

Using Lean Six Sigma Tools to Evaluate Air Travel Delays from Luis Muñoz Marín International Airport in San Juan, P.R.

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Abstract — *There has been an increase in the demand for air transportation creating more delays in flights. It is important for Puerto Rico to manage more efficiently their air transportation to be able to maintain a continuous flow of flights and prevent losing considerable amounts of money in flight delays. It is possible to analyze statistical data from Luis Muñoz Marín to identify areas that cause delayed departures. Using Lean Six Sigma tools, it is possible to understand better the causes of delays and then create plans to improve and reduce these. After analysis, it is possible to say that in 2013, the season with more passengers was summer and that the majority travel to Florida. Another observation is that the major causes of delays are aircraft late arrivals and air carrier delays. This type of analysis could be used by any airline to identify areas that they could improve.*

Key Terms — *Air travel delay, Causes of Delay, Lean Six Sigma, Luis Muñoz Marín.*

INTRODUCTION

During the past years there has been an increase in the demand for air transportation. Being P.R. an island, it becomes a challenge to efficiently manage cycle time in airport operations. The International Air Transport Association (IATA) announced full-year traffic results for 2013 showing a 5.2% increase in passenger demand compared to 2012 [1]. When there is an increase in air transit, there is also an increase in flight delays. As a result, flight delay becomes an important topic.

In Air travel, time is money and passengers may travel for business meeting or vacations. No matter what is the reason they want to arrive safely and on time. If airlines don't deal efficiently with these delays, passengers may get angry and may not

select that airline for future travels. It is important that airlines maintain their customers because there is a high competitive environment in the airline industry and passengers will select the airlines which maintain high quality standards in their services.

Dec 2013 vs. Dec 2012	RPK Growth ¹	ASK Growth ²	PLF ³
International	6.2%	5.9%	78.2
Domestic	7.4%	6.2%	79.4
Total Market	6.6%	6.0%	78.7

¹RPK: Revenue Passenger Kilometers measures actual passenger traffic

²ASK: Available Seat Kilometers measures available passenger capacity

³PLF: Passenger Load Factor is % of ASKs used.

Figure 1
Passenger Demand Increase

In order to reduce delays, airlines need to understand what are the major factors and contributors for delays. The five types of causes for delay are carrier delay, late arrival delay, NAS delay, security delay and weather delay. With a better understanding of these delays and statistical analysis, airlines could understand the areas that affect more their processes and create plans to improve them.

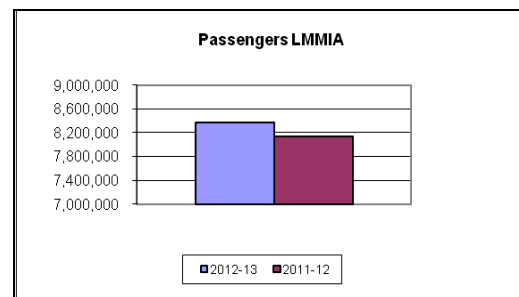


Figure 2
Passengers per Year in LMMIA

This project will be focused in International Airport Luis Munoz Marin (SJU). This airport is the major airport in the Caribbean region by passenger traffic. Over 8 million passengers board a plane at the airport per year, according to the Institute of Statistics of Puerto Rico [2]. Statistical data show that there has been an increase of 2.8% from 2012 to 2013. Knowing that this growth will continue it is important that airlines that provide services in Puerto Rico improve their operations.

Statistical data from 2013 of International Airport Luis Munoz Marin (SJU) will be analyzed. A pareto analysis will be used to identify the season were passengers travel more. After selecting the higher air traffic season, a pareto analysis will be used to determine which airline has more presence in SJU. For this airline, an analysis will be made to identify which of the 5 types of causes for delay affect them more. Using cause and effect diagram, it is possible to identify potential factors that cause delays in flights. The objective of this project is to use Lean Six Sigma tools to identify the causes of delays in SJU. Using this information, airlines with services in Puerto Rico will know which areas they can be focused on to improve their operations.

BACKGROUND INFORMATION

As a result of the continued growth over time, the number of flight delays has reached record levels. Increase in flight delay and cancellations cost billions of dollars per year to passengers and airlines. Air-traffic delays raised airlines' operating costs by \$19 billion. With each delayed flight, airlines paid extra for crew, fuel, and maintenance costs while planes sat idle at the gate or circled in holding patterns [3]. As well, delays are costly to passengers and crew members because they can lose business opportunities and vacation activities for example This could be worst if delayed flight delay other flight because will create the passengers could miss their connection, or flights be cancelled and may lose vacation time or money for vacation accommodation.

In 2008 the Joint Economic Committee Majority Staff create a report where explain the cost of this delay in the economy of the United States. In this reports explain all the involved cost when an flight is delay. Delayed flights cost the airlines (and customers) an additional \$1.6 billion in fuels costs, assuming an average wholesale price of \$2.15 per gallon in 2007 [3]. This will create an increase in the cost of the flight. Another observation from this report is that flights delays are longest during the months where more people travel. In the 2007 the 78% of the delays occurred before take-off. Almost 60 percent of flight delays occurred at the gate, and 20 percent of delays occurred during the taxi to the runway [3]. This means that the majority of the delays occurred when airplanes are in the gate.

A flight delay could be defined as when a flight takes off and/or lands later than the time that have been schedule. For the Federal Aviation and Administration (FAA) a flight is considered late when arrives or departure 15 minutes later than the time scheduled to do it. Sometimes could occur that the reason for the delay could cause that the flight will be cancelled. When a flight is delay or cancelled this could create other problems for the airlines. First, passengers will arrive late to their destination and for other may lose their connections. Lost customer loyalty by delay and services would be a cause for direct and indirect long-term consequences in the revenue of the company. This will affect the reputation of the airline and could cause the ruin of the company. There is a second reason why airlines could face problems. They may lose a lot of money. According to the US Congress Joint Economic Committee, the cost associated with domestic flight delays in the United States during 2007 was estimated at \$25.7 billion (\$12.2 billion in increased airline operating costs, \$7.4 billion in passenger time lost, and \$6.1 billion in costs to related industries) [4].

The FAA divided the causes of delay in five types. Carrier delay is within the control of the airline. Some examples of this type are: waiting for

passengers or crew that came late in connecting flights, airplane damage, cleaning in the airplane before boarding, fueling, engineering inspection, crew came late, maintenance, lavatory servicing, crew need to rest before another flight, food service, cargo loading, computer, weight, storage carry-on baggage and boarding disable passengers or family with children. This type of delay airlines need to have the ability to reduce. The second cause of delay is late arrival. Late arrival is when the airplane that will be used arrival late to the airport. This type of cause could create delay propagation. Delay propagation is when a delay flight causes a ripple effect in the subsequent stages of a flight. This means that flight arrives late at an airport and departs late, and then the same airplane arrives late to the next destination. The next cause is the National Airspace System (NAS) delay. The NAS delay includes when non-extreme weather conditions exist. As well, include heavy traffic volume, airport operations, air traffic control and delay that occur after the airplane exit the gate. The Security Delay is another cause. This one is caused by evacuation of a terminal, re-boarding an airplane because a concern with security, when screening equipment is out of service or damage and exist line of screening that exceed 29 minutes. The last cause is weather delay. The weather delay is defined as extreme or hazardous weather condition that is presented in departure, enroute or in the arrival of a flight. One example of this delay is January snow storm. More than 49,000 flights were canceled and another 300,000 delayed in January as airlines lost \$75 million to \$150 million because of costs such as deicing jets as well as lost revenue. 30 million people had their flights canceled or delayed. Flight cancellations cost passengers an extra \$2.5 billion in meals and extra hotel bills in January alone. Many stranded passengers had to wait days — and in a few extreme case up to a week — to get a seat on a flight out [5].

METHODOLOGY

This section provides a detailed plan of how the research will be performed. Statistical data was found in the Research and Innovative Technology (RITA) database. RITA is a unit of the United States Department of Transportation. This page provides data and statistics of the different methods of transportation in the United States. For this analysis airlines and airports was selected. RITA have different database related with the air transportation but for this analysis the only information needed is the amount of passengers traveling from Puerto Rico and the season they travel. Database T-100 Domestic Segment (U.S. Carriers) was selected. This table contains domestic non-stop segment data reported by U.S. air carriers, including carrier, origin and destination. The months were divided in 2013 season: summer (June, July and August), autumn (September, October and November), winter (December, January and February) and spring (March, April and May). After download data this were divided in season and then a table was created with the amount of passengers travel from the SJU in the different season. Using a pareto chart data will be presented. Pareto charts is a tool that help to identify and categorize the source of problems or common causes. In this case is to identify the season when more people travel from the SJU and can be the reason for the major amounts of delays.

When the season is selected another table is created with the information of the different airlines that provide services during the season selected. This information is also obtained using database T-100 Domestic Segment (U.S. Carriers). A pareto chart is created and after analyze data airline with more presence in the season selected is used for the next stratification analysis.

Another database from RITA is used for the next analysis. This database is Airline on-time statistics and delay causes. Before download information from database it was filtered by the airport. For this analysis the only information selected is the only related with SJU. Then with the

information downloaded the season selected was filtered. A table was created with the different causes of delay in the season and airline selected. A new pareto chart will be created and information will be analyzed. This information will help to understand which is the major offender.

When the major offender is selected an Ishikawa diagram will be performed. Ishikawa diagram or fishbone diagram method is used to identifying causes an overall effect. The causes are group into major categories to be able to identify the sources of variation. Figure below demonstrate how a fishbone diagram need to be made [6]. For this analysis five categories will be selected. These categories are: Manpower, Environmental, Equipment, Material and Procedure. Each category will have a list of possible reason of why airplanes departure late. This type of analysis will help to identify specific areas were airlines can improve to reduce delay in their flights.

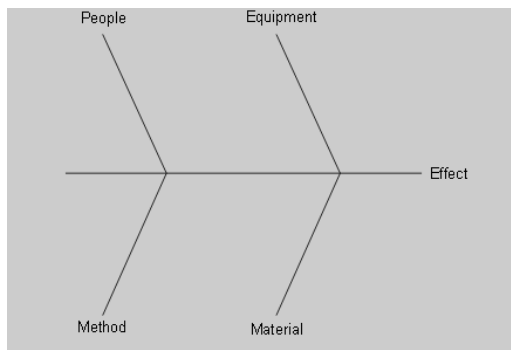


Figure 3
Cause and Effect Diagram

RESULTS AND DISCUSSION

The first step was to analyze data for the different seasons. In the figure below the pareto chart for the different season demonstrates that there is no a significant difference between season. Using 80-20 rule it cannot be possible to say that major caused for delay are from summer or if we focus our analysis in delay in the summer it is possible to reduce significantly the total amounts of delay. There is only a 1.9% of difference between summer and spring. We can infer that in Puerto Rico people travel more in summer because this is

the time of the year that majority of the person have vacations. The second season that more people travel in Puerto Rico is spring. This could be because in this time people take advantage of the low cost of flight to take vacations or travel during the Holy week.

Summer season was selected for this analysis but any season could be used. The reason for select summer was that have the major amount of people traveling and it should have the major amount of delay. While more people travel more are the possibility to have congestion and travel delays. A new pareto was created with the airlines that provides services for the summer season. As illustrated in the pareto below Jetblue is the airline that have more passengers traveling during the summer. We know that right know Jetblue is the airline with major presence in Puerto Rico. They have all the new Gate A in the SJ and continuously are they added new flight for different destination. Although Jet blue is the airline with more passengers if the rule of 80-20 is used it is not possible said that the majority of the delays are because them.

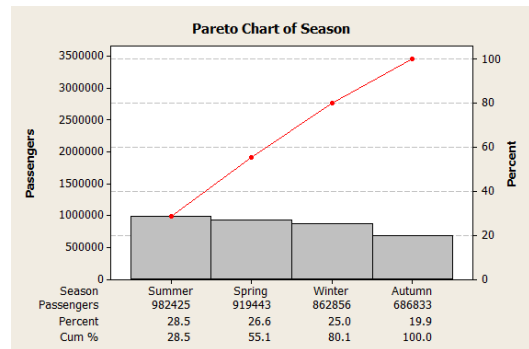


Figure 4
Pareto Chart of Season

The next analysis was made selecting the Jetblue and the summer season. Using these data was analyzed for the causes of the delay. As you can see in the pareto the major offender for the delays are Aircraft arrival late and air carrier delay. These two delays are selected for the major offenders because together they make the 82.9% of defects. Taking into consideration the 80-20 rule it is possible to conclude that if this two offenders are

improve the delays will decrease. These two offender may be related because an aircraft could arrive late because a delay for the air carrier.

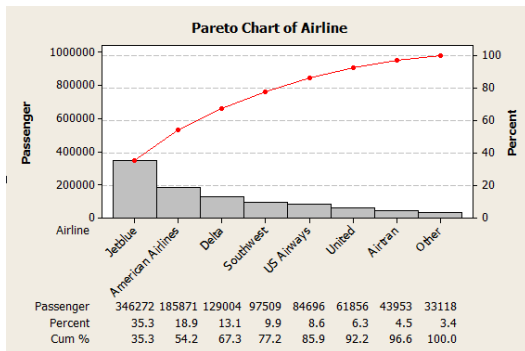


Figure 5
Pareto Chart of Airline

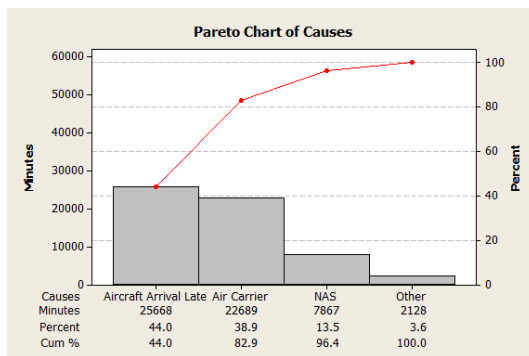


Figure 6
Pareto Chart of Causes

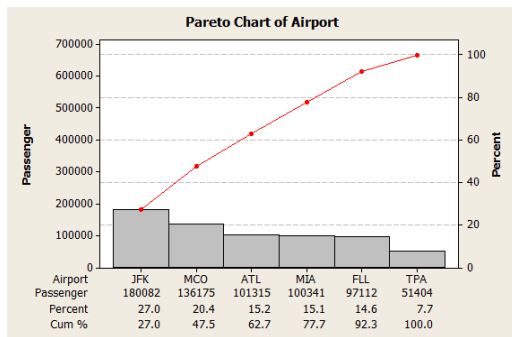


Figure 7
Pareto Chart of Airport

Other analysis that was made is with the departure destination. In the 2013 database exists 26 destinations for summer. In this analysis only the top 6 destination was selected. These top six destinations represent the 68% of the total passengers travel from Puerto Rico. If 80-20 rule is used it is not possible to conclude that JFK is the airport with more flight delayed. Using pareto chart

it is possible to conclude that John F. Kennedy International Airport (JFK) is the destination where more passengers from Puerto Rico travel. Another conclusion from this chart is that four airports from Florida are in the top six airports that summer 2013 passengers select to travel from Puerto Rico. Florida is one of the top destinations in Puerto Rico for summer vacations. Puerto Ricans select Florida for their vacation because in there they have families and also exist different type of parks that offer entertainment for family. Another reason Florida is one of the top destinations from Puerto Rico is that the cost of flights are lower compared with other destinations in the U.S. Florida passengers represent the 39% of total passengers travel from Puerto Rico in summer 2013. The second destination preferred in summer 2013 is New York City with a 23% of passengers traveling from Puerto Rico. As a recommendation, airlines with flights for these two destinations should attack the causes of delay because these destinations take in 62% of the total passengers traveling from Puerto Rico in the summer.

Cause and Effect diagram was created to illustrate the different possible causes for delay. In this diagram exist one cause that airlines could not be able to control and this is extreme weather condition in the environmental section. The extreme weather condition could be able to generate a considerable amount of loses in money but airlines could not be able to control this. It is possible to create strategic plans to prevent high impact of this type when occur. This winter large amounts of flights were cancelled or delayed for the winter storms. What was the cause that flights in Florida were cancelled if the storm was in the states in the north? The reason was the most of the airplanes were in the airports in these states. Airlines could create plans for winter season were routes with airplanes used in the south don't need to go to the north. This type of plan could be able to maintain the continuous flow of passengers in the Caribbean and the states in the south.

Exist other areas that airlines could be able to improve. The cause and effect diagram help to

consider all possible causes of the problem, rather than just the one that are most obvious. In this cause and effect diagram exist five more areas that provide possible causes of delay. In the manpower section there are five sub-categories. These categories are focused in the employees needed to from the beginning to the end for an airplane departure. In the case of gate agents don't process passengers quickly airlines could provide training to their agents and perform more detailed analysis of the capability of the employee.

In the section of equipment we found the materials necessary to the airplane departure. In this section one cause is very important and this is the mechanical failure. This is a big problem to airlines because this only don't affect the departure of the plane also create discomfort in the passengers. No matter with type of failure is passengers don't like to know that they need to travel in a plane that recently has a mechanical failure. Airlines could prevent this type of cause creating preventive maintenance checks in the planes. Sometimes they only focus in make money but they forget that preventive maintenance can prevent a large amount of money in loses. This section and the other four section airlines have the ability to control. In these areas the carrier is the responsible to perform the task. Sometimes they outsource this type of services to be able to focus in areas that are more important for them.

In the pareto of the Causes of delay we could see that the major offenders were the aircraft arrive late and air carrier delay. These two causes are related. If the air carrier have problem with one factor in the process the airplane will departure late therefore will arrive late to the next destination. In the cause and effect diagram these type of causes we could find in the section of manpower, procedure, measurement, material and equipment. These areas are the one that require more analysis. Airlines need to focus in causes that could generate larger delays. For example gate agents don't process passengers quickly, delayed check in, gate occupied and inefficient boarding process can be selected as major offenders for the flight departure.

Once the major offenders are selected other tools of Lean Six Sigma can be used.

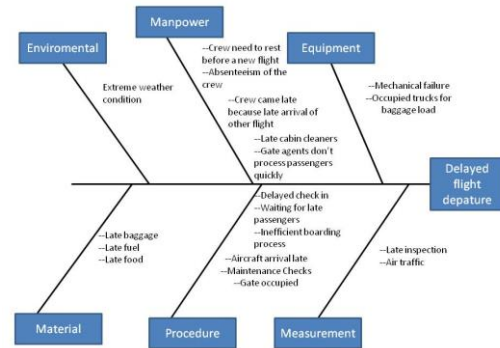


Figure 8
Cause and Effect Diagram for Delayed Flight Departure

Using DMAIC airlines will have a detailed plan of how improve their process. In the phase of Define we have that the objective of the project will be reduce the delayed departure by reducing the air carrier delay and the arrival of aircraft late. For this step value stream map is a tool that can be used to create a visual map of the flow of the process and to highlights opportunities of improvement. The next step is the measure. In this step pareto chart can be used. Already an analysis of pareto was made but know more detailed information for the major causes of delay is need. In this section is needed to obtain data of the reason why the air carrier have problems in the departure of the airplane and why the airplane arrives late. These causes could be the reason selected before in the cause and effect diagram that was made but only with data from the airline this could be selected. The next step is analyzed. In this section another cause and effect diagram could be used as well the 5 whys. Once the major reason why the aircraft arrive late and the problems with the air carrier are known is needed to search for the root cause of the defeat. For example one of the reasons is that gate agents don't process passengers quickly. For this the 5 whys could be used. It is possible after this analysis said that the root cause of this defeat is that employee does not receive any training of the boarding process in the last year and the boarding process was changed recently. The following step is implement

improvement. In this step kaizen, total productive maintenance and the 5S are tools that can be used. The reason for this step is to identify, test and implement innovative solutions to the problem. For example after the measure step it was find that one of the causes of the late departure is mechanical failure. This type of defect can be improved if total productive maintenance is used. This will create a preventive maintenance to maximize the operational time of the airplane. As a result a share responsibility between employee and the airline will be produced. The total productive maintenance reduces cycle times and eliminates defects. The last step is control the process. After the major defect is find an the step of analyzed and improve are perform is necessary to maintain this reduction. Two of the tools that airlines can use are standardized work and control chart. An example of this is create and standard work for the inspection of the airplane. Continue with the example of the mechanical failure and after using total productive maintenance the airlines want to maintain the reduction in defects. A standardize work could be created to prevent future failures. In this standardize work a periodic checks for the major reasons of why airplanes have mechanical failure need to be included. As well, include detailed process of how to inspect this area and what tools are needed. Another thing that airlines could do is having in stock the necessary spare parts that are used to reduce the time for repair. For this a kanban can be implemented. This method will replace automatic a part through card that indicates when more spare parts are needed. Other tools that can be used in this step are visual management. It is important to have the necessary tools needed to perform the repair and inspection accessible for the technician. Using visual management it is possible to maintain the tools organize and accessible in the time of the reparations or inspection. As well, if one tools is missing the technician will know before is needed and this will prevent long waiting time of looking for the necessary tools.

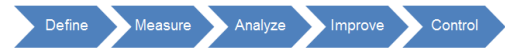


Figure 9
DMAIC Steps

CONCLUSION

In this research, the summer of 2013 was identified as the season with more passengers traveling from P.R. followed closely by spring. Another observation from this analysis is that, in Puerto Rico, the airline with more presence in the summer is JetBlue with a 35.3% of the total passengers. Puerto Ricans prefer Florida for travel in summer 2013 because four airports are in the top six airports with the major amount of passengers flow. This represents a total of 39% of the total passengers traveling from Puerto Rico that season. The second destination with more passengers is New York City with 23% of the total passengers. It is possible to conclude that the major offenders for delay this season was aircraft late arrival and air carrier delay. These two represent the 82.9% of the reason of flight departure delays.

For future analysis airlines can use DMAIC to investigate in more detail the two major offenders. Further investigation is needed to determine what factors caused that aircraft late arrivals and what problems airlines have in their process that generate flight delay. This type of analysis can be used by any airline that wants to investigate the causes of delay in their process and want to improve them.

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