Model For Reduce Flights Delays Using System Dynamics 
(Case Study in Iranian Airports Company) 

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Abstract 
In our country, whenever delay of flights is spoken, mind of every Iranian is concerned to the sanctions, shortage, bottleneck and aging aviation fleet unconsciously. But, studying records of flight delays in the past few years available in the Flight Data and Statistics System of Airports Company specifies that each of system components in turn can affect flights’ delay in air transportation system noticeably. In this study, system dynamics simulation is used to model flight delays reduction pattern for the first time in the aviation industry of the country. System dynamics is the perspective and set of conceptual tools which enable us to understand structure and dynamics of the complex systems. This tool is a subtle modeling method which gives us special ability to understand systems in simulation basis. This study has first identified factors which have been found effective in the flight delays and then, relationship between these factors has been specified. Finally, a model has been presented to establish relationship between these factors and strategies to reduce delays, caused by them, using system dynamics. A mental model is first considered to build a dynamic model. Then, causal diagrams will be used. Finally, these causal diagrams are converted into flow diagram using Vensim software package in order to achieve the desired results. In the model output, it can be observed that how increase or decrease of delay, caused by a factor, can affect general delay of flights? 

Keywords: Airport, System Dynamics, Flights Delays. 

1- Introduction 
In a system like air transportation system with its numerous complexities and costliest activity, the word “delay” is followed with other words such as cost increase, profit reduction and/or even gaining loss and negative political, psychological and social aftereffects. In recent two decades, increased air delays, due to the increasing number of flights, have provided necessary ground for this industry to accelerate activities and use facilities more optimally, available space and taking advantage of all existing equipment and capacities. Thereupon, the discussion of reducing delays through various methods and managing delay stages is one of the basic concepts of air traffic management. Air transportation is a system of different chained components; delay of each component will cause increase of domino delays such as flight. As a matter of fact, reducing flight delays, regarded as main subject of this study, is one of the unpleasant problems and phenomena which our country’s air transport industry faces it like many other countries and hefty costs are spent annually in the country as a result of flight delays. (Shahraki, 2009). This study tries to identify and analyze parameters which are effective in reducing flight delays. If fact, doing such research activity requires the tools in order to define structure and components of system, consistent with their actual specifications and relations. Moreover, possibility of participation of users of various levels in developing the model should be considered as one of the advantages of these tools. System dynamics approach is the object-oriented simulation approach based on feedback relations which creates simplicity and noticeable speed in defining system and developing the model in addition to establishing participation of users of each model in its development. The possibility of models’ group development and simplicity of correcting model in response to the changes in system is of the features of this method. System dynamics is the method of understanding certain types of complex problems of
the system. In fact, this course has been originated from the industry and problems arising from it. (Hamidizadeh, 2000, 34)

2- Statement of the Issue

In recent years, the interest of air travels has turned the aviation industry into the important and effective industry in the arena of global economy and transportation management. Different statistics, published by International Civil Aviation Organization, shows that aviation industry has faced average growth in 2011. However, a brief review to the situation of this industry in recent years shows that, despite progresses of this field, problems have been created, causing passengers’ dissatisfaction that are considered as main customers of this industry. Inattention to these problems will face the aviation industry with serious and deep challenges and consequently, passengers will be dissatisfied. Flight delays are one of the most important factors of these problems.

Statistics show that most airlines, despite efforts and planning made in this regard, lose major portion of their budget and time due to the flight delays. However, they feel objection of passengers at any moment. These delays are mainly related to the chain of air transport services sectors, based on which, necessary steps should be taken in this regard in order to prevent other sectors of this industry from delaying.

With due observance to the abovementioned explanations, and since Iran Airports Company, owning 54 equipped airports, is considered as a specialized holding company tasked with streamlining airport activities, it is necessary that problem of delay should be taken into consideration in such company. It is obvious that a flight delays reduction pattern, provided with system dynamics method, can help solving this problem greatly. According to Sterman, who is regarded as veteran of this scientific system,”“System dynamics is a subtle and professional modeling method which uses capable systems in manufacturing computerized simulation and using it will lead to design organizations and adopt effective policies.”

“In contrast, these tools make it possible to manage ambitious simulations.”

The necessity of applying scientific and professional methods based on documentary and instrumental data in order to find main roots of flight delays, happened in country’s domestic passenger flight network, isolation of share of each of components in order to valuate effective parameters and finally achieving a model to reduce flight delays are of the main problems put forward in this study. In this study, we are after presenting a model to reduce flight delays in air transportation system, using system dynamics. Causal diagrams will be used in order to build dynamic model. That is to say that a systemic program of these diagrams is used to implement mental model. Finally, these causal diagrams are turned into flow diagram using Vensim software package in order to achieve the desired results. (Sterman J.D, 2000,15)

3- Research Questions

1- What are the factors affecting flight delays?

2- What is the suitable pattern to reduce flight delays?

4- Review of Literature

4 – 1 – Definition of Delay

The time interval between preplanned time for taking off and actual time of take off is called flight delay (www.cao.ir,2012)

4 – 2 – Delay in Iran Airports

In 2011, of total 54 airports in Iran Airports Company, 48 of which were busy active, offering quality flight services to the passengers. The rest airports had not any flight activity due to the factors such as reconstruction, improvement and prolongation of runway. Total domestic and foreign flights of these airports, mentioned in above, stood at 322,905 while total delays stood at 5,532,387 minutes, i.e. about 17-minute delay was observed in each flight. (http://www.airport.ir, 2012)

4 – 3 – System Dynamics

System dynamics is a methodology to study, analyze, simulate and improve dynamic social, economic and management systems, using a feedback approach. (Barlas, 2006, 79)

In systemic contemplation and system dynamics, the tools are used in order to display structure of a system for its better understanding. Causal loops and flow accumulation diagram are the two important tools for systemic contemplation which these two diagrams have been used in the study model to reduce flight delays.
5-Open Analysis

5 – 1 – Open Coding

Open coding is a part of analysis, based on which, the data related to the subject of study are named precisely and then are categorized. (Soltaninejad, 2012, 119)

5 – 2 – Identifying Effective Parameters in Flights Delay and Delay Factors and Classifying Them

Two references of Flight Data and Statistics System of Iran Airports Company and comments of experts and technicians are used to identify flight delay factors. These two factors will be discussed later.

Table 1. Factors in delayed flights

<table>
<thead>
<tr>
<th>Factors in delayed flights out of the system boundary</th>
<th>The (parameters Factors flight delays within the system boundary used in the model)</th>
</tr>
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<tbody>
<tr>
<td>push back Facilities</td>
<td>Delay, passenger services</td>
</tr>
<tr>
<td>Logistics airlines</td>
<td>Output toll</td>
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<tr>
<td>The number and size of parking space plane</td>
<td>bagage delivery</td>
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<td>Buildings and terminals</td>
<td>Passport</td>
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<td>Dedicated staff parking</td>
<td>Customs</td>
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<td>Access to airport</td>
<td>Delay passengers</td>
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<td>The competitive transport market</td>
<td>check in</td>
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<td>Fleet Renovation</td>
<td>Flight restrictions</td>
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<tr>
<td>Comprehensive management of airport</td>
<td>Military flights</td>
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<tr>
<td>Computer Flight Coordination Network Deployment</td>
<td>VIP flight</td>
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<tr>
<td>Lack of materials</td>
<td>scrambling</td>
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<tr>
<td>Crisis Management</td>
<td>Emergency flights</td>
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<tr>
<td>Public Transportation to airport</td>
<td>Refueling</td>
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<tr>
<td>(VIP) passenger</td>
<td>Air traffic control (ATC)</td>
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<tr>
<td>Air transport policy</td>
<td>security check</td>
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<td>Management and human resources</td>
<td>crew delay</td>
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<tr>
<td>Supervisory Civil Aviation Organization</td>
<td>The delay in the arrival and departure of aircraft</td>
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<td>prohibitions</td>
<td>Natural Factors</td>
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<td>Meteorology</td>
<td>Disaster</td>
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<td>Old Navy</td>
<td>weather conditions</td>
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<td>Flights in same time</td>
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<td>Human Error</td>
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<td>Air Traffic</td>
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<td>airport size</td>
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<td>Increase technical centers</td>
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<td>Modern equipment</td>
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<td>Coordination</td>
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<td>Standards</td>
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<td>Airline delays due to performance</td>
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<td>Communication, navigation and surveillance systems (CNS)</td>
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<td>Qualified and experienced staff</td>
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<td>Aircraft defects</td>
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<td>police</td>
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<tr>
<td>IRGC</td>
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5 – 3 – Determining Weight of Factors Affecting Flight Delay

Weighing and determining our coefficients are done in two parts:
A: Determining weight of each of factors and parameters affecting flight delay which has been registered in Flight Data and Statistics System of Iranian Airports Company directly.
B: Allocating weight to each of factors affecting flights delay which have not been registered in Statistics and Data System of Iranian Airports Company directly, but a factor involves all of them.

A: Determining weight of each of parameters affecting flight delay which has been registered in Flight Data and Statistic System of Iranian Airports Company.

In the present studies, weight of parameters affecting flight delay has been measured in two parts and two methods. In the first part, flight delays in 2009, 2010 and 2011 have been studied with referring to the Flight Data and Statistics System of Iranian Airports Company. So, percentage of impact of important parameters, which have been mentioned by Iranian Airports Company as main reasons of flight delay, is obtained from reporting system.

Hereunder are the parameters, available in Flight Statistics and Data System of Iranian Airports Company, which enable us to report the main reasons of flight delay according to them:
- Technical defect
- Performance of company
- Weather conditions
- Delay in aircraft arrival
- IRGC
- Air traffic control
- Customs office
- Passport
- Refueling
- Delay in output
- Other reasons

Iranian Airports Company (IAC) embarks on collecting statistics of flight continually and also delay of all airlines’ flights daily thanks to the general classification behind main reasons of flight delay using a system installed in all its affiliated airports. Through using these statistics, share of each flight delay reasons can be achieved out of total amount of extant delays.

Since a remarkable number of these reasons include subset of delay reasons, and in fact, each of the delay reasons, which have been mentioned by Iranian Airports Company in Flight Data and Statistics System, includes several various reasons of delay that has been classified in one group. The subcategory factors and their weight need to be identified. If one flight delay reason is not envisioned in none of the aforementioned 10 cases, these factors have been considered in column of other reasons.

In this study, other reasons are also classified in the next chapter using comments of experts and specialists. At the end, share of each of delay reasons can be achieved from total amount of extant delays. The Flight Data and Statistics Base of the company is considered as the sole comprehensive and official database. The percentage of flight-delay reasons in 2009, 2010, and 2011 are shown separately based on name of Airport of Airline Company, number and duration of the delayed time.

The weight obtained from percentage of impact of these 10 cases in flight delays in 2009, 2010 and 2011 is as follows:

With the studies made in this regard by the Iranian Airports Company on the flight delays in 2009, 2010 and 2011, shows that technical defect, performance of airlines, weather conditions, delay in arrival, IRGC, flight care, customs office, passport, fueling, delay in output and other reasons account for 10, 29.8, 5.9, 10.96, 3.8, 2.26, 3.43, 2.2, 3 and 3.7 and 24.95 percent respectively. (http://www.airport.ir, 2012)

B- Determining weight of each of parameters affecting flight delay has been registered in Flight Statistics and Data System of Iranian Airports Company as other reasons:

Comments of managers and experts of air transport industry were used in order to study and identify reasons and determine share of each of components and secondary causes of delay in flights of airports of Iranian Airports Company which has been mentioned in Statistics and Data System as other reasons.

Totally, 23 employees employed in the Airline of the Islamic Republic of Iran, Mahan Airlines and Kish Air Airlines participated in this survey and presented their expert-level comments to identify factors behind flight delay. These persons are among the expert and specialist employees of the mentioned airlines with their different job positions as follows:
- Head of Station
- Pilot
- Air Hostess
- Dispatch
- Coordinator
- Traffic

Also, 28 employees of Iranian Airports Company participated in this study with the following positions: 1- Director General, 2- Deputy Director of Aviation Operations, and Deputy Director of Airports Operations, Terminal Dept. Manager, 5- Care Flight Controller, and 6- Employees of Airport Facilities Department.
In the interview conducted with the experts, they were asked to explain other reasons affecting flights delay other than technical defect, performance of airlines, weather conditions, and delay in aircraft arrival from previous destination, IRGC, care flight, customs office, passport, fueling and delay in output. After providing a list of all the identified factors, at the second stage, they were asked to allocate a weight percentage to the factors affecting flight delays due to their experiences in the aviation industry. The interviews conducted with the experts of this industry produced fruitful and very positive results.

5 – 4 – Final Causal Diagram

The relationship between variables is shown by this tool as unidirectional and bidirectional basis along with their positive and negative impact on each other simply. The causal diagram is shown according to the below figure after determining border of system and finding out the relationship of factors inside the border.

Figure 1. Causal Diagram
5 – 5 – Model Flow Accumulation Diagram

Loop causal diagram is turned into the flow diagram in order to conduct more detailed quantitative analysis. Flow diagram shows relationship of level and rates in a system. Accumulated flowchart shows the way of relationship between variables of a system with each other and can be considered as a base for developing a quantitative model. Based on the studies made in this regard and getting viewpoints of the senior experts in the aviation industry, important variables affecting flight delays were identified and relations between them were specified as well. Finally, the flowchart of the issue was provided as follows.

5 – 6 – Execution of Model

Model is executed after setting number in model and writing equations and weight of factors and diagram of some model accumulations and also flight delay variables after execution stage during five years from 1389 to 1393 (2010-2014) is as follows:
In this part, a number of parameters are changed in order to see results, output and sensitivity of the model. It is expected that the output, which is the model general delay, will be changed according to the significance and weight of that parameter. In other words, deceasing or increasing impact of one or more factors in flights delay is due to decrease and/or increase of that change in the delay.

Sensitivity of model to change of some variables indicates significance of the variable.

5 – 7 - Analysis of Delay Sensitivity Resulted from Change of All Factors

In this part, it is tried to answer the following questions: “What changes are obtained in the general delay with decreasing and/or increasing 5% delay of all factors? and/or “What measure can be predicted for the year if 5% delay of all factors is decreased in a year? And Vice versa.

Like the previous example, green-color line, which is marked with Figure 3, indicates normal conditions before the change while blue-color line, which is marked with Figure 1, indicates the delay resulted from all quantitative factors. Generally, total delay has been decreased as well. The red-color diagram, marked with Figure 2, shows that conditions that delay resulted from all factors has been increased and thereupon, the delay has been increased as well.
6- Conclusion

In this study, a model was presented in order to decrease flight delays in the airports affiliated to Iran Airports Company using Vensim software package. The constituent factors of this model have been selected according to the official data and documents of Iranian Airports Company and also expert-level comments of the experts and relationship between these variables has been specified. The pertinent data are collected using library documents and studies and also viewpoints of relevant experts, details of which were considered in the model. After that, model was executed and the results were specified. Finally, model sensitive analysis was studied.

The results were observed with the increase and decrease in significant delay factors in total delay output and then, they were compared with each other. According to a model, which has been developed based on this study, there are a set of factors and parameters in air transport industry of the country which can be effective in reducing flight delays. Finding out factors and presenting a model to reduce flight delays is the main objective of this model.

With the execution of model and impact of each of parameters on other factors and with studying the model, it can be concluded that all factors and parameters involve directly and indirectly in reducing and/or increasing flight delays. For example, delay in aircraft arrival affects flight delay positively and directly. That is to say that with the increased delays, resulted from delay in arrival of aircraft, general delay is increased immediately. Also, some factors affect flight delay negatively, i.e. if these factors are increased, flight delay is reduced. The most important of which, it can be referred to: observing standards which affects flight delay reduction negatively. That is to say that flight delay will be avoided through observing standards and standardization of aviation industry to a great extent.

Now, some factors affect flights delay indirectly, the most important of which can be referred to the expert and experienced employees. In the aviation system, cooperation and coordination will be increased under the auspices of experienced and trained employees. Under such circumstances, lack of interaction and cooperation is reduced in this system and consequently, flight delays are decreased remarkably.

Delay caused by the security agents is the other factor affecting flights delay which affects directly on airport delay factors and indirectly on the delay as well. The security agents can be divided into three groups of Police, IRGC forces and guard of airlines. Of total three factors i.e. police, IRGC forces and guard, the factor of IRGC plays a leading role in flights delay. Air traffic is the other effective and important factor in increasing flight delays. The more air traffic is increased; it leaves more impact in increasing the flights delay. Factors such as human error, coincidence of flights time in an airport, due
to the limited capacity of the airport, and defect of airport systems and equipment, and lack of coordination can be effective in increase of air traffic of a region or airport. Also, flight limitations in an airport are the other factor in this respect, based on which, complex of factors such as military flights, VIP (very important persons)flights, air tracking flights, and emergency flights can be effective in emergence of these limitations, although the abovementioned flights are prioritized in taking off and landing procedures according to the international aviation rules and regulations.

Effect caused by airport agents and also passenger services delay is the other important factor in this respect. These delays could be due to the long queues behind bank counters to pay exit toll from the country, long queues behind passenger reception counters due to the shortage of airport equipment such as conveyor belt, reception and personnel desk, or delay as a result of standing for a long time in checking passport and customs office. Each of them, due to the shortage of personnel and equipment, can lead to the slowness in trend of formalities of receiving passenger of airports as well. Such delay can be observed in large airports in the early hours of morning as well.

As mentioned in the above examples, each of the variables can be effective typically in increase or decrease of the flight delay and if the relationship is turned negative, delays are reduced and if the relationship turned positive, the delays are increased.

7- Suggestions

With due observance to the identification and study of delay factors and value of their impacts in total delays of flights conducted in airports affiliated to Iranian Airports Company, the following suggestions can be put forward due to the model in reducing flight delays resulted from each of the delay parameters:

7 – 1 – The following cases are suggested to reduce flight delay due to the security control:

A: Installing gateway and x-Ray inspection system according to the number needed in this respect, utilizing more gates in transit gate,
B: Removing shortage of expert and experienced manpower in inspection departments of IRGC, Police and Guard of airlines,
C: Considering co-inspection backup system in order to replace with the main system if it is malfunctioned.
D: Activating surplus inspection gates during peak time of flights,
E: Since removal of inspection police in terminal entrance of some airports has reduced standing time of passengers noticeably, it is recommended to delegate inspection services of cargo to the police ONLY such as airports in Bam, Kish, Assaluyeh, etc. In other words, cargo should be inspected by police ONLY and passenger inspection should be removed.
F: Delay caused by guard chamber of Airlines can be minimized through increasing number of personnel and entrance gates at the flying time.

7 – 2 – Reducing Passenger Services Delay

For paying exit toll from the country personally in the banks stationed in foreign terminals, it is recommended to take effective steps to pay the exit toll in other banks via internet or personally before entrance of passenger to terminal. Also, it is recommended to install ATMs (Automated Teller Machines) and e-payment devices in foreign terminals in order to minimize standing time of passengers in banks’ queue.

7 – 3 – Check In (Reducing Passenger Admittance Delay)

It is necessary to remove all shortfalls and bottlenecks in this sector such as reception desk and shortage of personnel. Also, modern electronic systems should be used, like other airports in the world, to check in passenger, issuing flight card and admitting cargo carried by passenger.

7 – 4 – Reducing Delay Due to the Delivery of Cargo

In some airports, there are not enough weighing devices, conveyor belt and reception desk. These devices should be installed sufficiently.
7 – 5 – Reducing Delay Due to Passport

It is recommended to use a great number of passport gates in equal condition in large airports especially during peak hours of foreign flight.

7 - 6 – Reducing Delay Due to Customs Office

With crystallizing customs offices’ rules and facilitating some part of customs formalities, standing time of passenger for a long time can be decreased noticeably.

7 - 7 – Reducing Delay Using Navigation, Radar and Modern Communication Equipment

With due observance to the phenomenon of particles and dusts in recent years and vision loss in many airports, it is recommended to identify the airports which lack modern navigation and radar equipment. Necessary steps should be taken in this respect in order to install devices like ILS (précised lighting lamps) in these airports lacking necessary equipment and devices.

7 – 8 – Other Suggestions

- Making plan for noticeable shortage of bird to provide air travels demand and necessity of renovating bird appliances and decommissioning dilapidated and worn-out fleet,
- Intensifying coordination between traffic, technical and dispatch units, etc. airlines with modifying modern management methods and monitoring procedure
- Necessity of paying due attention to the airport facilities and capacities during grant of flight license by the airport managers
- Necessity of modernization, using modern technologies and electronic tools to shorten activities such as issuance of flight card, receiving cargo card, reservation, information services, etc.
- Paying attention to provide a substitute airplane (STAND BY) in highly-transited air routes in order to use substitute plane if the main plane encountered with technical problem.
- Training staff and personnel: Organizing necessary and specialized on-the-job-training courses
- Accurate and formulated planning for easy transport of flight crews to the airport in order to prevent flight delay
- Using strong and comprehensive database
- More interaction and cooperation of state and military airlines with one another,
- Necessity of developing light and short-range fleet with low operational costs for small airports in domestic routes,
- More cooperation of responsible organization in offering quality services at airports such as customs office, passport department, IRGC of the airport,
- Implementation of favorable airport management system and stabilization of status of Airports Company as parent and specialized company through legal supports.
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