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The Historical Development of Civil Aviation Security with Applications of Time Series Modeling

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The examination of civil aviation security has started to be examined in more detail after the first successful sabotage event in 1971. The purpose of the study is to determine the affecting factors to the number of sabotage events between the years 1979-2018. The Vector Autoregressive Model was used to analyze this relationship. In the time series model, the series was examined beginning from the year 1979, the beginning period of the crew resource management concept. In this year, human factors also started to be examined in civil aviation accidents. While the number of casualties and the number of total passengers in the events negatively affect the number of sabotage in the short term, their effects disappear in the long term. It was found that the number of commercial passengers had a positive effect on sabotage in the short term. This situation suggests that sabotage events trigger terrorist acts against commercial passengers in order to make an impression in the world. For this reason, the rules should be structured in the most effective way to prevent sabotage events.

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In the early period of civil aviation security, the X-ray scanning security check system started to be implemented in the early 1970s. After 9/11, the World Trade Center terrorist attacks, the developments in civil aviation security has changed drastically. After the year 2001, the civil aviation security concept became significantly improved at airport security checkpoints around the world. For this reason, numerous passengers are uncomfortable due to long waiting times. Therefore, there is a problem among the passengers' claims to reduce waiting times and the requirement for reducing the security checkpoint which passengers expect. An effective queue structure for airport security checkpoints--without any reduction in terms of security criteria--is an essential subject for civil aviation security (Podemska-Mikluch & Wagner, 2017). Usually, passengers' identity documents, passports along with their luggage and body scans at the airport security checkpoints constitute the basic needs of civil aviation security. Although the objects that are forbidden to be transported are almost the same at different airports, security screening procedures could be reasonably dissimilar (Janic, 2007). For instance, at some airports (e.g. Canada) passengers are required to wait in a single queue prior to entering the security checkpoint, while in other airports (e.g. China) passengers wait in two distinct security checkpoints. Consequently, these strategies influence the control point efficiency, even when the same security control principles are used. Looking at the identical conditions, people can wait in queues at one or two security gates. Therefore, it is possible that the waiting time in queues will be dissimilar (Schwartz, 1974). The importance of security in air transportation has increased over the years and security is essential to avoid injuries and fatalities. The consequences of a terrorist attack can be incalculable that would involve national reputation, public interest, and commercial trust (Gordon, Moore & Richardson, 2009). Generally, the community could be influenced by violations in air transportation security, despite having national protection, and boundary guards. These security services are identified as the public economy that is financed from the common treasury related to nations. The protection of the airport and passengers is a more complicated, significant, and expensive process. Beside the security personnel, x-ray machines and handheld detection equipment are expensive, hence they must be used by qualified and educated personnel. The boundary of civil aviation security depends on the revenue that airline companies receive from their passengers. The countries which receive these payments are classified as; Canada, the United States, the United Kingdom, Germany, and Spain (Aviation Security, 2007). This study aims to identify the affecting factors of a possible sabotage event. The literature review consists of two parts: privatization of airport security, and evaluation of the impact of 9/11 on civil aviation security.

Literature Review

When the concepts and institutions are examined, crew resource management (CRM) is defined as the management of all resources that are available to the crew rather than the resources themselves. In other words, it is a management process that enables aircrew to use their cognitive abilities--technical and non-technical skills--to effectively display expected behavioral performance by using time, information, human, and equipment effectively (Lauber, 1984). Secondly, the Canadian Air Transport Security Authority (CATSA) is a representative establishment which is funded by parliamentary appropriation and responsible to the Parliament owing to the Minister of Transport. CATSA is accountable for ensuring effective, efficient, and continuous screening of persons that access aircraft or restricted areas, and the belongings or baggage which they offer to an air carrier for transportation (Canadian Air Transport Security Authority, 2020). The Canada Revenue Agency is accountable for directing the Air Travelers Security Charge (ATSC) that came into influence on April 1, 2002. Since then, the fee has been gathered by air carriers or their representatives at the time of buying (Air Travellers Security Charge, 2020).

For instance, the Canadian Air Transport Security Authority (CATSA) carries out passenger screening and other security tasks. CATSA informs the parliament owing to the Ministry of Transport and all payments are paid from the common treasury. In addition, the airport finance district applies the Air Travelers Security Charge system to arrange payoffs from the treasury to CATSA for passengers. In line with this system, passengers using air transportation in Canada have to pay privately to benefit from national security services. Poorly designed taxation policies may have undesirable consequences for the economy. Increasing airline-related taxes reduce overall taxes collected for aviation-related economic activities. High taxes that increase expenses, reduce the competitiveness in exports and the domestic market. Taxing air transportation also reduces the demand for tourism. For example, the activities of secondary service tasks such as hotels and restaurants will be negatively affected by applied tax policies (Canadian Air Transport Security Authority, 2020). ATSC has produced a solution in this regard, with taxes attached to an airline ticket, thereby reducing the tax rate of Canadian passengers using air traffic. The Canadian attempt in air security strategy was progressively and structurally in line with the U.S. aviation implementations, but after the 9/11 attacks the ATSC was subsidized by the government because of substantial budget deficits (Prentice, 2015).

Table 1
Remarkable Terrorist Attacks Related to the Security of Air Transportation

Years	Events
1985	The bombing of Air India Airlines.
1988	The explosion over Scotland on Flight 103 of PanAM Airlines with a concealed bomb.
September 11, 2001	Terrorist action by using aircraft as weapons.
2001	The presence of a bomb in the shoe.
2004	Russian aircraft destroyed by suicide bombers (remote detonation by device).
2006	UK authority published a strategy used to eliminate the problems that happened before by drafting laws related to liquids.
2007	Attack on Glasgow Airport with special vehicles.
2009	An Unsuccessful attempt by the underwear bomber.
2010	Explosive toner cartridges shipped by air cargo transportation.
2011	Terrorist attack in the public area of Moscow airport.

Source: (Plungis, 2013).

After 2011, the 2014 Jinnah International Airport attack, the 2015 Paris Charles de Gaulle Airport attack, the 2016 Brussels Airport bombing, andthe 2016 Atatürk Airport terrorist attacks were additional, remarkable examples of civil aviation security (Plane Crash Info Database, 2020). Table 1 presents several terrorist attacks against the security of air transportation that shapes the development of the aviation security strategy. These attacks were remarkable examples of sabotage incidents in the history of civil aviation. These events started at the beginning of 1985. This strategy developed and based on abduction incidents and international obligations. So, international obligations with the concept of privatization and the density of airports have also increased accordingly. Terrorist attack attempts have also increased so that they would make an impression all over the world (Cooper, 1971). In December 1970, the International Civil Aviation Organization (ICAO) held conferences which ensued in the Hague Convention on blocking the illegal seizure of aircraft. Security precautions were related to the concept of security by Canada in ICAO Annex 17, defined at international meetings in line with the measures for the protection of International Civil Aviation against illegal activities (International Civil Aviation Organization, 2019). As a result of these meetings, Canada has been identified as liable for the progress of national policies about civil aviation security. On December 26 1971, U.S. citizen Thunder Bay was armed with a pistol and grenade, forcing Air Canada airline pilots to fly to Toronto, refuel and fly to Cuba (Airliners, 2020). Later, the armed citizen was forced to land the aircraft and delivered to Canada. On June 8 1972, in the destination of Prague Airport to Marianske Lázně, the captain was killed in the cockpit. Ten hijackers (including three women, one with an infant) escaped and were later caught by the police. As a result of these incidents, carrying weapons and explosives in the aircraft's cabin (next to the passenger) was described as a crime with the amendment made in the Canadian Criminal Code in 1972 (Aviation Safety, 2020).

Time Process of Privatization Concept in Airport Security Privatization of Airport Security

In 1973, the Air Transport Law was altered to allow airline companies to set up and operate security programs at their self-expenditure (Canadian Air Transport Security Authority, 2020). Transport Canada as the possessor and operator of national airports in Canada, stated that it is necessary to purchase metal detectors and X-ray machines for controlling passengers with luggage. Airline laws have also been updated to ensure that all checked baggage must be scanned by X-ray machines. Since 1985 more stringent measures have been applied, such as passenger and baggage matching on international flights. Technically, the concept of airport security privatization started in 1973 when the government made it mandatory for airlines to pay for passenger screening. After 21 years, the following process in security privatization emerged as part of the National Airports Policy (1994), which created authorities to manage 26 airports which formed the national airport framework of airports in Canada (CAA). Afterwards, all procedures were prepared for the screening of passengers and pieces of baggage related to the rules of CAAs and police security. As of 2003, all international airports in Canada were commercialized. The timeline for the privatization of civil aviation security is shown in table 2.

Table 2
Timeline of the Aviation Security Privatization Concept

Years	Events
1973	Aviation Law Amendment.
1985	Aviation Law Amendment.
1992 - 2000	Commercialization of airports.
2001 - Present	Safety procedures in air transport.
2001 - Present	Charges of safety equipment on airlines (purchase of x-ray equipment).
2001 - Present	Detectors that detect explosives in line with the baggage matching strategy have started to be used in airlines.
2001 - Present	Airports are allocated an area to be assigned to the police for security calls.
2001 - Present	Establishment of CATSA and ATSC institutions.

Source: (Prentice, 2015).

Following the implemention of the National Airports Policy (1994), the commercialization of airports dramatically increased between 1994 and 1996. Hence, 26 airports were commercialized all over the world. By the end of 2000, this number increased to more than 100 airports. Increasing the appropriations for aviation security after the 9/11 attack enabled airports to become more equipped to perform security functions. There have been radical changes in aviation security after the 9/11 terrorist attacks. For example, CATSA was established on April 1 2002 (Canadian Air Transport Security Authority, 2020). This law mandated the inspection of passengers and luggage for screening and limited access of non-passengers to the customs areas of airports. Transport Canada is an aviation agency that has been identified as responsible for civil aviation security. However, an important part of the transport security strategy has been passed from the relevant agency to the Ministry of Finance. In this case, the security fee allowances of airline passengers fall under the responsibility of the Minister of Finance. The concept of airline passengers' security fee was set at the level of $12 for domestic passengers and $24 for international passengers in 2002. It was thought that the air passenger traffic in Canada increased by ten percent, but no progress has occurred in the following years. However, air traffic data recovered faster than hoped and the Ministry of Finance started to charge more taxes than other aviation security disbursing under CATSA. As a result of the complaints received with the reflection of these taxes on ticket prices, the relevant tax rates were reduced in the following years (Prentice, 2015). While entering an airport, great numbers of passengers are oblivious about the institutional infrastructure available to mitigate potential security threats. However, in the event of a crisis with the institutional infrastructure, appropriate and coordinated decisions should be taken to ensure the safety of airport employees and through all processes of passengers (Comfort et al. 2010; Barbash et al. 1986).

When security officers and managers need to make decisions under extreme time pressure, the most accurate decisions can be made in a way that will not harm daily airport operations. However, since the concept of safety comes first in the priority of such decisions, the importance of the sustainability of the operations comes second. However, companies build airports that work with security experts to plan the designs of airports with safety and security principles in mind. They design the airports by bulk-operated engineering structures that focus on technology and logistics (De Neufville et al. 1995; Horonjeff et al. 2009). From a security aspect, the security level of airports is evaluated to utilize technology for improving regulations related to safety and security required by federal regulators (United States Government Accountability Office, 2005; Transportation Security Act, 2011). In this context, compliance with the rules infers compliance with airport security standards. Better-planned security technology ensures better security coverage. Manipulating passengers and employees with system engineering create a strategy to remove the human element as much as possible in safety-related decision-making. With this strategy, decreasing human interposition in security determination operations is the most appropriate decision (Harris, 2002). For that purpose, technology has undergone a significant operational process to ensure security. In this way, decisions are made by security software. Such software does not only detect objects that represent potential threats, it can also detect behavioral abnormities that could be evaluated as threats. This aspect is related to the principal security access outlined by security agencies and regulative agencies. Briefly, when the rules of security are followed at airports, security is provided for passengers and airport personnel that are at risk. This security strategy has been largely examined at most security checkpoints across the airport. Thereupon, in spite of the interferences to reduce human-based decision-making on security issues at airports, the proof is the gathering of the effort that has not been completely accomplished (European Union Aeronautics Research, 2006; Transportation Security Act, 2011; Federal Aviation Agency, 2013).

Evaluation of September 11th, 2001 Impact on Civil Aviation Security

Since the hijack of five aircraft simultaneously on 9/11, the World Trade Center Attacks, the procedures about civil aviation security concept has increasingly developed over time. Therefore, the important articles are classified related to the operation of security criteria during flight communication with the cockpit:

- Communication between the cockpit and the cabin is provided through the interphone.
- The company must have a cryptic word used in flight evasion and similar emergencies.
- When this word is said to the cockpit, the pilots can realize that the plane has been hijacked.
- The cockpit personnel should never open the cockpit door in any case.
- It should also be quickly given information to the cockpit in cases where there are unserious, uneasy, impatient, and similar passenger profiles (Lee, Oh & O'Leary, 2005, p. 356).

After 9/11, Standards, and Recommended Practices (SARPs) related to the certification of aerodromes were presented inside ICAO Annex 14, Volume I. This document has demonstrated a powerful source to guarantee the aerodrome facilities and operations conformity with the appropriate SARPs. These SARPs are applied for promoting the safety, regularity, and efficiency of aircraft operations. Besides ICAO Annex 14, the primary SARPs are concerned with the ICAO Annexes of 6, and 11 (Lee, Oh & O'Leary, 2005).

In the following part of the study, a sample of data analysis is examined with five selected time series. The aim was to find the parameters which had an impact on sabotage. For this reason, the time series modeling was conducted and the affecting parameters were found. To show the efficiency of security precaution, on September 11 2001, the World Trade Center was included in this study as a case stdu. The pairwise comparisons of the ratio of sabotage in the total event, and the ratio of fatalities in the total passenger in total events were examined in two-phase as the years between 1979-2001, and 2002-2018.

Methodology

This paper includes yearly data released by deaths and incidents per year according to ACRO and Bureau of Aircraft Accident Archives (2020) data, and Plane Crash Info Database (2020) from 1979 to 2018. All the variables are taken from commercial civil aviation databases. All of the countries which share the accident and incident information are examined in this time series model. In this analysis, it cannot be examined in 2019, because the data was not available. Time series modeling is used in this research to determine the factors affecting sabotage. This model shows the effectiveness of the precautions, rules, and regulations taken over time. The decreasing trend in the number of sabotage over the years shows the effectiveness of the precautions, rules, and regulations taken in civil aviation security. This efficiency is statistically proven in the light of the numerical data obtained in this study. So, total events, the total number of casualties, the total number of passengers in these events, the total number of commercial passengers are taken as endogenous variables thought to affect the sabotage events in the Vector Autoregressive (VAR) Model. After creating the VAR model, impulse response functions are shown the relationship between Sabotage and the other endogenous variable. After mentioning the important developments in the history of civil aviation security, the concept of sabotage related to civil aviation security is examined in this section with four time series. These selected series were evaluated in order to make an inference as they give the total number of commercial passengers in air transportation as well as the total number of events, casualties, and the total commercial passengers which took place in air transportation accidents.

Table 3
Description of Sample Data

Total Events	Total Number of Casualties	Total Passenger In These Events	Total Commercial Passengers	Sabotage
This data is related to the number of flights that ended with the fatal injury of passengers.	This data is related to the number of fatal injury passengers which is a death lower than 30 days duration following the accident (World Trade Organization, 2020)	This data is related to the number of passengers which were in fatal injury flights.	This data is related to the number of commercial passengers who used civil air transportation.	This data is related to the intentional intervention of aircraft during flights. Its meaning is different from abduction but it usually evaluated as the hijacking of aircraft.

Source: (Security and Facilitation, 2020).

These data are related to the outcomes of all accidents. Total events give the number of such accidents. The total number of casualties gives the number of fatalities about these accidents that resulted in death within 30 days. The total passengers in these events give the number of people that take part in the accidents. Total commercial passengers are related to the yearly number of passengers who used civil air transportation. Sabotage deals with security-related events that include intentional intervention of aircraft. These data have the possibility to threaten civil aviation security in terms of sabotage as it is specified in the Aviation Security Manuel (Doc 8973-Restricted) and ICAO Annex 17 (The ICAO Annex 17 Aviation Security Manual, 2020).

The original monthly series are shown in Figure 1 to indicate the range of the real values. It can be seen that the series have stationarity during the yearly period. The term *stationarity* is explained in the following section. Series are standardized in order to avoid variability to interpret the results correctly by subtracting the mean and dividing the standard deviation in time series modeling. The time series analysis is conducted in R 4.0.2.: "TSA, vars packages" (Pfaff, 2008, p. 12).

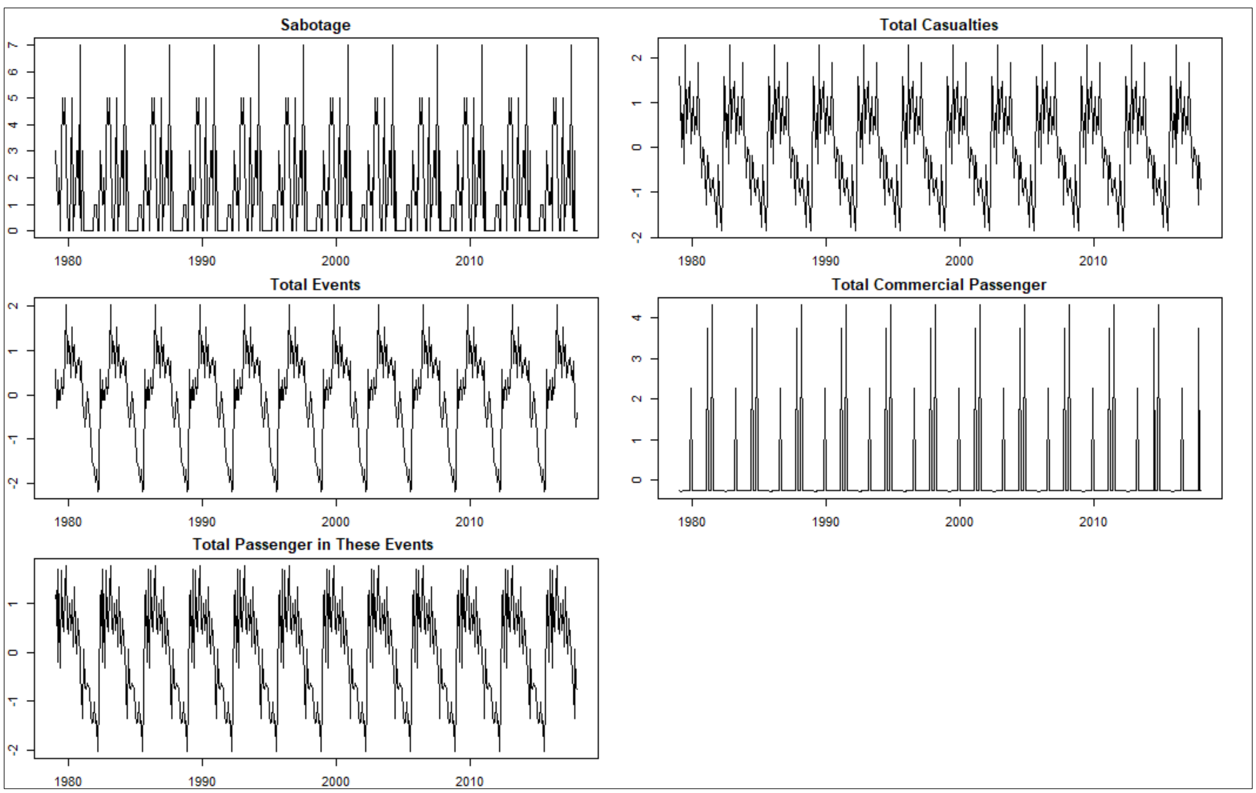

Figure 1. The Time Series Plot of the Original Series

Unit Root Test

The concept of *stationarity* has great priority for the time series analysis. The concept of stationarity is expressed as the mean and variance of a time series are constant and the covariance between the two values of the series depends not only on the examined time but only on the difference between the two-time series. In order to apply the time series models, the series should be adjusted from the trend and seasonality (time-invariant). A subjective way to evaluate stationarity is using Augmented Dickey-Fuller (ADF) test statistics (Dickey & Fuller, 1979; Dickey & Fuller, 1981). The null hypothesis is that the series has a unit root. The alternative hypothesis is that the time series is stationary (or trend-stationary). As it can be seen in Table 4, the null hypothesis is rejected at the 0.05 significance level for the variables of the number of Total Events (S_TE), the number of Total Casualties (S_TC), the number of Total Passenger in These Events (S_TPE), the number of Total Commercial Passenger (S_TCP) and the number of Sabotage (S_S).

Table 4
ADF Test Results for Evaluating Stationarity

	S_TE	S_TC	S_TPE	S_TCP	S_S
ADF test value	-5.4208	-8.0372	-7.356	-17.1845	-12.2473
p	<0.001	<0.001	<0.001	<0.001	<0.001

When the standardized series (Figure 2) are examined, it is obvious that there is stationarity and the relationship between sabotage and other series can be examined. Therefore, the cointegration test is not necessary, and it can be used the series in the estimation of regressions for causality analysis.

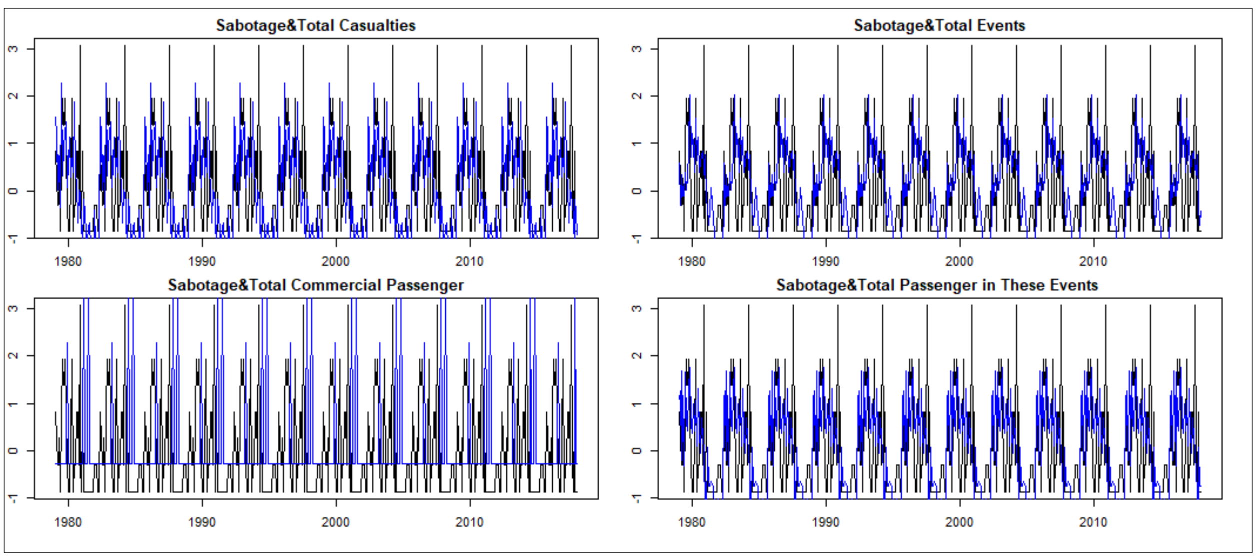

Figure 2. The Time Series Plot of S_S (Black Legend) And The Other Series (Blue Legend)

The VAR Model

The vector autoregressive (VAR) model takes each endogenous variable as the delay value of all endogenous variables to create the model and then generalizes the univariate regression model to a vector consisting of the multivariate time series variable regression model. The VAR (p) model involves the estimation of the following equations (Lütkepohl, 2005):

$$y(t) = a_1\, y(t-1) + a_2\, y(t-2) + \cdots + a_p\, y(t-p) + \varepsilon_t$$

In the formula, the vector of endogenous variables (S_TE, S_TA, S_TPE, S_TCP, S_S); *p* is the order of lags, ,…,is the coefficient matrix, each of vector of the lag endogenous variables and is a vector of systems' random error. The lag length *p* in VAR is selected by the minimum Akaike Information Criterion (AIC) by using the "VARselect" function with maximum lag equals 8. Table 5 shows the estimated VAR results. The greater *t*-values are showing a significant relationship with high evidence.

Table 5
Estimated VAR Model Results (for S_S)

Variables (lags)	Estimate	Variables (lags)	Estimate	Variables (lags)	Estimate	Variables (lags)	Estimate
S_S (1)	-1.223e+00 (-2.105e+13)	**S_S (2)**	-3.827e+00 (-1.902e+13)	**S_S (3)**	-1.672e-01 (-1.251e+13)	**S_S (4)**	-2.024e+00 (-2.402e+13)
S_TC (1)	-3.661e+00 (-3.004e+13)	**S_TC (2)**	-2.479e+00 (-1.902e+13)	**S_TC (3)**	-2.645e+00 (-1.209e+14)	**S_TC (4)**	-8.866e+00 (-2.074e+13)
S_TE (1)	5.929e-01 (9.873e+12)	**S_TE (2)**	-9.643e-01 (-3.091e+13)	**S_TE (3)**	-2.804e+00 (-1.278e+13)	**S_TE (4)**	2.931e+00 (9.882e+12)
S_TCP (1)	6.301e-01 (5.087e+12)	**S_TCP (2)**	-3.651e+00 (-2.102e+13)	**S_TCP (3)**	-1.894e+00 (-1.344e+13)	**S_TCP (4)**	1.146e+00 (4.867e+13)
S_TPE (1)	7.763e-01 (9.115e+12)	**S_TPE (2)**	6.656e+00 (2.036e+13)	**S_TPE (3)**	4.945e+00 (3.701e+13)	**S_TPE (4)**	8.081e+00 (2.265e+13)
Variables (lags)	**Estimate (t)**	**Variables (lags)**	**Estimate (t)**	**Variables (lags)**	**Estimate (t)**	**Variables (lags)**	**Estimate (t)**
S_S (5)	-1.716e-01 (-3.535e+12)	**S_S (6)**	-1.856e-01 (-3.602e+12)	**S_S (7)**	1.914e+00 (1.794e+13)	**S_S (8)**	-1.594e+00 (-2.796e+13)
S_TC (5)	-7.258e-01 (-1.008e+13)	**S_TC (6)**	-5.420e+00 (-2.977e+13)	**S_TC (7)**	-6.915e+00 (-3.276e+13)	**S_TC (8)**	-6.666e+00 (-1.995e+13)
S_TE (5)	-6.295e+00 (-3.107e+13)	**S_TE (6)**	-6.143e+00 (-2.031e+13)	**S_TE (7)**	-2.616e+00 (-6.519e+12)	**S_TE (8)**	7.151e+00 (1.687e+13)
S_TCP (5)	3.520e-01 (1.163e+13)	**S_TCP (6)**	-6.913e-01 (-5.138e+13)	**S_TCP (7)**	-1.426e+00 (-2.596e+13)	**S_TCP (8)**	2.008e+00 (-1.767e+13)
S_TPE (5)	2.020e+00 (1.549e+13)	**S_TPE (6)**	1.039e+01 (2.300e+13)	**S_TPE (7)**	1.036e+01 (2.044e+13)	**S_TPE (8)**	4.953e+00 (1.879e+13)

Impulse Response Functions

According to the estimated VAR model of each endogenous variable, it can be demonstrated an impulse response function analysis of the interactive relationship between S_S and the other series.

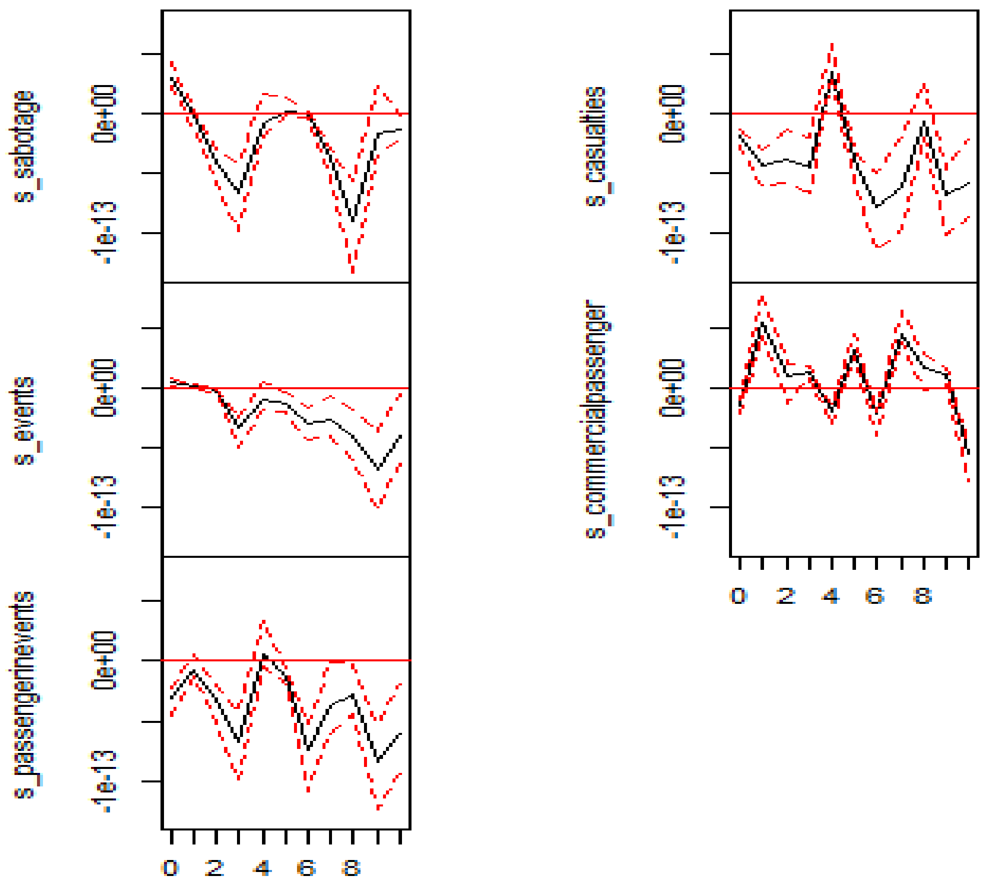

Figure 3. S_S Impulse Response.

In the first graph the impulse-response of S_S to S_S, at the initial period, a positive shock on S_S will obviously lead the S_S to go up by the shocking amount. Thus, the initial value is greater than zero. S_casualties (S_TC) graph shows that after being impacted by S_TCP, S_S remains negative in the short term. At stage 4, this impact becomes positive. The graph on the middle left-hand side shows that S_S began to rise after being impacted by S_events (S_TE) and then the impact slowly decreased. The graph on the middle right-hand side shows that S_S began to rise after being impacted by S_commercial passengers (S_TCP). The short term positive effect of commercial passenger numbers on sabotage can be attributed to the terrorists trying to make an impression with these actions. The graph on the bottom left-hand side shows that S_S stays negative after being impacted by S_passenger in events (S_TPE), and then impact slowly decreased in long term (Figure 3). Civil aviation is protected in the short term in line with the precautions, rules, and regulations applied in civil aviation, but as time passes, terrorist acts develop sabotage actions against these precautions, rules, and regulations. In the long term, this effect develops in the direction of increasing the number of sabotage.

Granger Causality Test

According to the VAR model, the Granger Causality Test is used to verify whether the S_S and S_TE, S_TA, S_TPE, S_TCP have Granger Causal Relation. The main idea of the Granger

Causality Test is to test whether the past values of a time series have the ability to predict the future values of another time series. If it is provided statistically significant information about future values, there will be a Granger Causal Relationship between these time series. On the contrary, if it is not achieved statistically significant information there has no Granger Causal Relationship (Granger, 1999, p. 165).

Table 6
Results of the Granger Causality Test

	F	***p***
S_TC	5.405	<0.001
S_TE	14.738	<0.001
S_TCP	14.100	<0.001
S_TPE	20.029	<0.001

The p-value stands for the rejection probability of Granger Causality. If the p-value is less than 0.05, the null hypothesis is rejected. As can be seen in Table 6, S_TC, S_TE, S_TCP, S_TPE has a significant impact on S_S. So, it can be established a causal relationship. During the period of 1979-2018, the Twin Tower Attacks on September 11th, 2001 have played an important role in sabotage events. So, before and after the year 2001 is examined in terms of the ratio of sabotage in total events and the ratio of fatalities in the total passenger in total events in the following section.

Table 7
The results of comparisons between the years 1979-2001 and 2002-2018

	1979-2001	**2002-2018**	***p***
The ratio of sabotage in total events	53/1,363 (3.89%)	7/608 (1.15%)	0.0014
The ratio of fatalities in total passenger in events	45,820/71,530 (64.06%)	16714/25,336 (65.97%)	**<0.001**

According to Table 7, the ratio of sabotage in total events is found statistically significantly higher between the years 1979-2001 than 2002-2018. Furthermore, between the years 1979-2001, the ratio of fatalities in the total passenger in total events is found statistically lower than 2002-2018 (Fisher's Exact, $p<0.05$). These numbers show that the ratio of sabotage events has dramatically decreased, so it can be said with the security applications after September 11, 2001, civil aviation security is more secure. However, the ratio of the fatality level in total events has not decreased (there is a slight increase), despite these applications after September 11, 2001.

Conclusions

In this paper, the civil aviation security concept was expressed in detail with historical developments and examples of applications. Furthermore, the terms were defined with the description of the sample data. In civil aviation, accidents have usually occurred from safety and security problems. First of all, the safety concept is related to the factors such as human errors, weather conditions, mechanical problems, air traffic control, ground crew, maintenance error and, other reasons such as that harmed passengers, facilities, airports. These factors are included in nearly all phases of accidents. Besides safety, this study is related to the security concept that included intentional events. To examine the 40-year accident data, all the information was taken from ACRO and Bureau of Aircraft Accident Archive (2020) and plane crash info database (2020). These data are related to the total number of casualties, total commercial passengers, total passengers in these events, and the total number of events. These four variables are examined against sabotage which only a part of civil aviation security. Sabotage means carry out intentional event against the rules and procedures about civil aviation safety. So, the reason for security problems is based on only one term that specified as sabotage. In general, sabotage is the most dangerous intentional activity in civil aviation security and it is related to having damage to civil aviation safety that means corrupt the system (Plane Crash Info Causes, 2020). Furthermore, at the end of the literature review and the time series analysis, the VAR model is explained in detail. According to the VAR model; there is a significant relationship between sabotage and total casualties, commercial passengers, passengers in these events, total events. The most significant causality of the sabotage is related to the number of total passengers that involved these events according to the Granger Causality Test. The second significant causality (with a slight difference) of the sabotage is the number of total events, and the third causality of the sabotage is the number of total commercial passengers. Finally, the fourth and the last significant causality of the sabotage is the number of total casualties. According to the impulse response functions, the number of total casualties has a negative short-term impact on sabotage. This situation means when the number of total casualties are increased, the number of sabotage will be decreased for a short period of time. To prevent these events, the rules and regulations in civil aviation are designed for the safety of civil aviation. Civil aviation is safe when these rules are implemented in an effective process. To show the efficiency of the rules and regulations, the Twin Tower Attacks on September 11th, 2001 played a dramatically important role in civil aviation. It has seen that the number of sabotage events decreased after 2001 with the implementation of new security precautions. So, this situation shows that civil aviation security has more secure more than three times after the year 2001. It is found a significant effect on sabotage events with the selected variables in this study. In future studies, the reasons for sabotage events can be discussed and classified in terms of the different parameters.

Acknowledgement

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Disclosure Statement

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