verifying the activities carried out during the actual work the airport. Delays generated at the airport are entered into the system then verified and the result is the actual sequence of operations performed and its graphical representation. For example, the third module is responsible for the information on the planes taking off (includes: actual time of withdrawal sleeve, push the aircraft taxiing for takeoff, take off the belt and direction and the actual start time), while the fourth module landing aircraft (including: aircraft type, carrier, staging, and direction of the landing strip, the way downhill and assignment of the taxiway.

Interactive map (Fig. 5a, Fig. 5b), which displays information about the currently executing operations (aircraft status is determined appropriate color), allows for verification of the taxiway for a particular plane.



a) b)

Fig. 5. Animation of the process of taxiway: a) for taking off aircraft; b) for landing aircraft (Printout from the AIRS program [11])

The system allows you to change the road and its editing. Depending on the conditions on the maneuvering controller in any way and at any time can edit and change taxiway route. Graphics capabilities allow for graphical display of the solutions proposed ground controller. The system will calculate the real-time schedule of new roads sequence (Fig. 6.).

Fig. 6. The tab "controller" selecting "operations" (Printout from the AIRS program [11])

3.2. The results presented using AIRS support system

The task of the AIRS system is to support decision making in the operations of aircraft taxiing on the apron. In particular, the preparation of an optimal schedule for moving aircraft performing operations taxiing for takeoff and taxiing after landing in such a way that the difference between scheduled and actual implementation of the operations to a minimum.

The Tab. 1 shows the distribution of flights in the morning to Okęcie Airport.

Tab. 1. Taxiways and taxiing times of aircraft traffic on the manoeuvring area before laying schedule using AIRS program

Runway	Type of an airplane	Time			Taxiway *AIRS*	Shedule	Real
		To the taxiway	Taxiing	Setting tothe sleeve			
33	B737	1.05	5.42	1.49	SOMZU5	9:00	9:01
	B737	1.1	4.21	no 1.4	SA51	9:00	9:03
	MD87	1	2.22	no 0.1	SOM24	9:00	9:05
	JS32	1.01	4.33	no 0.12	SAW87	9:15	9:10
	A320	1.15	9.05	power + 2.34	SOM11	9:20	9:12
	A321	1.12	2.17	no 1.05	SOMZ10	9:20	9:15
	CRJ	1.03	1.15	no 0.15	SOM35	9:20	9:17
	ER180	1.08	2.47	2.2	SOM14P	9:20	9:19
	A319	1.1	2.15	1.54	SOM13L	9:20	9:20
	ER180	1.03			SOMZU8	9:25	9:21
	MD82	1.07	2.26	power + 2.30	SOM70	9:25	9:24
	A319	1.2	3.56	power + 1.23	SOM19	9:25	9:26
	ATR72	0.57	1.29	no 0.14	RD76	9:30	9:30
	ATR72	1.2	2.06	no 0.2	SOMZA32	9:35	9:32
	FOKKER	1.1			SOMZV97	9:35	9:34
29	ER145	0.41	2.54	no 0.2	DRA33	9:40	9:37
	AVRO	0.47	3.19	no 0.11	DRA36P	9:40	9:39
	B737	0.36	3.41	power + 4.17	DRAZM12	9:40	9:41
	B767	0.40		power + 3.2	DRAZ10L	9:40	9:43
	ER190	1.1	2.3	no 0.17	DRAZM32	9:45	9:45
	ATR72	0.52	7	no 0.2	DRAZM31	9:45	9:47
	FOCKER	0.46	3.15	no 0.15	DRAZM35	9:45	9:49
	A320	0.34		power + 2.34	DRAZU6	9:50	9:51
	CRJ	0.31	3.1	no 0.21	DRA34	9:55	9:53
	ER170	0.38	4.3	no 0.22	DRAZM21	9:55	9:55
	B737	0.41	6.29	no 0.18	DRAE48	9:55	9:57
Runway	Type of an airplane	time			Taxiway	Shedule	
		Withdrawal	Pushing	Taxiing			
29	ATR72			3.23	39AE	9:05	9:06
	ATR72			4.50	31AE	9:15	9:15
	FOCKER			8.26	96VZME	9:15	9:18
	ER145	2.56	3.0	2.56	17ME	9:30	9:21
	AVRO			7.45	92UZME	9:40	9:40
	B737	2.34	1.0	5.46	9ZME	9:55	9:59

Source: [11]

In the column “schedule” have planned the hour of the operation, while in the "Real" real time the operation. The result of the development schedule by the *AIRS* program is to determine the taxiway located in the “taxiway”. The data contained in Tab. 1 show how the aircraft circled the instructions of the controller ground, while Tab. 2 summarizes the taxiway after optimization times to perform the same operation after the change.

Based on the analysis contained in Tab. 1, it can be seen that uses only rapid exit route called S and D. Only the application of the program AIRS shows the possibility of using other rapid exit roads that allow you to designate other and also faster taxiways. The AIRS system optimization allowed for the use of roads S, D, R, A0, O, so that some of the planes were directed at other taxiway, the same time the traffic load taxiways decreased by a few minutes.

The Tab. 2 summarizes the taxiway designated by the AIRS program. The schedule of flights which introduces a decision support system for operations of taxiway allows you to perform the same number of operations in shorter time of 6 minutes 6 seconds.

Tab. 2. Times and taxiways of aircraft traffic on the maneuvering area after application schedule by the AIRS program

Runway	Type of the airplane	Time			Taxiway *AIRS*	Schedule	Real
		To the taxiway	Taxiing	Setting tothe sleeve			
33	B737	1.05	5.42	1.49	SAZU5	9:00	9:01
	B737	1.1	3.22	no 1.4	RA51	9:00	9:03
	MD87	1	2.22	no 0.1	SOM24	9:00	9:05
	JS32	1.01	4.21	no 0.12	A0W87	9:15	9:10
	A320	1.15	8.05	power + 2.34	SAZM11	9:20	9:12
	A321	1.12	1.54	no 1.05	OAZ10	9:20	9:15
	CRJ	1.03	1.05	no 0.15	SA35	9:20	9:17
	ER180	1.08	2.47	2.2	SOM14P	9:20	9:19
	A319	1.1	2.15	1.54	SOM13L	9:20	9:20
	ER180	1.03			SOMZU8	9:25	9:21
	MD82	1.07	1.35	power + 2.30	D70	9:25	9:24
	A319	1.2	3.56	power + 1.23	SOM19	9:25	9:26
	ATR72	0.57	1.29	no 0.14	RD76	9:30	9:30
	ATR72	1.2	1.54	no 0.2	RA32	9:35	9:32
	FOKKER	1.1			RAZV97	9:35	9:34
29	ER145	0.41	1.44	no 0.2	SA33	9:40	9:37
	AVRO	0.47	3.19	no 0.11	DRA36P	9:40	9:39
	B737	0.36	3.41	power + 4.17	DRAZM12	9:40	9:41
	B767	0.40		power + 3.2	DRAZ10L	9:40	9:43
	ER190	1,1	1.48	no 0.17	DRA32	9:45	9:45
	ATR72	0.52	2.33	no 0.2	DRA31	9:45	9:47
	FOCKER	0.46	2.4	no 0.15	DRA35	9:45	9:49
	A320	0.34		power + 2.34	DRAZU6	9:50	9:51
	CRJ	0.31	3.1	no 0.21	DRA34	9:55	9:53
	ER170	0.38	4.1	no 0.22	DRAOM21	9:55	9:55
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		Withdrawal	Pushing	Taxiing			
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	ER145	2.56	3.0	2.56	17ME	9:30	9:21
	AVRO			7.45	92UZME	9:40	9:40
	B737	2.34	1.0	5.46	9ZME	9:55	9:59

Source: [11]

With the help of graphical map can be implemented daily process of scheduling tasks on the apron. By clicking on the aircraft can get information about the departure time, flight number or type of aircraft. The program generates the status of the aircraft with the markings appropriate colors. Green means hour, yellow thirty-minute and red is fifteen-minute period for the scheduled flight of the departure. Routes performing operations are generated hours in advance.

Additionally, the system includes the current time and Zulu time. By clicking on a line from a flight, access to detailed information on the aircraft. The application also lets you pause airport

operations in the event of snow belts. In the event of a change of wind direction, you can reevaluate taxiways for the new direction of landing or taking off. The system automatically archives all operations at the airport, including changes in the planned flight table.

4. Conclusions

Taxiing operations of aircraft on the apron are the binding part of planning and air traffic control phase including the sequencing of arrivals and departures, planning of air traffic in the immediate vicinity of the airport and issues of passenger traffic in the terminals and ground handling of aircraft.

One of the key elements of the infrastructure of the airport is the apron with of runways, taxiways, points of service. In this part of the airport operations are performed related to landing, take-off and taxiing aircraft. During these operations, depending on the traffic aircraft can reach to conflict consequences arising from the time of landing and take-offs of different types of aircraft.

Application *AIRS* is suported to determine the optimal taxiways on schedule. Optimizing algorithm takes into account information such as: number of taxiways, the number of parking spaces, obstacles or weather conditions. Using *AIRS* program we can optimise assignment of stopping place. Algorithm determines the appropriate technical and economical to assess the effectiveness solutions chosen parking space assignment. In addition, the program can calculate the number of infrastructure funds needed to carry out the tasks planned in the schedule for the day, which are the result of the analysis.

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