QUEUING BASED SIMULATION MODELS FOR ANALYZING RUNWAY CAPACITY AND MANAGING SLOTS AT THE AIRPORTS

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***Abstract**: The scarcity of the runway slots is the crucial factor, which has a drastic influence on the aviation market worldwide. Both airports and airlines suffer because of the lack of the slots in the periods they are the mostly desired and when they would yield the highest profits. The biggest problem is the infrastructure or being more precisely the lack of the airport runway capacity or utilization and resulting attributes which lead to the difficulties in traffic operations. The problem is necessary to solve as it will reduce the costs involved and increase the profits generated. The main aim of this article revolves around the justification of the fact that the various simulation methodologies can be incorporated to solve this issue. The simulation models, which are used in this article, are the queuing based models as they precisely determine the behavior exhibited by the runway systems.*

***Keywords**: Slot Management, Runway Capacity analysis, Air Traffic Controllers, Queuing Theory and Models, Probabilistic Distribution, Simulation and Optimization*

***ACM Classification Keywords**: B.2.2 Performance Analysis and Design Aids Simulation, B.4.4 Performance Analysis and Design Aids, B.5.2 Design Aids, F.1.2 Modes of Computation, G.3 Probability and Statistics, G.m Miscellaneous. .*

Introduction

This article provides the theoretical concept for examining the standard day of operation at the airports and their evaluation from the airside perspective. In the process of the evaluation, the models of Queuing theory has been used which will lead to the design of the automated system. The simulation has been applied with adoption of three different models of queue. Each model is characterized by the different probability distributions of the time while examining the aircraft's occupancy of the runway.

To realize the above stated objective following sub-goals are to be taken into account:

- Selection of mathematical models of examining the queues for the decision situations given by the issue.
- Implementation of the chosen models
- Derivation of the hypothesis to check their correctness with the usage of applied models.
- Modeling the simulation process with application of M/M/1 , M/G/1 and M/Er/1 models.

The absolute necessity in the projection of runway operations is to perform a simulation. The model, which will be designed, will show the most important features of operational activities on the runway. The model should consist of the expected time of each aircraft movement that has been taken from the historical data. The model has to also include the slot time intervals and separation times. The major part of the simulation is to calculate the inter-arrival time and the service time (the time each scheduled aircraft occupies the runway in the sense of landing or taking-off). All these actions have to be been taken into account to check if the airport, in the examining period of the day, suffers from the waiting lines or all the operations are performed without any delay and in an optimal way. Three different models stated above are based on the similar concept and are key in simulating the runway operations. The article describes two types of the simulation – short and long run. Its purpose is to check if the number of cases influences the received results. The simulation is needful to put into practice the theoretical concepts of functioning of the airport on its airside.

After the simulation models will be planned and implemented, it will be important to form a particular hypothesis that will be examined at the later stage of the research.

The article covers the Queuing Theory modeling concepts and its implementation environment in the field of slot management in detail. Slot management is the most important theoretical part as it describes the importance of the issue. It starts with basic problem scope, followed by the various concepts that regulate the process of allocating and coordinating the slots and number of movements on the runway.

Problem Scope

Most of the international airports suffer due to the lack of the capacity. In Europe, the situation is complex, as the airports built decades ago are not planned for huge flow of passengers and cargo. The European Commission confers the statuses of coordinated and uncoordinated to each airport on the territory of the Community. The major problems are insufficient infrastructure to handle the demand and the problem of scarcity of slots, limited by the infrastructure and international regulations. While the background is constrained often by the small area occupied by the airport and the situation is not expected to improve. Only reasonable improvement proposed by many experts is application of market mechanisms [Doganis, 1991].

This article presents the approach to the problem with the application of the queuing theory. Besides the mathematical studies over the queues appearing on the runway at an airport during everyday activities, the models designed in this article can be also used to simulate the amount of money the airlines loose globally when their aircraft misses a slot and has to wait for the next available.

Slot Management

The main purpose of this part is to present the concept of the slot management, which is the backbone of the runway operations. The aviation area distinguishes two types of slots, namely, the airway slot and the airport slot (which is also known as a landing slot or runway slot). The latter is the right, which is allocated to the specific entity (like commercial airline) by the airport and which allows the owner of the slot to perform landing or departure on the runway in the determined period of time [Doganis, 2001]. Airport slot is mandatory at coordinated airports for each movement (arrival and departure) and is valid for a specific time and specific weekday for the complete planning season (summer/winter season). The airport slot is used to plan the runway capacity (and/or other constraints) for a period of half a year to minimize airport congestion and potential cancellation or delays.

On the other hand, Airway slot or the Air Traffic Control Slot is needed in case of traffic limitations in the airspace. It is provided for a departing flight and is only valid for this specific light, for a specific departure time window (15 minutes) during a specific day. According to European Regulation EEC, “the airport slot means the permission given by a coordinator, in accordance with the Regulation to use the full range of airport infrastructure necessary to operate an air service at a coordinated airport on a specific date and time for the purpose of landing or take-off, as allocated by a coordinator in accordance with this Regulation” [Official Journal L 138, 2004].

The scarcity of the runway slots is the crucial factor that influence the aviation market worldwide. Both airports and airlines suffer because of the lack of the slots in the periods they are the mostly desired. This problem turns the clock back and limits the development of this extremely important arm of global economy.

Due to an imbalance between the demand for worldwide air transport and the availability of adequate airport facilities/infrastructure and airspace systems to meet such demand, the number of congested airports is growing. As a result, the airlines industry is increasingly subjected to serious operational disruptions, with a significant number of delayed departures and arrivals, which results in significant economic penalties.

Runway Capacity

The capacity of the runway is simply the number of movements (counted on hourly or daily basis) that the airport is able to serve or is allowed to serve by the international regulations [Simpson, Belobaba, 1992]. Capacity of the runway is the crucial constructive factor considering the group of restrictions affecting the number of slots that airports offer. It presents a performance of runway system and depends on many elements. The major element being the number of runways and their independent utilization. At some airports, there are more than four runways but they are not allowed to use them in parallel. The great impact on the system is also exerted by the surrounding area (the topography of the landscape) and obviously approach and departure routes. All aircrafts are taking-off opposite to the direction of the wind and if it changes, it automatically limits runway capacity. If the airport is located in the neighborhood of water region or in wooded area it can possible affect the landing approach what eventually could translate into regularity of the operation on the runway [Madas, 2007].

Additionally the ICAO regulations apply at all airports, which limit the number of movements in time. The authorities also put these regulations into practice with compliance of their own runway capacity.

Peak period problem

The peak period is time where the majority of airlines are willing to make their movements at the airports. However, the number of slots limits it. As air traffic grows, demand can exceed capacity at key points of the air transportation network and at critical times. These local overloads create delays, which propagate to other parts of the air network, amplifying congestion as increasing numbers of local capacity constraints come into play. Moreover, the average delay generally increases faster than linearly with traffic.

As it is observable, the peaks occur during the specific period of the day and create the waves of the periods where the number of flights are greater and smaller. The insufficient number of slots or the physical constrains create delays in the system. When such a queue begins to create, the ATC controllers and the airport authorities cannot simply utilize First-In-First-Out rule, because next flights are supposed to start or land on time to avoid further delays. Delayed flights have to wait even for tens of minutes for their movements. Moreover the situation on the destination airport has to be taken into consideration as well, if the aircraft starts but will not be able to land on target airport it will create even more delay and perturbation at the other airport. It creates the absurd situation where the flight despite the fact it possess the right to start and available slot will not be able to do so due to lack of permission to land at its destination [ACI, 2007] .

The peak period problem will be also taken care of by the models developed in this article. The historical data will serve to investigate the queue that is created during the delays in the system and finally the model will examine the stability and intensity of these queues.

Queuing Theory for determining runway utilization and managing slots

The main purpose of this section is a presentation of concepts of the sphere of knowledge known as queuing theory (or traffic theory) [Bose, 2002]. The subject of this conception, studies the waiting lines from the mathematical point of view. The mathematical model of functioning of mass service systems are based on the stochastic theory [Gajowniczek, 2008]. The theory provides an opportunity to investigate a number of processes, which are related to each other. It could include arrival of the customers, the process of waiting in the queue (that is known also as a storage process) and the service at one or more servers. The term of traffic theory is often applied to the theories of telephone and communication traffic; however, it finds adoptions in various areas of life like designing of hospitals, shops, or factories. The main aim of this article is to apply these mathematical models to study the waiting lines in the utilization of airport runway. As it has been mentioned before, the optimization of runway capacity is a key success factor in functioning of the airport at its airside as well in avoiding possible delays resulting from queues. The theory permits the differentiation and calculation of several performance measures like the average waiting time in queue or in the system, expected number of clients in the beginning of queue or in the service station or generally investigation if the whole system is stable or there are delays in it. The application of the queuing theory will not solve the capacity problems, but instead it can be used to provide some suggestions about the use of runway. If the aircraft is scheduled to land or take-off at the certain time and it does not find the available runway, it must take some specified action such as waiting or flying away. Whereas the latter is not very likely, we can consider the model of waiting in the line and define it in terms of three characteristics: input process, the service mechanism and queue discipline [Cooper, 1981]. The basic queuing model at the runway is shown in figure 1.

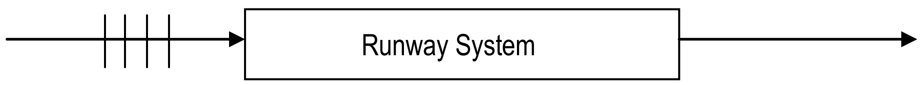

Fig.1. Basic runway queuing model.

If the time of the service is greater than the average separation between the arriving customers, the queue can become longer in infinity. The input process or the arrival process of the customers describes the sequence of request of service. Often, the arrival process is specified under condition of the distribution of lengths of time between consecutive arrival instants. Usually there is an assumption, which provides inter-arrival times in independent way and gives them common distribution. In the most cases, the researchers assume that customers arrive according to the exponential inter-arrival times (Poisson stream). The arrival time counts the time that last between appearance of the customer, which is the last in queue, and the customer, which has just arrived.

The service mechanism includes such characteristics as the number of servers and the period of time the client holds the server. For example, clients may be processed in a single server and each client holds the station for the same length of time. In this particular investigating case, the focus us on the single server model (the airport with only one runway).

The queue discipline gives the disposition of blocked customers (the ones who find all station busy). For example, the system might employ the assumption that blocked customers leave the system immediately or wait for server in a queue and are served in arrival order. The arriving customers might be served in groups or one-by-one. There are number of possibilities for the order in which they enter the service.

Some examples are:

• First-come-first-served, so in arrival order what (in common use in runway utilization)

• Random order,

• Last-come-last-served,

• Priorities, like the urgent service firstly or the shortest processing time first (setting priorities on the largest aircrafts in peak periods) [Gross, Donald, Harris, 1998].

Among above characteristics of queues we can also mention some others like the behavior of the customers, service time and capacity and the waiting rooms. The behavior of the service is not very topical in given problem because a pilot of aircraft will not leave the waiting line due to impatience, which can happen in other types of queues. The waiting rooms are also not applicable in our case.
Whereas the service capacity simply refers to the number of servers, the very important characteristic is service time. Usually it is assumed that the times spent for service is independent of each other and inter-arrival times and identically distributed. The service times can be for example exponentially distributed or deterministic and depend on the length of the queue.

For the purpose of this article, the runway capacity is analyzed by the characteristic of M/M/1, M/G/1 and M/Er/1 queues. In all of the considered cases, the Poisson arrival process is applicable. It differs in terms of service process, which will be respected as Poisson, General, or Erlang distributions [Cooper, 1981].

In M/M/1 Queue, each queue could be described by the arrival rate λ (which is the number of customers arriving to the system of service in the accepted unit of time) and the service rate (known as the number of application to the system in the accepted unit of time) [Jędrzejczyk, Skrzypek, Kukuła, Walkosz, 1997]. In this model with single server, exponential inter-arrival times with the mean $1/\lambda$ (which is also the intensity of arrival) and exponential service times and the mean $1/\mu$ (known also as service intensity will be analyzed. The customers will be served in the arrival order. The occupation rate is p is given by the formula 1:

$$p = \frac{\lambda}{\mu} \tag{1}$$

The value p is the fraction of time when the server is working. The occupation rate is considered by the three possible values. If p is equal 1, the system is able to serve one unit per one time unit and such situation causes the system during its work will serve the exact number of customers that are willing to use the station. If the $p > 1$ the length of the queue could explode, the queue will become longer with every arriving customer and considering infinite time of working will never be totally served. Finally, in the last case when $p < 1$ the system in long run is stable, however some waiting lines might appear in some periods of the day depending on the density of the interarrivals. The exponential distribution gives opportunity to very simply describe the system at the time t state or the number of clients in the system (like customers which are served or the one which wait in the queue). It is neither necessary to remember when the arrival of the last customer occurred nor to register entering the service by the customer [Adan, Resing, 2002] . The other formulas considered in the model as given below:

- The mean number of the customers in the waiting line E(Lq) is given by the formula 2:

$$E(L^q) = \frac{p^2}{1-p} \tag{2}$$

- The average waiting time E (W) is represented by the formula 3:

$$E(W) = \frac{p / \mu}{1 - p} \tag{3}$$

- an expected number of users in queuing system is calculated by formula 4:

$$L = \frac{\lambda}{\mu - \lambda} \tag{4}$$

- the expected time spent in the system by the one customer is calculated by formula 5:

$$W = \frac{L}{\lambda} \tag{5}$$

Formula 1,2,3,4 and 5 refers to the queue M/M/1[Cooper, 1981] can be used to present the situation on the runway in examining period of the day.

In M/G/1 Queue, it is reasonable to give some basic characteristics and differences from other types of queue. In M/G/1, the arrival of the customers happens according to the Poisson process and the rate λ. This queue is not a continuous-time Markov chain because the service time need not have the exponential distribution. Similar to the previous investigated queue, they are served in arrival order. The times of the service are independent and distributed in identical way with including distribution function FB (·) and Fb (·). For the stability the occupation rate (p= λE (B) is required to be less than one.

In this queue the state (a summary of its prior history that suffices to evaluate current and future actions [Denardo, 2002]) of the system normally consist the number of the customer in the system and the time that has elapsed since the customer who is being served entered service. As mentioned before, the arrival process is Poisson (memory less) so the state does not include the time that has elapsed since the last arrival. The service distribution is not assumed as exponential. In order to determine the distribution of the time that remains until service is complete, the state must include the time that has elapsed since service began. The formulas considered in the model as follows:

- The mean number of the customers in the waiting line E (Lq) is given by the formula 6:

E (All) = λ E (W) (6)

- The average waiting time E (W) is represented by the formula 7:

$$E(W) = \frac{\overline{\frac{\lambda}{\lambda - \sigma}}}{p - 1} \tag{7}$$

- Formula 8 gives an expected number of users in queuing system:

$$L = \frac{p^2 + \lambda^2 \sigma^2}{2(1 - p)} \tag{8}$$

- And finally the expected time spent in the system by the one customer is represented by formula 9:

$$W = \frac{L}{\lambda} \tag{9}$$

Formulas 6, 7, 8 and 9 refer to the basic characteristics of M/G/1 queues [Cooper, 1981].

In M/Er/1 Queue is the last from queue types. The Erlang distribution in service station part of the system could be used to model times of the service which has low coefficient of variation(low means less than one), but it can also arise in natural way. The example might be the job, which has to be proceeding systematically, through the series of r steps that are independent where every stage takes time with exponential distribution. While analyzing the M/Er/1 queue it easy to observe that is it alike to the M/M/1 queue. The analyzing waiting line possess single server and the arrival of the clients is according to the Poisson process where the rate is λ. They are treated in arrival order and the queue has service time is Erlang-r distributed where the rate is r/μ. The occupation rate (p = λr/μ) as in the previous examples is required to be less than one [Adan, Resing, 2002].

The natural way of describing the state of the system which is nonempty is by the pair (k,l), where k indicates the number of clients in the system and l the remaining number of service phases for the client who is in service [Adan, Resing, 2002] . The formulas considered in the model as follows:

- The average waiting time E (W) is represented by the formula 10:

$$E(W) = \frac{p}{1-p}\frac{r+1}{2}\frac{1}{\mu} \tag{10}$$

- The mean number of the customers in the waiting line E (L^q) is given by the formula 11:

$$E(L^q) = \lambda E(W) \tag{11}$$

- formula 12 gives an expected number of users in queuing system:

$$L = \frac{\lambda}{\frac{r}{\mu} - p} \tag{12}$$

- And finally the expected time spent in the system by the one customer is represented by formula 13:

$$W = \frac{L}{\lambda} \tag{13}$$

Formula 10, 11, 12, and 13 refers to the characteristics of the M/Er/1 queue [Tijms, 2003]. The considering queue differs from the previous two types by the fact it allows to divide the service process on stages or steps. This characteristic is included in the simulation.

Simulation

The simulation, which will be used for the above stated purpose, is limited to discrete event digital simulation. Digital simulation means that the simulation occurs entirely inside a digital computer, and discrete event means that the studying system can be viewed intermittently, not continuously.

A discrete event digital simulation can emulate systems that evolve in continuous period and the laws of this evolution are governed by discrete events. In addition, queuing systems illustrates this point well. A queue evolves in continuous time, but it can be described in terms of a sequence of customer arrivals, service initiations, and service completions. The simulation of the runway queue keeps all of those features that why it is reasonable. The simulation uses the generator of pseudo-random number what makes it stochastic model. In its result, it will produce the set of data what is typical characteristic of static simulation. Moreover, only one computer is used to perform the simulation so the model will be local.

A simulation imitates the behavior of a system, but it does not show how the system should behave. It neither tells which settings of the system's parameters cause the best performances. It is important to remember that in nearly every digital simulation the central role is played by the uncertainty. Sometimes, when a simulation samples uncertain quantities, its result produces the behavior of a system in a particular instance, what in consequence delivers the situation in which simulation has to be run many times in order to get the average of the system behaviors. In the same case, it is required to perform repeatable simulation and to experiment with a variety of parameter settings in order to verify how the system reacts to different settings of its parameters [Denardo, 2002].

There are three areas of computer simulation, which are interconnected on each level of simulation: model design, model execution, and model analysis [Denardo, 2002]. The simulation model presented by this work is a simple approach to the problem of optimizing the runway at the airport and slot management. It is designed to reproduce a phenomena or its behavior by creating a model, which comprises dependencies that occur in it.

Implementation environment

This topic focuses on the implementation environment, which is the VBA language in Excel environment. Visual Basic for Applications (VBA) is based on Visual Basic (VB) programming language, implemented in Microsoft Office applications and several others, like popular in designer and architecture' environments AutoCAD. This simplified version of Visual Basic is used primarily for automation of work with documents, for example through macros [Walkenbach, 2002]. A macro is a set of commands that can be run with just one click or press of the button. Macros can automate almost anything that can be done in preparing program or spreadsheet and sometimes even allow increasing the usability of it by fastening the basic work with the program and make some calculation more automatic. Macros are a kind of programming, but the applied in the programming language is logic and by the numeric specialist considered as one of the simplest. Often there is not even required to be a professional programmer to successfully create or use them. Most of the macros that can be created in Office programs are written in Microsoft Visual Basic for Applications, usually abbreviated VBA. Macros save time and extend the programs usability during every day work with it. They could be to automate repetitive tasks during creating documents, simplify hard tasks, or create solutions, for example, to automate document creation in often-used formula. The VBA language allows using macros to create custom add-ons, such as templates, dialog boxes, and even to store frequently used information. There is no debate that the macros are mostly harmless and helpful, they are however an important issue from the perspective of system security. For the purpose of the simulation models explained in this article, the macros are mainly present the results of the simulation in a better way and give the user who browse those results the opportunity to choose the model of the simulation.

Simulation structure and Decisional situation

Using the capabilities of the program MS Excel and standing behind it language Visual Basic for Application, we can perform a simulation of the problem of runway capacity. Then a user interface can be built and the application stands behind it, which allows examining the utilization of airport runway during a given the period of the day. The Chapter's structure starts from the defining the characteristic of the problem scope and the processes of decision making in the investigating situations. Firstly, the presentation of the decision problems of the subject and the process of simulation and building the application is to be done.

For the purpose of the simulation, any airport, which fits the given criteria can be chosen. Firstly, it is necessary to perform a simulation on the airport with one runway, because it is simplest runway configuration and acts as a single server model. More than one runway at an airport builds a great complexity. In reality, it is usually dynamic decision of Air Traffic Control Tower, which allocates the runway for aircraft landing, or aircraft take off. For testing the model it is advisable to select the aerodrome that has the busiest one-runway system and possesses capacity comparable with some two-runway equivalents. This will make sure that if the model provides exact results for a complicated single runway system airport then the final application will be able to examine any single-runway airport in world.

Next step is to choose the period to examine. The selection of the appropriate period directly depends on the historical data taken into account. As it was mentioned before, the slots are allocating for the particular flight on the seasonal basis, which implies that for half a year the flight schedules for peculiar day of the week will reiterate for the whole six-month season. For the purpose of the simulation, the time period can selected randomly, for example selected period can be between 7.00 pm and 9.00 pm. To select time period, which will adequately test the creditability of the model, it should be kept in mind that the time period with maximum number of movements can be taken into account. The created application will give an opportunity to its user to unrestrictedly choosing the period of the day and the study over it, what is also helpful is that in examining the periods of the day hour after hour and choosing the peak periods in simpler way will make the analysis and optimization clear.

After characterizing the scope of the problem and the decision taken to the simulation process, next step is launching the model. In the next sub section, the exact process of launching the model is presented.

Model Launching

This sub-section provides an important insight in launching the model. First step of launching the model is the selection of the appropriate simulation software, which is a computer program imitating a real life process using a set of mathematical formulas. In this case, as mentioned in the simulation environment, MS Excel can be used as it possess all the required tools and methods to perform the simulation. The simulation can be performed easily on the computer with the parameters appropriate to perform the simulation.

The steps for launching the model i.e. overall simulation is provided below. These steps also provide answer to the various issues defined previously.

Step 1: Firstly, it is reasonable to study the whole normal day of the operations on the runway and pick up the busiest period. It will simply identify the hour, when the number of movements is the largest or when the airport suffer due to the incapacity. Possessing such knowledge, it will be possible to advice how to unburden overloaded period by dynamic slot management that is normally conducted by the Air Traffic Controllers. Due to that need, the first part of the simulation model will focus on identifying the busiest period or using the appropriate nomenclature – peak period during the everyday operation. For that goal, the model of queue M/M/1 seems to be the most appropriate in its readability and that is why this part of work will use it.

Step 2: As the main goal of the simulation is to examine, using Queuing Theory analysis, whether the runway of an airport creates a waiting lines or the aircrafts landing on or taking-off from that runway make their movements without any delay. The three way approach already mentioned previously is applied to the given research problem due to the examination and consideration of the runway utilization from the point of view of three different queues – M/M/1, M/G/1 and M/Er/1. Each of them will produce different results; however, the major trends and indicated problems with capacity are expected to be similar.

Step 3. Each queue will be investigated in the long term. This can be done more precisely by analyzing the crucial parameters obtained from the simulation. The important parameter will be copied to the table where the further investigation can be conducted. This step also uses the model for clarifying if the queue is stable in the longer run. Testing if queue is stable in the longer run implies the number of attempts or the observations of inter-arrivals customers to the queuing system. This particular clarification can be conducted for all of the queuing models chosen to simulate the operations at the airport runway.

Step 4: After step 3, we can compare the results that are obtained by three different probability distributions in service station– Poisson process, General distribution, and Erlang distribution. It is also reasonable to compare the results of mean inter-arrival and service times got form the simulation.

Step 5: this particular step will test if the system of slots are planned in optimum way and if particular flights catch their slot or they more often miss them causing additional delays and costs for the both airlines and airports. The simulation counts up the aircrafts that have missed their slots what is another factor indicating if the single-runway system works in optimal way and is not queue creating. The missed slots are counted in the examined period of the day and both operational and economic efficiency are derived.

Step 6: during this step, we can estimate the economical aspect of the runway utilization and capacity. The major problem of the airlines, beside the insufficient number of slots that the airport offers in the most attractive periods of the day, is additional costs caused by standing in queue or missing the slot. The economic parameter, which can be estimated here, is the cost of fuel consumption considered by the type of movement and extra costs of missing the slot that will be summed up and can be presented in the results section.

Step 7. This step is the decision making step. From the knowledge attained from the previous steps of simulation, the airport managers can analyze their airport runway and based on the results judge if it is used in optimal way or some upgrades and changes are sought to be made.

Hypothesis Testing

On based of the results, several hypothesis can be tested . The following hypothesis can be investigated:

Hypothesis 1: Occurrence of the busiest period or the peak period

Hypothesis 2: Airport capacity's situation for stability and profitability.

Hypothesis 3: The stability of the situation on the researching airport.

Hypothesis 4: The influence of the number of events on the parameters used in main simulation.

Hypothesis 5: fixed maximum number of aircrafts that missed the slot in a particular investigating period.

Hypothesis 6: The airlines at the airport do not suffer due to additional costs caused by missing the slot or extra fuel consumption.

Conclusion

The simulation model presented in this article has a practical application. It can be used to analyze the various operational aspects of the runway system. The final simulation will equip the manager will a powerful tool to access the efficiency of the runway while keeping in view both operational and economic aspects of the business. Various conclusions which an airport manager can draw from the simulation are closely correlated with the hypothesis mentioned in the above section. In general, the simulation model developed in this article will provide the information related to various factors mentioned below:

- the air traffic behavior and customer segmentation from the peak periods;
- the bank structure at the airport;
- overall air side capacity utilization and its overall profitability;
- number of aircrafts waiting in the queue at a particular instant of time;
- additional costs which can be incurred by the airlines;
- and lastly the efficiency of various strategies incorporated to improve the air side operations.

This type of modeling will be used by all the airport in order to minimize the losses due to congestion of air side. The model is lost cost and can be initiated and used easy while providing the exact results.

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