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Original Research Article

Statistical Analysis of Aviation Accidents Data: A Case Study of United States Aviation Department

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Abstract

The Federal Aviation Administration (FAA) provides air traffic services for the world largest and busiest airspace. Despite of its extreme focus on safety, aircrafts face numerous accidents every year. The purpose of this study is to explain the trends in aviation data of the United States (US) and explore the meanings associated with each trend. We collected data of aviation accidents and aviation operations for a period of 21 years, Jan 1992 to Dec 2012, mainly from three different sources, i.e. NASA maintained database "Aviation safety reporting system" (ASRS), the National transportation safety board (NTSB) maintained database "Aviation accident and incident data system" (AIDS) and the Federal Aviation administration database (FAA, 2016). Accidents were grouped into their respective segments of aviation operations which include General Aviation (GA), 14 CFR (Codes of Federal Regulation) Part 135 and 14 CFR Part 121. The stratification help to identify and analyze the trends in each segment of aviation operation separately. Descriptive statistical and correlation tools were used in the study to identify and explain trends in the data.It was found that accidents in General Aviation (GA), the smallest segment of aviation operations, dominate over other segments (14 CFRPart 121 and 135). The analysis showed that aviation accidents overall decreased over time. The decreasing trend in accidents is because of few factors such as strengthen safety measures, advancement in technology, improved training of pilots, etc. It was also found that aviation activities (flight hours) were following different trends in each segment. Flight hours of Part 121 were increasing, remained flat for Part 135 and consistently decreasing for GA. The difference in trends for each segment is because of different weight-age of the factors affecting aviation operations for each segment. The factors include Gross Domestic Product (GDP) growth, changes in regulations, price hike of fuel, economic recessions, and world major events like 9/11, etc. which affects aviation activities. The aviation data also show a significant seasonal effect. In summer from the months of May to August, 44% of all aviation accidents occurred, 29% in the months of September to December and only 27% of all aviation accidents in the months of January to April occurred. The study may be helpful in preventing aviation accidents, after identification of trends and explaining the associated meanings to them.

Keywords: Aviation Accident, General Aviation, Codes of Federal Regulation (CFR), The Federal aviation administration (FAA)

INTRODUCTION

Despite the rapid advancement in technology to forecast and display the hazard associated with airlines, a huge number of aviation accidents happened across the globe. However, continues efforts are being made to reduce aviation accidents. Introducing newrules and regulations for different segments, vast advancement in technology and its application in aviation industry, promoting safety practices and skill development training for the pilots and many more such initiatives taken by the Federal aviation administration (FAA) in the United States (US) to make the aviation industry safer. These initiatives/factors have different meanings and havedifferent impact on each segment of aviation operations. As a result, aviation accidents and flight hours have different trends in each three identified segments ofaviation operations i.e. General Aviation (GA), 14 CFR Part 135, and 14 CFR Part 121. The purpose of this study is to identify the trends and behaviors of aviation accidents of each segment exclusively and explore the meaning of the unusual fluctuations in the data. Aviation accident, the frequently used term in this study,defined under 49 Code of Federal Regulations (CFR) 830.2 as "an occurrence when the operation of an aircraft, with the intent of flight, results in substantial damage to the aircraft, death or serious injury to any person" (International Investigation Standards, 2016). The term substantial damage has explained under 49 Code of Federal Regulations (CFR) 830.2 as "damage or failure which adversely affects the structural strength, performance, or flight characteristics of the aircraft, and which would normally require major repair or replacement of the affected component".

Accidents' statistics presented in this study are confined to civil flights of the United States (US). In the United States, civil flights (non-military) are classified as either air carrier operations (Part 135 and Part 121) or General Aviation (GA). We analyzed the trends in the data of the threerespective segments of aviation operations of the United States (US), which include General Aviation (GA), 14 CFR Part 135, and 14 CFR Part 121. GA activities include agricultural operations, recreational, sightseeing, and business travel (Li et al., 1999). Most of the General Aviation (GA) flights are used mainly for personal and recreational purposes. However, some flights are conducted for revenue generating purposes as well. 14 CFR Part 135 is commuter airlines (Part 135 scheduled) and air taxis (Part 135 unscheduled) and 14 CFR Part 121 are generally referred to major airlines and cargo carriers (US Government publishing office, Electronic Code of Federal Regulation, 2017). Since March 20, 1997, the aircrafts used in scheduled operations and have 10 or more seats have been operated under 14 CFR Part 121. Before the legislation scheduled aircrafts with 30 seats have been operated under 14 CFR Part 121, while those with less than 30 seats were operated under 14 CFR Part 135. Some commuters once regarded as 14 CFR Part 135 are now considered 14 CFR Part 121 (Federal Aviation Administration, 2009).

The accident rate is a better indicator of explaining variation in accidents as compared to the number of accidents. It explains the drivers of variation in the data more exclusively. Unlike the number of accidents which give information regardless of aviation activities, the accidents ratecounts aviation activities as well. Accident rates have been defined as "a measure of accidents per million departures. Departures (or flight cycles) are used as the basis for calculating rates because there is a stronger statistical correlation between accidents and departures" (Boeing, Statistical Summary of Commercial Jet Airplane Accidents Worldwide Operations, 2017). Researchers have also calculated the accident rate as accidents per million flight hours (National Transportation Safety Board, 2005).

Total flight hours have long been considered one of the risk factors in aviation, and are often used to represent either pilot flight experience or cumulative risk exposure (Li et al., 2003). The flight hours increase the potential thread of accidents. Fora higher number of flight hours, chances of accident occurrence is higher as well. Researchers have reported that the flight hours and crash rate is approximately linear on logarithmic coordinates (Lyons et al., 2007). Flight hours are correlated with the number of accidents and so helpful in identifying and explaining the trends in data.

The rate of accidents in GA is higher than other segments of aviation operation i.e. 14 CFR Part 135 and 14 CFR Part 121 (Gail, 2017). Researchers have identified many reasons responsible for a higher rate of accidents in smaller planes. The commonly discussed reasons/factors that affect general aviation operations include GDP, fuel price, tax benefits, decreasing business travel due to increased use of the internet in business. GDP is a common factor, which have significant impact on all three identified segments of aviation operations (Shetty, 2012). In the study we have compared aviation activities of each segment with the GDP growth of the United States (US).The World Bank data show that United State GDP is consistently increasing with few exceptions of recession eras since decades (See World bank data X1). It gives meaning to the consistently increasing trend in aviation activities of Part 121.

GDP is not the only factor that influences that aviation operation, there are other factors as well. The other factors, which are not directly related to legislation or economics and have influence on aviation activities. World events like US involvement in the Persian Gulf War, Andrew hurricane (August 1992) and 11th September 2001 terrorist attacks are coincided with the decline in aviation activities. As aviation activities were immediately stopped for days after 9/11, and it brought more prolonged effects on changing the public perception of aviation. It resulted in a negative perception of aviation among the public, increased security procedures at airports, and tighter regulation of the airspace (Shetty, 2012).

This study is confined to a span of year 1992 to 2012. During this period from year 1992 to year 2012, a consistent increase in US GDP, global economic recessions in certain points of time, emerging of the internet and other social networks, a record increase in fuel prices for a long period followed by a drastic decrease in prices, major changes in regulations and the bloodiest terrorists attack in the history of civil flights happened. The above discussed factors have either positive or negative impact on aviation activities. Therefore, both the accidents and operational activities show much complicated trends. We have attempted in this study to explain the trends and give correct meaning to each variation.

The study has been organized in separate sections. We have started with the introduction and have presented a brief literature review of the problem. In the next section, we have provided research methodology, which covers the methods of data collection and analysis techniques. The section also providesthe foundationsof study and direction to our research work. In the third section, we have presented our results and discussion. We have explained the meanings associated with each trend in aviation data in this section. In the last section, we have summarized our findings and present the conclusion along with putting some recommendations for the aviation industry, regulatory authorities, Governments, and researchers, etc.

RESEARCH METHODOLOGY

Research methodology represents the methods and strategies used for collecting and analyzing the data. This section explains techniques applied in the study. Further, it gives a direction to the research work.

Methods of Data Collection

Data used in this study have been collected from mainly three sources i.e. NASA maintained database "Aviation safety reporting system" (ASRS, 2017), the National transportation safety board (NTSB) maintained database "Aviation accident and incident data system"(AIDS) (NTSB, 2017) and the Federal Aviation Administration (FAA) database (FAA, 2016) for a period 21 years, Jan 1992 to Dec 2012.

Pilots, air traffic controllers, dispatchers, flight attendants, and maintenance technicians voluntarily submit reports of unsafe and hazardous situation on a specific-designed report format of NASA Aviation safety reporting system (ASRS. The filled out form can be submitted either by posting on ASRS address or electronically by using Report Submission Form (RSF). ASRS receives, processes, and analyze reports of unsafe and hazardous situation.

NTSB gathered information through the NTSB investigation of accident or incident involving aircraft within the United States, its territories, possessions or international water. AIDSdoesn't just record the number of accidents but describesits complete situation such as the location of the accident, flight phase, environment, injury level, and the date of the accident. For this study data have been stratified into their respective segments of aviation operations, which include 14 CFR Part 135, 14 CFR Part 121 and General aviation.Because of the different operating practices within Part 135 and 121 segments of aviation operation, the operations were further segregated as scheduled and non-scheduled operations. Scheduled flights operate regularly and plan a long time before where unscheduled or charter flights operate irregularly and may plane a short time before flying. Further detail can be found on 14 CFR 119.3 about the regulatory differences between the scheduled and non-scheduled operations.To see and track trends over a yearly and monthly period, we have gathered both annual and monthly data for each segment of aviation operations.

Aviation accidents have been grouped into four events as proposed by the International Civil Aviation Organization (ICAO) on the basis of severity level of damage, an aircraft resulted in an accident, i.e. Destroyed, Substantial, Minor and None. Destroyed means "the damage sustained makes it inadvisable to restore the aircraft to an airworthy condition". Substantial, "the damage adversely affects the structural strength performance, or flight characteristics of the aircraft. It normally requires major repair or replacement of the affected component". In minor damage, the aircraft can be rendered airworthy by simple repairs or replacement. It doesn't need any extensive inspection. In None, the aircraft sustained no damage in the occurrence (International Civil Aviation Organization, 2016).

Data Analysis

Our analysis is mainly based on descriptive statistic and correlation studies. The purpose of these analyses is to see the pattern associated with the accidents of each segment of aviation operations.Descriptive statistics tells more about the distribution, behaviors and trend of aviation accidents. Minitab statistical package and excel spreadsheet havebeen used in this study fordata refinement, presenting and statistical analysis. We also identified distributions and carried out correlation study to show the structure of data.

RESULT AND DISCUSSION

In this section, we discuss our results and findings in details. We have discussed the results and findings under three different subtitles to explain each factor properly.

Trends in Aviation Accidents

The accidents in this study havebeen stratified into respective segments of aviation operationsi.e. General Aviation (GA), 14 CFR Part 135, and 14 CFR Part 121.

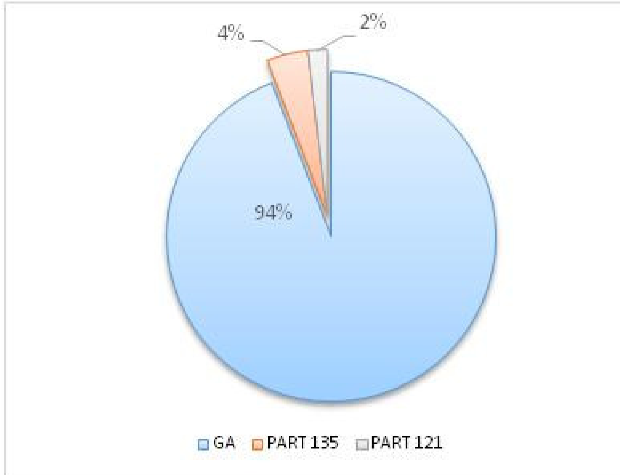

Figure 1. Segment wise percentage of Aviation Accidents for 1992 to 2012

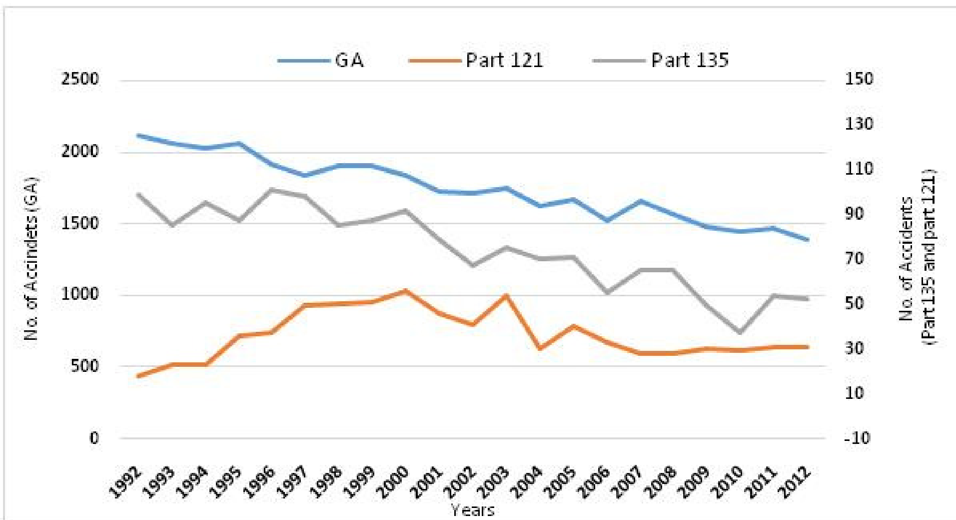

Figure 2. Number of Annual Aviation Accidents from year 1992 to 2012

As shown in Figure 1, General Aviation accidents dominateover other two segments (14 CFR Part 121 and 135). General Aviation accidents are responsible for 94% while 14 CFR Part 121 and Part 135 for only 2 % and4% of all aviation accidents respectively (See Figure 1).

There are several reasons discussed in the aviation literature, responsible for the higher risk of small planes i.e. General Aviation (GA). Small aircrafts, which are mostly personal, lack safety features as compared to commercial flights. They don't have proper backup systems for navigation information, co-pilot, and extra-engine etc. Pilots are not as professional and trained as of commercial flights. The rules are looser for private pilot license than commercial and air transport licenses. GA aircrafts are less weather tolerant. Studies show that the adverse weather is responsible for a major portion of accidents i.e. 52% of the total accidents of GA. Fuel management is another reason for the higher risk of GA aircrafts. Aircraft Owners and Pilots Association data show that planes (Small planes) crash almost twice per week because of going run out of fuel. Bad landing is another biggest reason for GA accidents with an average of eight accidents per week.Generally small planes land at small airports that may not have even a proper smooth runway.During takeoff and landing aircrafts are close to the ground and in a more vulnerable configuration than in other phases of flight. Due to small trips, GA conducts more takeoffs and landings than other air carriers (Aircraft Owners and Pilots Association, 2017).

The number of GA accidents has dropped from 1908 to 1209 during the last two decades, i.e.: from the year 1992 to 2015. There is a consistent downward trend in General Aviation (GA) accidents (See Figure 2). The data show that 34.07% decrease occurred in the number of

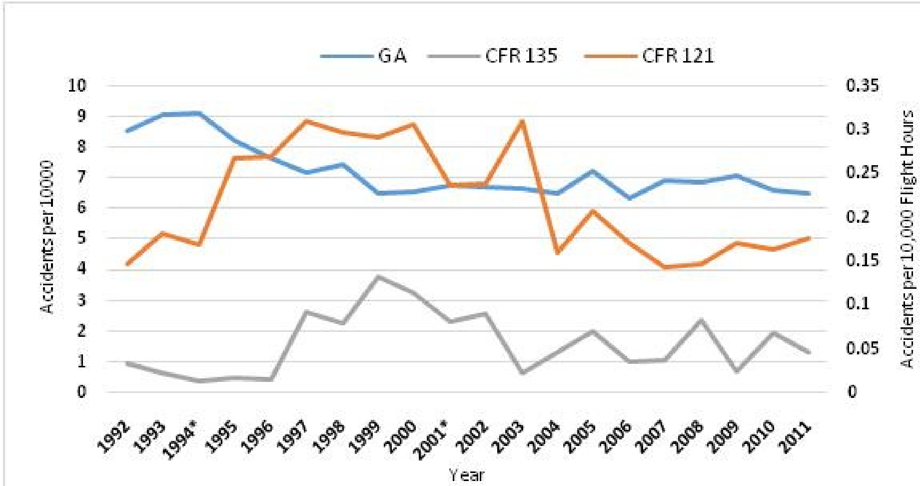

Figure 3. Annual Aviation Accidents per 100,000 flight hours from year 1992 to 2011

General Aviation accidents during the period.As the number of accidents show how risky or safer each segment is. However, the numbers of accidents are not as an informative measure as accident rate, expressed the number of accidents standardized by a specific flight time. The trend in the number of accidents without considering the flight hours may mislead the analysts. To avoid the confusion, the rate of accidents have been determined to explain the trends in datamore accurately as shown in Figure 3. The rate of General Aviation (GA) accidents have significantly decreased during the period of 1992 to 2011.In other two segments, 14 CFR Part 135 and 14 CFR Part 121, the rate of accidents has reasonably decreased, but not as enormous as in GA. GA aircrafts got a visible reduction in the accidents rate, i.e. from 7.17 to 6.51 accidents per 100,000 flight hours during year 1997 to 2011. In 14 CFR Part 135 accidents per 100,000 flight hours decreased from 2.628 to 1.303 in the same period from year 1997 to 2011. In 14 CFRPart 121 the reduction in the rate of accidents is not as sharp as in GA and 14 CFRPart 135. The rate of accidents is already lower for 14 CFR Part 121, i.e. rate of accidents decreased from 0.309 to 0.175 accidents per 100,000 flight hours in the period of year 1997 to 2011.

As shown in Figure 3, GA is riskier as compared to other aviation flights. The rate of accidents in GA segment is much higher than other segments. GA segment needsmore focus and efforts to make it safer to fly. With advancement in technology, aircrafts are getting safer each day. The emerging of new hi-tech personal planes to the market and the addition of recently trained pilots who are more affected by new safety initiatives and regulationshave contributed much in reducing aviation accidents. These new aircraftshave the highest safety features, which the pilots of GA aircrafts could only dream of a decade ago. The other reason forthe reduction in therate of accidents is the NTSB initiative to bring the accidents down to zero in commercial airlines. NTSB extended the same solutions to the general aviation segment. Most of these are voluntary safety enhancements, such as providing more information to the plane's cockpit instruments about the craft's positioning during landing etc.

Figure 3 shows variation in the accidents rate of General aviation, 14 CFRPart 121 and 14 CFRPart 135. Though the rate of accidents for 14 CFR Part 121, moves in a small range of 0.146-0.306. Ithas both increasing and decreasing trends in certain points of time. The figure shows that the rate of accidents for the segment has been increased from1992 and remained at the upper side till 2000 i.e. from 1.46 to 0.306. From 2002 to onward, there is a decrease in the rate of accidents of 14 CFRPart 121 i.e. from 0.306 to 0.175. As discussed in the earlier section, with the vast advancement in technology, aircrafts become safer every day. The other possible explanations for the decreasing trend in accidents rate is strict security and safety measures after 9/11 terrorist attack in the United States and the NTSB efforts to bring down the number of fatalities in commercial airlines to zero. The flight hour's data show an upward increase till 2000, then suddenly decreased and remained on the lower side onward. The drivers affecting the flight hours have been discussed in detail in the upper portion.The flight hours are positively correlated with aviation accidents.

Unusual fluctuations have been observed in the accidents rate of 14 CFRPart 135 after 1997 as shown in Figure 3. We have plotted the rate accident of scheduled and unscheduled operations (On demand services) of Part 135 in Figure 4 to see and compare the trends in both services (See Figure 4). The analysis shows that rate of accidents for 14 CFRPart 135 unscheduled services are steadily decreasing. The decline inthe rate of accidents of Part 135 unscheduled services may be the

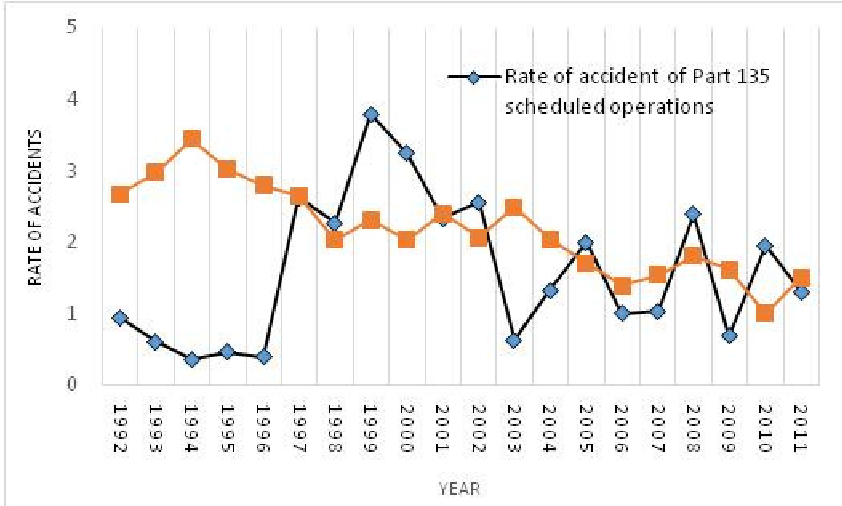

Figure 4. Rate of accidents 14 CFR Part 135 Scheduled and On-Demand services

result of a number of factors including strict security and safety measures after September 11, 2001, a fluctuation in overall U.S. aviation accidentsdue to initiative for improving infrastructures, emerging of new hi-tech devices, safer aircrafts, Initiative of NTSB, etc.

Figure 4 shows that the fluctuation is mainly due to 14 CFRPart 135 scheduled services. It became prominent due to legislation according to which since March 20, 1997, the aircrafts used in scheduled operations and have 10 or more seats have been operated under 14 CFR Part 121. The legislation also have influenced the rate of accidents and flight hours of Part 121. The increase in the rate of accidents in scheduled 14 CFR Part 135 is because of shifting a safer operation group to 14 CFR Part 121. Historic data show that crash rates of flight with 10-30 seats were even lower than the crash rate of flights with more than 30 passenger seats. Studies also show thatthe decline in the crash rate happened in the beginning of 1994, three years before the changes in regulation. The crash rates of scheduled commuter with less than 10 seats were much higher than the scheduled commuter having 10-30 passenger seats (Baker et al., 2009). Reasons for the improved safety of 10-30 seats scheduled commuters probably include the 1992 requirements, i.e. turbine-powered aircraft with 10 or more seats must be equipped withthe ground proximity warning system to prevent controlled-flight-into-terrain crashes (Thomas et al., 2000).

After year 2000, the accidents rate of Scheduled 14 CFRPart 135 operations declined drastically (See Figure 4). The declination in the accidents rate happened as a result of the efforts made to reduce crashes in Alaska. As around 90% of total crashes of scheduled 14 CFR Part 135 commutersoccurred in Alaska. For reducing crashes FAA carried out the Alaska Capstone project,which provided information to the pilot about weather, terrain, and air traffic and permits trained pilots to fly safely at lower altitudes using GPS (Call and Hallinan, 2001). For providing weather information, live remote cameras at different locations in mountain passes were installed (Alaska Aviation System Plan, 2016). The air carriers operated under the regulation of 14 CFRPart 135 scheduled operations, went through 47 accidents in Alaska out of total 56 accidents by the period of 2001 to 2012. It shows 83% accidents still in 14 CFRPart 135 Scheduled operations occurred in Alaska State. In 14 CFRPart 135 unscheduled services, 30% accidents in the US occurred in Alaska State. At the results of Capstone initiatives, a consistent decline was observed in Alaska accidents. In Alaska fatalities declined 42.5% in 2000-2009 over the previous decade of 1990–1999 (Lincoln et al., 2013).

Flight hours of each segment follow different trends as shown in Figure 5. 14 CFRPart 121 follows an increasing trend, 14 CFRPart 135 remained almost flat where GA shows mix trends, i.e. both increasing and decreasingtrends are seen in Figure 5. Historic data show the factors that are responsible for changing aviation activities. The regional and global economy is one of the strong factors positively correlated with the flight hours. The annual increase in air travel of commercial aviation, measured in revenue passenger kilometers (RPK), is approximately twice the annual growth rates of the gross domestic product (GDP) (Belobaba et al., 2015).

Figure 6 compares the growth of United States GDP with the flight hours of GA and Part 121.Part 135 has been excluded from Figure 6 as there are no major changes occurred in the flight hours of the segment over the given span of time. The analyses indicate that commercial aviationfollowsmore closely the economic indicator, i.e. GDP. The fuel price hike, which was higher

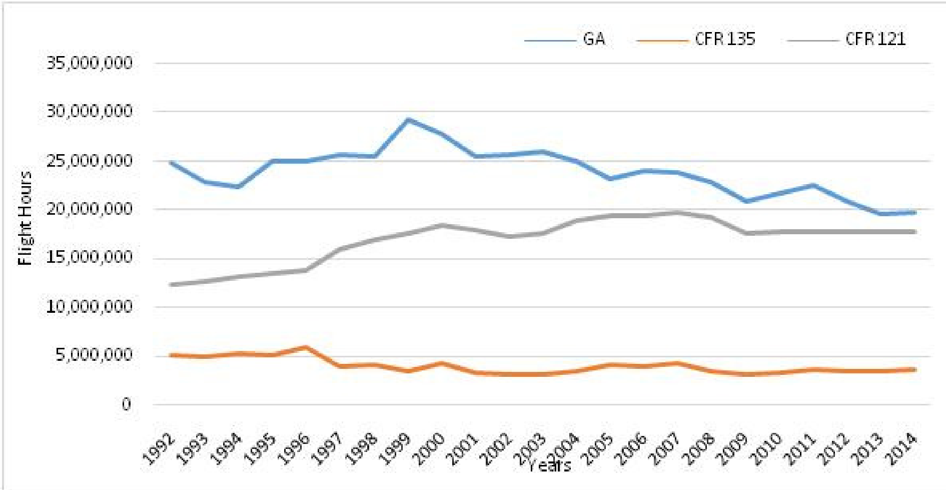

Figure 5. Flight hours of GA, Part 135 and Part 121

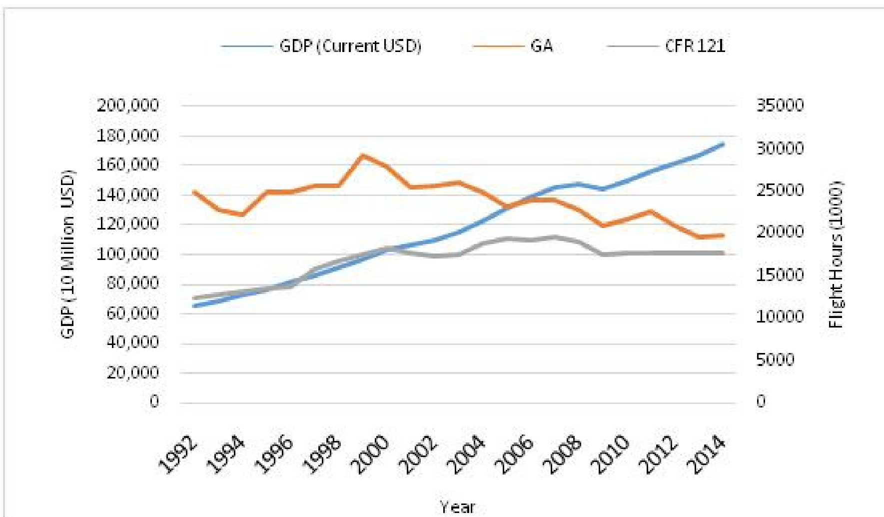

Figure 6. Comparison of GDP and Flight Hours of GA and Parts 121

from 2001 to 2008, have negative impact on aviation activities. Higher the fuel prices reduce the flight hours (Shetty, 2012). The GA flight hours follow different trend than commercial aviation. It indicates that there are some other factors additional to GDP and fuel price hikes affecting the flight hours of GA. Some of these factors include the increased use of the internet in business (hence, decreasing business travel), tax incentives for aircraft ownership, the costs of owning and operating personal aircraft, legislation such as General Aviation Revitalization Act (GARA), the total private pilot and GA aircraft populations (Shetty, 2012; Kister, 1998). The impact of 9/11 terrorist attack on the flight hours can be noticed in the figure. The impact of 9/11 has been widely discussed in literature (Shetty, 2012). Flight hours of 14 CFRPart 121 and 14 CFRPart 135 have been greatly changed due to regulation of March 1997 of converting all aircraft having 10 or more than 10 seats as Part 121 scheduled operations (Baker et al., 2009). We further investigated the data for the seasonal effect in the next session.

Seasonal Distribution of Accidents

There is a stronger seasonal trend exists in the data. A regular repeating pattern of highs and lows are available in the annual data. The accidents reach to peak at summer and then reduce to the smallest number in winters (See Figure 7). To see the trend more closely, we put the average monthly accidents in the plot (See Figure 8). The plot indicates that there are more Aviation accidents happened in summer in the United States of America than other months.The seasonal effect also has been reported in other studies (Ayat et al., 2017). As the weather gets warmer in the USA, more families start

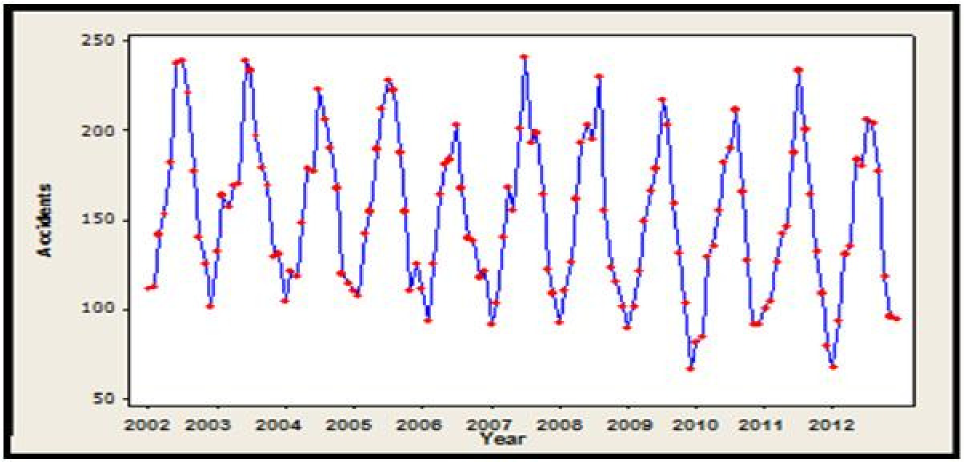

Figure 7. Monthly Aviation Accidents for the period of 2002 to 2012

Table 1. Event wise grouped data of GA, Parts 121 and 135 for the period of 2009 to 2012

	General Aviation (GA)		**Part 121**		**Part 135**	
	No: of events	**%age**	**No: of events**	**%age**	**No: of events**	**%age**
Destroyed	143	2	3	3	2	1
Substantial	5618	96	45	43	160	97
Minor	48	1	11	10	1	1
None	36	1	46	44	2	1

planning their getaways. During the summer, there are more occasions to have a great time in great weather, but with the increase in aviation activity level, there is a potentially greater chance for more accidents to happen. (Figure 7)

The data show that in the first quarter (January-April), 124 accidents at average occurred. The number of accidents increases to 200 in the second quarter (May-August) and reduce back to 133 in the third quarter (September-December). The analysis shows that 44% of all aviation accidents took place in the months of May to August. While 27% aviation accidents took place in the first fourth months and 29% of all aviation accidents in the last four months of the year. Accidents reach at the peak in the month of July. (Figure 8)

The monthly distribution is positively correlated with aviation activities. The chances of accidents increase asaviation activities increase. The exact relationship between activities and accidents may change over time, but the number of accidents or mishaps will always be dependant on the number of aviation activities (National Transportation Safety Board, 2005).

Probability Distribution of Accidents

The statistics of aviation accidentsfor the period of 2009 to 2012 show that substantial event dominates over other events. The aviation accidents are caused for 3% destroyed events, 95% substantial, and 1% for each Minor and None events. (See Table 1). The statistics suggest that high focus should be given to the accidents cause substantial damage. The distributions of these events are different for different segments of aviation operations. Weidentified the probability distribution of each type of accident separately for respective aviation operations using Minitab statistical package. The distributions of each type of accidentsmay need a separate study to discuss in details. In this study, we have just identified the types of probability distributions for aviation accidents of each segment separately to explain the available trends.

The analyses show that accidents were either Weibull or Exponentially distributed. The detailed statistical outputs and graphs are given inAppendix I.In General Aviation (GA), all four categories of accidentsin which aircrafts were destroyed, substantially damaged, have minor damaged, or None having Extreme Value distributions (Weibull). In 14 CFR 121, three events i.e. Destroyed, Substantial and minor were exponentially distributed while the accidents in which aircraft wasn't damage (None) have Weibull distribution. There were only 3 accidents in which aircrafts were destroyed and 10 accidents in which aircrafts were minor damaged which was not a good number to give any proper distribution pattern. In 14 CFR Part 135, Sub-stantial and destroyed events are exponentially distributed.

Figure 8. Average Monthly Aviation Accidents for the period of 2002 to 2012

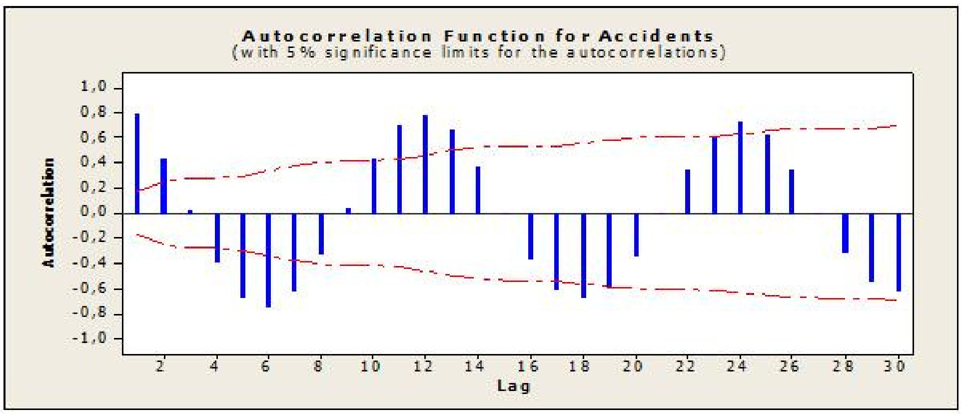

Figure 9. Autocorrelation Function of the monthly aviation accident data

Time Series Analysis

Time series is a sequence of observations over regularly spaced intervals of time. It is a mathematical function of the combination of variables known as values of interest and one or more random components.Aviation accidents exhibit seasonal patterns as has been discussed and shown in the earlier section (Figure 7 and Figure 8). Accidents are higher in the second quarter (May–August) and dipping either side of this. The data indicate a decreasing trend as well (Figure 2 and Figure 3).

For explaining the structures of the data, we obtained the autocorrelation function for monthly accidents. Figure 9 shows the autocorrelation function for monthly accidents' data with 5% significant limits. The series appears to slowly wander up and down and shows a distinct seasonal pattern for autocorrelation. The ACF decreases from a positive value P=0.8 toward 0 as the lag increases, then from 0 toward negative reaching to its extreme P=-0.8 and again decaying toward 0 and so on. It has an alternating pattern of positive and negative lags. It is clear from the auto-correlation patterns that accidents' data have strong similarities with each other. The data are depended on one another in a specific pattern. The analysis indicates that data have seasonal and downward trends along with a random component.

As the aviation accidents seem to exhibit both trends and random components, it is necessary to decompose the series (Wold 1958). Holt's method can be used to deal with the time series, which contains both trends and seasonal variations. The Holt-Winters method has two versions, additive and multiplicative. The use of the versions depends on the characteristics of the particular time series. The analysis shows that data better fit to the multiplicative version than the additive version of the Holt-Winters method. The data as given in Appendix II show that the mean square error (MSE) value is smaller for the multiplicative version than the additive version of Holt's method. Small value of the MSE shows fitness of the version of Holt's method.

The general forecast function for the Multiplicative Holt-Winters method is

$Y_t = (S_t + G_t)\ C_t + \varepsilon_t$………………........................(1)

The components of forecasting function, i.e. Level "S_t ", Trend "G_t", the Seasonal component "C_t" and Random component ε_t have been shown below.

For modeling the periodic components, the time series was decomposed a into number of componets, i.e. the

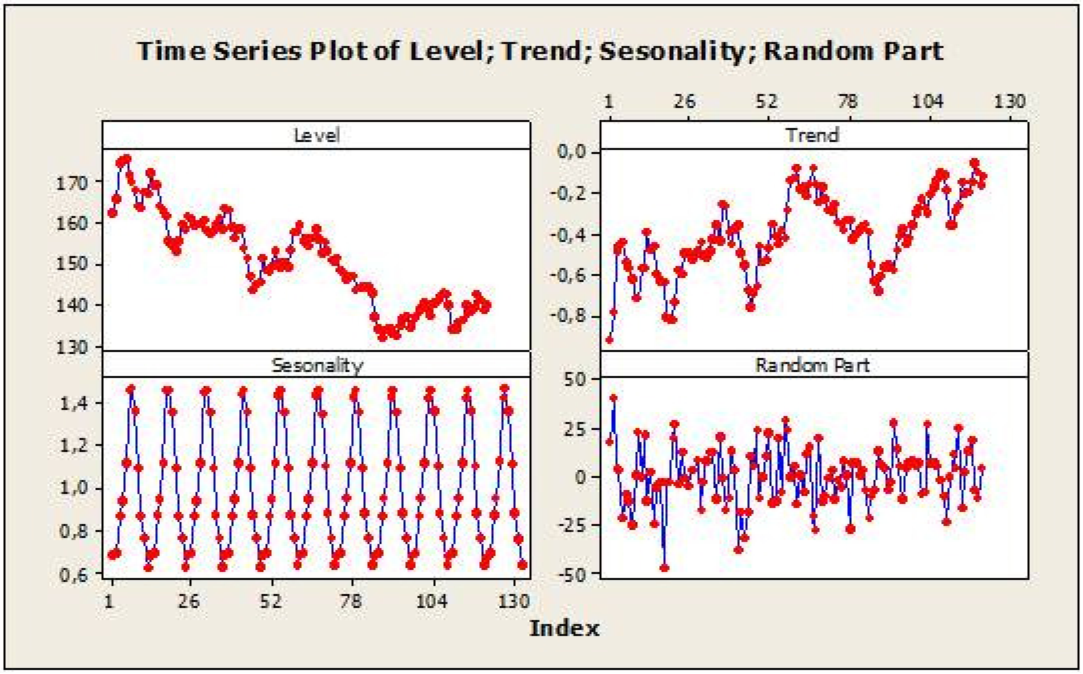

Figure 10. Estimated components of Multilicative version of Holt-Winters method

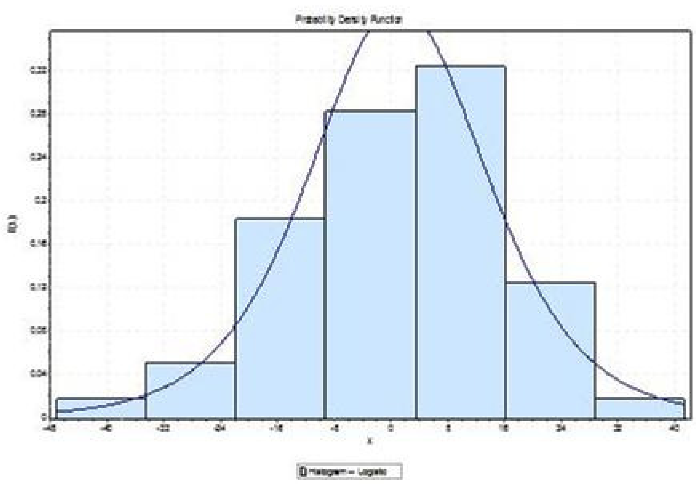

Figure 11. Probability distribution of the random component of the Time series

Level, Trend, Seasonal component, and Error componentas given. (Figure 10).

The Level,

$S_t = \alpha^* (Y_t/C_{t-n}) + (1-\alpha) * (S_{t-1}+ G_{t-1}$……….. .(2)

The Trend,

$G_t = \beta *(S_t - S_{t-1}) + (1- \beta) * G_{t-1}$……………. ..(3)

The Seasonal component,

$C_t = \gamma * (Y_t / S_{t-1} - G_{t-1}) + (1- Y)*Ct-n$ ………..(4)

The values for the smoothing constants in this model are α=0.13, β=0.13, and Y=0.19 for which the MSE is minimum. After the decomposition of the series, the random component can be found by using the equation (5). The distribution of the random component is identified as Logistic distribution (8.285, 0.981) (Figure 11).

Random component,

$\varepsilon_t = Y_t - (S_t + G_t) C_t$…… ....(5)

Equation (1) may be the possible mathematical model to forecast the monthly accidents.The analysis also shows that the random component is not so distinct in the data. Figure 12 shows forecasting of monthly accidents' data using time series decomposition plot without

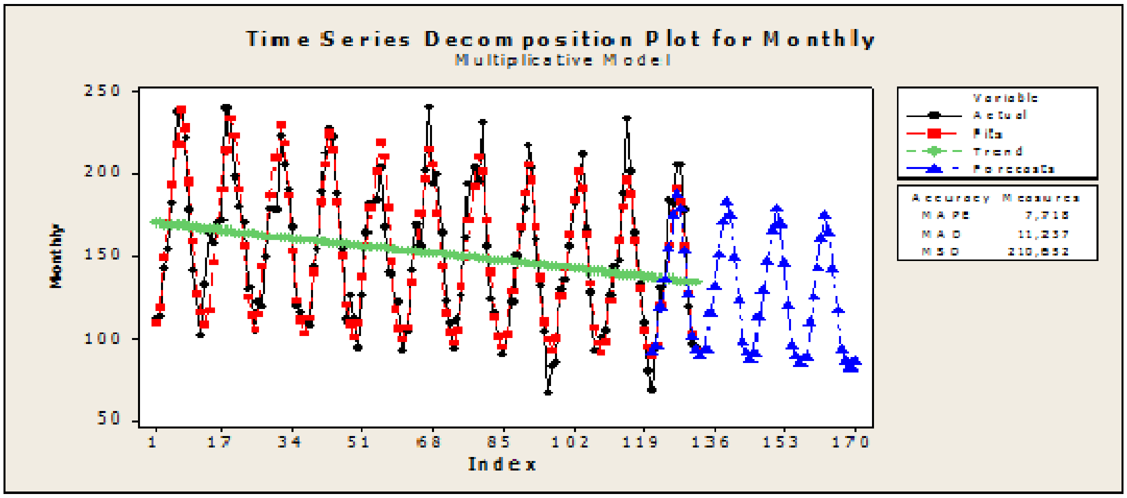

Figure 12. Forecasting of Accidents Using forecasting model without considering Random component

considering the random part.

CONCLUSION

The analysis of the data for the given period of 24 years show that all the respective segments varies differently.General aviation dominates over other two segments, i.e. 14 CFR Part 135 and Part 121. GA is responsible for 94% where 14 CFR Part 135 and Part 121 are responsible for 4% and 2% of all aviation accidents respectively. The study show that General Aviation accidents have been reduced enormously at a higher rate than other two segments. Nevertheless, GA is riskier and still have ahigher rate of accidents than other commercial airlines. A thorough review of GA legislation is needed to introduce new flight rules and regulations for raising safety standards. Further, the administration should work closely with the GA community and manufacturing industries to educate them about safe practices and make sure the newly manufactured aircraft have installed mandatory technology devices.

The analyses illustrate that aviation accidents follow a seasonal trend. In just second quarter from May to August, 44% of total accidents occurred.It may be helpful in reducing accidents to educate those who intend to fly in the beginning of the season about safe practices. The flight hours of the airlines of all three segments of aviation were analyzed. All segments of aviation were following different trends. We explained the trends in flight hours from each segment with the help of historic data. It is obvious from the study that flight hours are positively correlated with the number of aviation accidents. The study show that accidents either have extreme value distributions or exponential distributions. The values of the parameters of Extreme value distribution also support the decreasing trend of accidents.

In this study we explained trends and behaviors of accidents and flight hours for each segment of aviation operation separately and attempted to explore the associated meanings of the trend in each segment. The study could be beneficialfor the researchers, academicians and aviation communities for further study to combine these analyses with the data containing the causes of accidents. One key factor that this dataset did not include was the determined cause of the accident. In the future, combining this analysis with data containing the cause of accidents could yield more impactful results as to why we are still having so many accidents. Another limitation of this study is that we have used flight hours instead of departure (Flight cycle) in calculating rate of accidents. There is a stronger statistical correlation between accidents and departures than there is between accidents and flight hours. Though flight hours have also used by various researchers in calculating rate of accidents.

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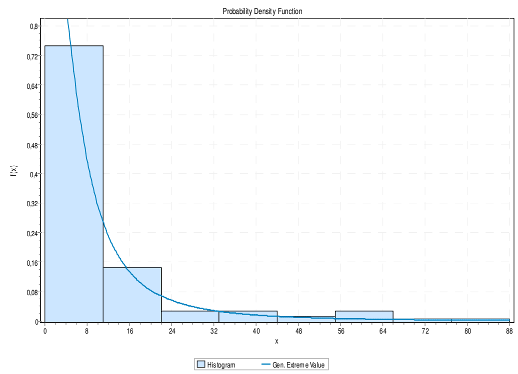
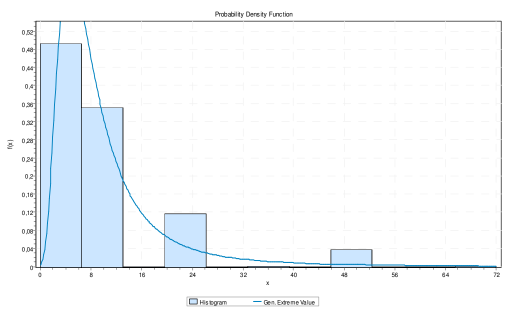
APPENDIX I

Identification of Probability Distributions
General Aviation



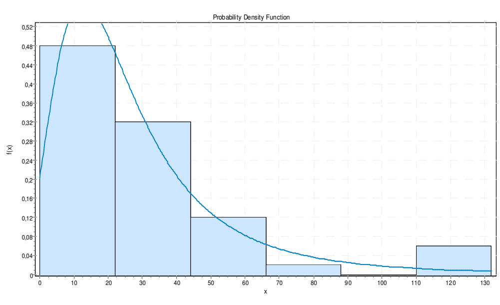
Segment: General Aviation
Accident: Destroyed
Distribution: Smallest Extreme Value
(25.986 < 0.010)

k= 0.51925**μ**= 3.045
σ = 4.084



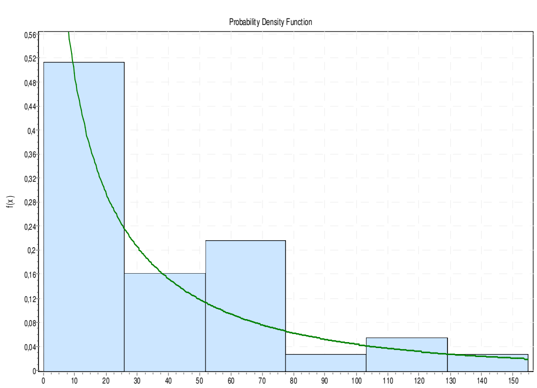
Segment: General Aviation
Accident: Substantial
Distribution: Smallest Extreme Value
(213,838 <0,010)

k= 0.37744 **μ**=5.9012 **σ**=3.8993



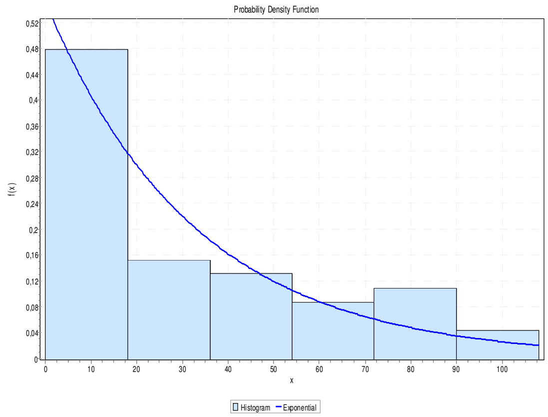
Segment: General Aviation
Accident: Minor
Distribution: Largest Extreme Value
(0,760 0,045)

k=0.34477 **μ**=5,9012
σ=3,8993



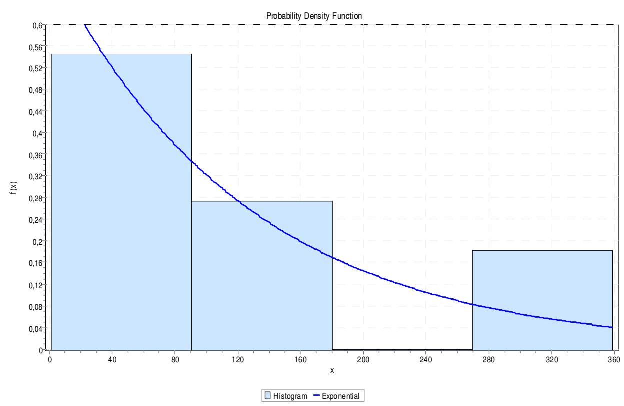
Segment: General Aviation
Accident: None:
Distribution: 3-Parameter Weibull
(0.333 >0.500)
β= 0.64922
α= 31.985
γ= 0

14 CFR Part121

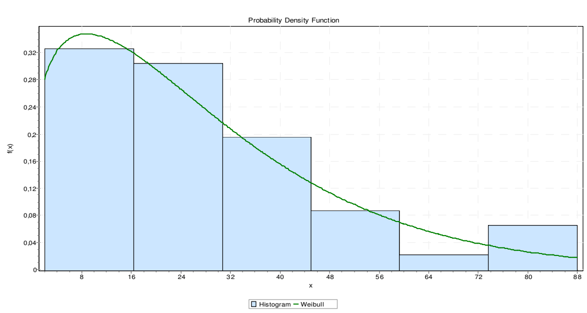


Segment: 14 CFR Part 121
Accident: Destroyed,
Distribution: 2-Parameter Exponential
0.492 0.228 1.000
λ= 0.03067

Segment: 14 CFR Part 121
Accident: Destroyed,
Distribution: 2-Parameter Exponential
0.603 >0.250
λ= 0.03067

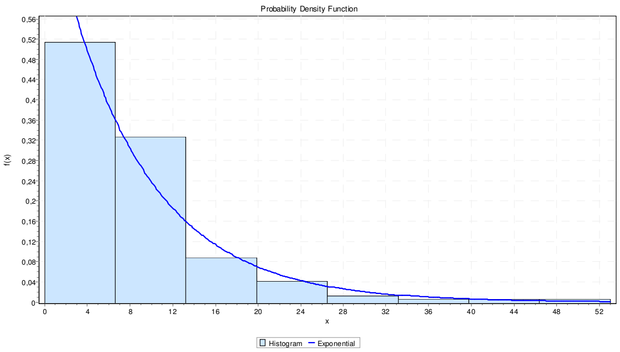


Segment: 14 CFR Part 121
Accident: Minor
Distribution: Exponential
0,454 0,519
λ=0,008



Segment: 14 CFR Part 121
Accident: None
Distribution: Weibull
0.220 > 0.250
β= 1.2621
α= 30.482

14 CFR Part135



Segment: 14 CFR Part 135
Accident: Destroyed, Substantial
Distribution: 2-Parameter Exponential
1,534 0,026
λ= 0,1233

We are using data of four years in determining their probability distribution. During this four year there was one "Minor" accidents and two "None" accidents.

APPENDIX II

Holt-Winter's Forecast, Multiplicative Model

	AlphaHW	0.14					
	BetaHW	0.03					
Orig. Data	GammaHW	0.03			MSE(HW)	325.6104	
Y_t	S_t	G_t	C_t	F_t	E_t	E_t*E_t	Random Component
112			0.689231				
113			0.695385				
142			0.873846				
154			0.947692				
183			1.126154				
238			1.464615				
239			1.470769				
222			1.366154				
178			1.095385				
141			0.867692				
126			0.775385				
102	162.5	-0.90909	0.627692				
133	165.9838	-0.7773	0.692592	111.3734	21.62657	467.7087	
164	175.0953	-0.48064	0.702622	114.8821	49.11794	2412.572	18.57924233
158	175.482	-0.45462	0.874642	152.5863	5.413659	29.3077	41.31189367
170	175.6372	-0.43633	0.948299	165.8721	4.127917	17.0397	4.913704183
171	171.9309	-0.53442	1.122207	197.3031	-26.3031	691.853	3.857276295
240	170.3422	-0.56605	1.462945	251.0299	-11.0299	121.6596	-21.34231139
234	168.2815	-0.61089	1.468362	249.7015	-15.7015	246.5364	-8.373073146
198	164.4873	-0.70639	1.361281	229.0639	-31.0639	964.9635	-12.20116111
180	163.8572	-0.7041	1.095479	179.4031	0.596942	0.35634	-24.95187533
170	167.7407	-0.56647	0.872066	141.5667	28.43333	808.4545	1.269299254
130	167.2421	-0.56444	0.775443	129.6243	0.375661	0.141121	24.21308946
131	172.5609	-0.38794	0.631636	104.6223	26.37773	695.7847	0.751066509
105	169.2934	-0.47433	0.690421	119.2457	-14.2457	202.9392	22.24934029
122	169.4933	-0.4541	0.703137	118.616	3.384028	11.45165	-11.55625449
119	164.4215	-0.59263	0.870115	147.8488	-28.8488	832.2534	3.142251549
149	162.8901	-0.62079	0.947292	155.3587	-6.35871	40.43313	-23.55001353
179	161.8826	-0.6324	1.121713	182.0997	-3.09974	9.608401	-4.716358582
178	155.7093	-0.79862	1.453351	235.9002	-57.9002	3352.431	-1.876438716
224	154.5803	-0.80853	1.467784	227.465	-3.46499	12.00617	-47.13965002
206	153.4297	-0.8188	1.360722	209.3267	-3.32671	11.06699	-1.703743648
191	155.6548	-0.72748	1.099426	167.182	23.81805	567.2995	-1.660984001
168	160.2079	-0.56906	0.877363	135.1068	32.89323	1081.965	20.66882816
120	158.9545	-0.58959	0.774827	123.7908	-3.79077	14.36992	27.93880932
115	161.6832	-0.49005	0.634025	100.029	14.97103	224.1317	-2.705425637
111	161.1341	-0.49182	0.690375	111.2912	-0.29116	0.084773	12.799532
108	159.656	-0.5214	0.702337	112.9535	-4.95354	24.53754	0.096653924
143	159.8642	-0.49952	0.870847	138.4654	4.534583	20.56245	-3.766039768
155	159.961	-0.48163	0.947942	150.9648	4.03522	16.283	4.21775226
190	160.866	-0.44003	1.123495	178.8901	11.10993	123.4306	3.822733639

213	158.4844	-0.49827	1.45007	233.1553	-20.1553	406.2352	9.762275658
228	157.6152	-0.5094	1.467147	231.8895	-3.88951	15.12831	-16.09100185
223	158.0547	-0.48094	1.362228	213.7773	9.222708	85.05835	-2.497262906
188	159.4532	-0.42455	1.101815	173.2407	14.75927	217.8359	8.348727774
155	161.4978	-0.35048	0.879835	139.5258	15.47422	239.4515	12.77995903
111	158.6428	-0.42561	0.772573	124.8614	-13.8614	192.1372	13.21695638
126	163.889	-0.25546	0.638069	100.3137	25.68634	659.7882	-11.23432647
112	163.4372	-0.26135	0.690222	112.9685	-0.96847	0.937939	21.59054677
94	159.0687	-0.38456	0.698995	114.6044	-20.6044	424.5398	-0.627510091
126	156.7245	-0.44335	0.86884	138.1896	-12.1896	148.586	-16.91935201
165	158.7703	-0.36868	0.950681	148.1455	16.85452	284.075	-9.783348642
182	158.9046	-0.35359	1.12415	177.9634	4.036611	16.29423	14.41053801
184	154.1186	-0.48656	1.442384	229.9101	-45.9101	2107.741	3.764826244
204	151.5899	-0.54783	1.463505	225.4007	-21.4007	457.9916	-37.59642533
168	147.162	-0.66423	1.355609	205.7536	-37.7536	1425.337	-17.05074938
140	143.7769	-0.74585	1.097972	161.4134	-21.4134	458.5331	-30.59365553
139	145.1245	-0.68305	0.882174	125.8437	13.15628	173.0877	-17.04412174
118	145.6027	-0.64821	0.773709	111.5916	6.408424	41.0679	11.57753725
122	151.4292	-0.45397	0.643096	92.49095	29.50905	870.7839	5.847434116
92	148.4993	-0.52825	0.688101	104.2064	-12.2064	148.9958	24.90839575
104	148.0851	-0.52483	0.699094	103.431	0.568973	0.32373	-9.819076782
141	149.6217	-0.46298	0.871047	128.2063	12.7937	163.6787	0.841542155
169	153.1639	-0.34283	0.955263	141.8024	27.19758	739.7085	11.07578462
156	150.8542	-0.40184	1.121449	171.7939	-15.7939	249.4458	23.01571361
202	148.9954	-0.44554	1.439785	217.0101	-15.0101	225.3034	-12.72459387
241	150.8072	-0.37783	1.467542	217.4034	23.59655	556.7972	-11.87994654
194	149.4045	-0.40857	1.353895	203.9233	-9.92329	98.47177	20.23871761
199	153.5106	-0.27313	1.103923	163.5934	35.40663	1253.63	-7.724851
165	157.9695	-0.13117	0.887044	135.182	29.81797	889.1115	29.83772896
123	157.9974	-0.1264	0.773852	122.1209	0.879133	0.772875	24.99050613
109	159.498	-0.07759	0.644305	101.5263	7.473731	55.85666	0.831185542
93	156.0232	-0.1795	0.68534	109.6974	-16.6974	278.8023	6.284576011
111	156.2544	-0.16718	0.699433	108.9494	2.050614	4.20502	-13.8059286
127	154.6472	-0.21038	0.869552	135.9592	-8.9592	80.26722	1.827556352
162	156.5578	-0.14675	0.957648	147.5277	14.47229	209.4473	-7.290823717
194	158.7322	-0.07712	1.124471	175.407	18.59299	345.6991	12.21332574
204	156.2797	-0.14838	1.435752	228.4292	-24.4292	596.7881	15.59698741
196	152.9708	-0.24319	1.461954	229.1291	-33.1291	1097.539	-20.16583774
231	155.2324	-0.16805	1.357921	206.7772	24.22281	586.7446	-27.28077651
156	153.1393	-0.2258	1.101365	171.1791	-15.1791	230.404	20.43487012
124	151.0763	-0.28092	0.885056	135.641	-11.641	135.5125	-12.41368339
116	150.6699	-0.28468	0.773733	116.6933	-0.6933	0.480659	-9.462278845
102	151.4947	-0.2514	0.645175	96.894	5.106	26.07124	-0.358078592
90	148.4543	-0.33507	0.682967	103.6531	-13.6531	186.407	4.421621485

102	147.7991	-0.34467	0.699153	103.5994	-1.59939	2.55805	-11.1605693
122	146.4531	-0.37471	0.868456	128.2193	-6.21925	38.67909	-1.093231616
150	147.5561	-0.33038	0.959415	139.8916	10.10841	102.18	-4.862677413
167	147.4061	-0.32497	1.124725	165.5511	1.448923	2.099377	8.749408136
179	143.9441	-0.41908	1.429986	211.1722	-32.1722	1035.047	1.574191656
218	144.3077	-0.3956	1.463415	209.8269	8.173057	66.79885	-26.23872658
204	144.7965	-0.36907	1.35945	195.4212	8.578792	73.59568	7.396893295
160	144.546	-0.36551	1.101532	159.0674	0.932583	0.869711	7.658157526
132	144.8753	-0.34467	0.885838	127.6078	4.392231	19.29169	1.180583359
104	143.1142	-0.38716	0.772322	111.8282	-7.82815	61.27996	3.969319058
67	137.2839	-0.55045	0.640461	92.08387	-25.0839	629.2007	-6.231231233
82	134.3998	-0.62046	0.680782	93.38448	-11.3845	129.6063	-20.57242323
85	132.0708	-0.67172	0.697487	93.53226	-8.53226	72.79939	-9.074531152
130	133.9599	-0.59489	0.871516	114.1144	15.88564	252.3536	-6.649092428
136	134.5394	-0.55966	0.960958	127.9524	8.047581	64.76356	13.77026136
156	134.6406	-0.53984	1.125742	150.6903	5.309748	28.19342	7.251106388
183	133.2429	-0.56557	1.428289	191.7622	-8.76225	76.77701	5.037108046
191	132.3749	-0.57465	1.462799	194.1621	-3.16208	9.998773	-6.501667535
212	135.1806	-0.47324	1.365714	179.1757	32.82426	1077.432	-1.79721677
166	136.9462	-0.40607	1.104851	148.3844	17.61559	310.3091	28.028302
128	137.6539	-0.37266	0.887159	120.9524	7.047595	49.6686	15.14357446
92	134.7389	-0.44893	0.769637	106.0254	-14.0254	196.7111	6.20970967
92	135.5999	-0.40963	0.641601	86.00744	5.992555	35.91072	-11.35445403
101	137.0338	-0.35432	0.68247	92.03506	8.964939	80.37013	5.261809106
105	138.6201	-0.29611	0.699286	95.33213	9.667872	93.46775	7.72036637
127	139.3598	-0.26503	0.87271	120.5515	6.448488	41.583	8.272001735
143	140.4549	-0.22423	0.962673	133.6643	9.335698	87.15525	5.610622946
147	138.8797	-0.26476	1.123724	157.8636	-10.8636	118.0171	8.003696141
188	137.6365	-0.29411	1.426418	197.9822	-9.98219	99.64404	-8.764872179
234	140.5098	-0.19909	1.468876	200.9042	33.09576	1095.329	-7.907614323
201	141.2719	-0.17025	1.367426	191.6244	9.375605	87.90198	27.90091673
165	142.2552	-0.13565	1.106502	155.8962	9.103811	82.87938	8.05393878
133	143.2112	-0.1029	0.888405	126.0826	6.917405	47.85049	7.744491655
109	142.9006	-0.10913	0.769431	110.1413	-1.14135	1.302671	5.861913661
80	140.257	-0.18516	0.639464	91.61517	-11.6152	134.9122	-0.868146082
68	134.4111	-0.35498	0.677173	95.59481	-27.5948	761.4735	-9.570973298
94	134.1075	-0.35344	0.699335	93.74359	0.25641	0.065746	-22.77920567
131	136.0435	-0.28476	0.875416	116.7284	14.27155	203.6771	0.461071316
136	136.5308	-0.2616	0.963676	130.6913	5.308715	28.18246	12.1546096
184	140.1153	-0.14621	1.129408	153.1289	30.87108	953.0233	4.680625806
181	138.1382	-0.20114	1.422934	199.6544	-18.6544	347.9869	25.91778749
206	138.2599	-0.19146	1.469508	202.6124	3.387626	11.47601	-15.27529612
205	139.7272	-0.14169	1.370418	188.7985	16.20154	262.4901	3.107301941
178	142.565	-0.05231	1.110763	154.4516	23.5484	554.5269	13.70950691

119	141.3136	-0.08828	0.887016	126.609	-7.60896	57.89622	19.70217453
96	138.9212	-0.1574	0.767079	108.6631	-12.6631	160.3532	-6.269084983
95	140.1356	-0.11625	0.640618	88.73453	6.265473	39.25615	-10.44278847
							5.301130364

Holt-Winter's Forecast Additive Model

		Alpha HW	0.14				
		Beta HW	0.03				
	Orig. Data	Gamma HW	0.03			MSE(HW)	2197.343
	Y_t	S_t	G_t	C_t	F_t	E_t	E_t*E_t
1	112			-50.5			
2	113			121.5			
3	142			-20.5			
4	154			-8.5			
5	183			20.5			
6	238			75.5			
7	239			76.5			
8	222			59.5			
9	178			15.5			
10	141			-21.5			
11	126			-36.5			
12	102	162.5	-0.90909	-60.5			
13	133	164.6581818	-0.81707	-49.9347	111.0909	21.90909	480.0083
14	164	146.8533538	-1.32671	118.3694	285.3411	-121.341	14723.66
15	158	150.1429177	-1.18822	-19.6493	125.0266	32.97335	1087.242
16	170	153.0910423	-1.06413	-7.73773	140.4547	29.5453	872.9247
17	171	151.8131471	-1.07054	20.46061	172.5269	-1.52692	2.33147
18	240	152.668642	-1.01276	75.85494	226.2426	13.75739	189.2659
19	234	152.4740594	-0.98821	76.65078	228.1559	5.844117	34.1537
20	198	149.6678272	-1.04275	59.16497	210.9858	-12.9858	168.6322
21	180	150.8475627	-0.97608	15.90957	164.1251	15.87493	252.0133
22	170	155.6994755	-0.80124	-20.426	128.3715	41.62852	1732.933
23	130	156.5224826	-0.75251	-36.2007	118.3982	11.60176	134.6009
24	131	160.7721744	-0.60245	-59.5782	95.26997	35.73003	1276.635
25	105	159.4368305	-0.62443	-50.0698	110.235	-5.23498	27.40504
26	122	137.0869457	-1.2762	114.3657	277.1818	-155.182	24081.39
27	119	136.2081444	-1.26427	-19.5761	116.1615	2.838539	8.057301
28	149	137.9950101	-1.17274	-7.17545	127.2061	21.79386	474.9724
29	179	139.8626669	-1.08153	21.02091	157.2829	21.71712	471.6335
30	178	133.6520871	-1.2354	74.90973	214.6361	-36.6361	1342.202
31	224	134.5072417	-1.17268	77.03604	209.0675	14.93253	222.9806
32	206	135.2246248	-1.11598	59.51328	192.4995	13.50048	182.2629
33	191	139.8460929	-0.94386	16.9669	150.0182	40.98178	1679.507
34	168	145.8355596	-0.73586	-19.1483	118.4763	49.52375	2452.602
35	120	146.6538375	-0.68923	-35.9143	108.899	11.10097	123.2316
36	115	149.9705018	-0.56906	-58.8399	86.38644	28.61356	818.7359
37	111	151.0350154	-0.52005	-49.7688	99.33164	11.66836	136.1507
38	108	128.5516708	-1.17895	110.3182	264.8807	-156.881	24611.55
39	143	132.3011881	-1.0311	-18.6678	107.7967	35.20333	1239.275

40	155	135.596843	-0.90129	-6.37809	124.0946	30.90536	955.1411
41	190	139.4952463	-0.7573	21.90542	155.7165	34.28354	1175.361
42	213	138.6472702	-0.76002	74.89302	213.6477	-0.64767	0.419482
43	228	139.7179882	-0.7051	77.37342	214.9233	13.07671	171.0005
44	223	142.4392252	-0.60231	60.1447	198.5262	24.47383	598.9686
45	188	145.924381	-0.47969	17.72016	158.8038	29.19618	852.417
46	155	149.463196	-0.35913	-18.4077	126.2964	28.70358	823.8953
47	111	148.7974939	-0.36833	-35.9708	113.1898	-2.1898	4.795206
48	126	153.5266738	-0.2154	-57.9005	89.58923	36.41077	1325.744
49	112	154.4953203	-0.17988	-49.5506	103.5425	8.457493	71.52919
50	94	130.4267314	-0.89654	105.9158	264.6336	-170.634	29115.83
51	126	131.6494556	-0.83296	-18.2773	110.8624	15.13762	229.1475
52	165	136.4951153	-0.66261	-5.3316	124.4384	40.5616	1645.243
53	182	139.2291992	-0.5607	22.53138	157.7379	24.26207	588.6479
54	184	134.5298823	-0.68486	74.13033	213.5615	-29.5615	873.8831
55	204	132.834438	-0.71518	77.18718	211.2184	-7.21844	52.10582
56	168	128.7223029	-0.81709	59.51869	192.264	-24.264	588.7397
57	140	127.1176606	-0.84072	17.57503	145.6254	-5.62538	31.64488
58	139	130.6352531	-0.70997	-17.6045	107.8692	31.13077	969.1251
59	118	133.2916536	-0.60898	-35.3504	93.95452	24.04548	578.1851
60	122	139.2931783	-0.41066	-56.6823	74.78214	47.21786	2229.526
61	92	139.2560437	-0.39945	-49.4817	89.33196	2.668043	7.118455
62	104	119.1484488	-0.9907	102.2839	244.7724	-140.772	19816.88
63	141	123.9144807	-0.818	-17.2164	99.88049	41.11951	1690.814
64	169	130.2694001	-0.60281	-4.00974	117.7649	51.23512	2625.037
65	156	130.198874	-0.58684	22.62948	152.198	3.802025	14.4554
66	202	129.3681017	-0.59416	74.08538	203.7424	-1.74237	3.035838
67	241	133.6793853	-0.447	78.09118	205.9611	35.03888	1227.723
68	194	133.407238	-0.44175	59.55091	192.7511	1.248918	1.559797
69	199	139.7498152	-0.23822	18.82528	150.5405	48.45948	2348.321
70	165	145.5446078	-0.05723	-16.4927	121.907	43.09295	1857.002
71	123	147.2881998	-0.00321	-35.0185	110.137	12.86302	165.4572
72	109	149.8606195	0.074063	-56.2077	90.60268	18.39732	338.4615
73	93	148.8912687	0.042761	-49.674	100.453	-7.45296	55.54657
74	111	129.3035179	-0.54615	98.66629	251.2179	-140.218	19661.07
75	127	130.9216248	-0.48123	-16.8175	111.541	15.45901	238.981
76	162	135.4201055	-0.33184	-3.09205	126.4307	35.56934	1265.178
77	194	140.1677856	-0.17945	23.56556	157.7177	36.28225	1316.402
78	204	138.5780154	-0.22176	73.82548	214.0737	-10.0737	101.4797
79	196	135.4936143	-0.30764	77.56364	216.4474	-20.4474	418.0978
80	231	140.2628109	-0.15533	60.4865	194.7369	36.26311	1315.013
81	156	139.6968905	-0.16765	18.74962	158.9328	-2.93276	8.601091
82	124	139.6641303	-0.1636	-16.4679	123.0365	0.963508	0.928348
83	116	141.1130459	-0.11523	-34.7214	104.482	11.518	132.6644

84	102	143.4071957	-0.04295	-55.7637	84.79015	17.20985	296.1789
85	90	142.847615	-0.05845	-49.7692	93.69024	-3.69024	13.61784
86	102	123.2654044	-0.64416	95.06834	241.4555	-139.455	19447.82
87	122	124.8887249	-0.57614	-16.3997	105.8037	16.19629	262.3197
88	150	128.3417138	-0.45526	-2.34954	121.2205	28.77946	828.2572
89	167	130.0631708	-0.38996	23.9667	151.452	15.54799	241.74
90	179	126.2433945	-0.49285	73.19341	203.4987	-24.4987	600.1858
91	218	127.8065549	-0.43117	77.94253	203.3142	14.68582	215.6733
92	204	129.6347173	-0.36339	60.90287	187.8619	16.13812	260.4388
93	160	130.9483915	-0.31308	19.05868	148.0209	11.97906	143.4978
94	132	133.1318707	-0.23818	-16.0078	114.1674	17.83258	318.0009
95	104	133.7095605	-0.21371	-34.571	98.17232	5.827677	33.96182
96	67	131.9933438	-0.25878	-56.0405	77.7322	-10.7322	115.1801
97	82	131.7394122	-0.25864	-49.7683	81.96534	0.03466	0.001201
98	85	111.6638982	-0.85314	91.41637	226.5491	-141.549	20036.15
99	130	115.7932014	-0.70367	-15.4815	94.41109	35.58891	1266.571
100	136	118.3459312	-0.60598	-1.74943	112.74	23.26001	541.0279
101	156	119.7410212	-0.54595	24.33547	141.7066	14.29335	204.2999
102	183	117.880686	-0.58538	72.95119	192.3885	-9.38849	88.14367
103	191	116.7020095	-0.60318	77.8332	195.2378	-4.23784	17.9593
104	212	120.9985941	-0.45618	61.80582	177.0017	34.9983	1224.881
105	166	124.2382569	-0.34531	19.73977	139.6011	26.39891	696.9025
106	128	126.709028	-0.26083	-15.4888	107.8851	20.11486	404.6076
107	92	126.4653941	-0.26031	-34.5678	91.87719	0.122807	0.015082
108	92	129.2620472	-0.1686	-55.4772	70.16454	21.83546	476.7873
109	101	132.1279282	-0.07757	-49.2091	79.32512	21.67488	469.8004
110	105	115.4650181	-0.57513	88.35993	223.4667	-118.467	14034.37
111	127	118.7527117	-0.45924	-14.7696	99.40842	27.59158	761.2954
112	143	121.9973028	-0.34813	-1.06687	116.544	26.45596	699.9179
113	147	121.7913249	-0.34386	24.36166	145.9846	1.01536	1.030957
114	188	120.5516501	-0.37074	72.7861	194.3986	-6.39865	40.94272
115	234	125.2189365	-0.2196	78.76163	198.0141	35.98589	1294.984
116	201	126.9866165	-0.15998	62.17205	186.8052	14.19484	201.4934
117	165	129.4073403	-0.08256	20.21536	146.5664	18.43359	339.7973
118	133	132.007751	-0.00207	-14.9944	113.8359	19.16406	367.2613
119	109	133.6243842	0.046492	-34.2695	97.43784	11.56216	133.6835
120	80	133.9237599	0.054079	-55.4306	78.19369	1.806311	3.262761
121	68	131.630217	-0.01635	-49.6417	84.76872	-16.7687	281.1901
122	94	113.9775355	-0.54544	85.10981	219.9738	-125.974	15869.4
123	131	117.9593476	-0.40962	-13.9353	98.66249	32.33751	1045.715
124	136	120.2821248	-0.32765	-0.56332	116.4829	19.51714	380.9188
125	184	125.5102154	-0.16098	25.38551	144.3161	39.68386	1574.809
126	181	122.9502894	-0.23295	72.34401	198.1353	-17.1353	293.6199
127	206	123.3502861	-0.21396	78.87828	201.479	4.521023	20.43965

128	205	125.893155	-0.13125	62.68009	185.3084	19.69162	387.76
129	178	130.2450852	0.003242	21.04154	145.9773	32.02274	1025.456
130	119	130.7727791	0.018976	-14.8978	115.2539	3.746085	14.03315
131	96	130.7186441	0.016782	-34.283	96.52222	-0.52222	0.272712
132	95	133.4927485	0.099502	-54.9224	75.30484	19.69516	387.8993