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A Study on Prohibited Items at Airport Screening Checkpoints: Examining the Relationship with Passenger Volume and Its Economic Impact

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Abstract: Evolving aviation threats and methods of attack have led to an increase in both the variety and number of prohibited items detected at airport screening checkpoints. While security measures are essential for safeguarding passengers and infrastructure, procedures such as manual bag searches require additional resources, increase operational costs, and may disrupt efficiency. Despite ongoing efforts by security authorities to improve screening processes and enhance public awareness, a substantial number of prohibited items continue to be intercepted. This trend may be driven by growing air traffic volumes, but it may also reflect limitations in current public outreach campaigns and operational strategies. This study employs statistical analysis to examine the relationship between passenger volume and the number of confiscated items, using historical data from the United States and the Republic of Korea. The results reveal a strong positive correlation between passenger volume and the number of confiscated items, with the average cost of a manual bag search—when the selected bag contains prohibited items—estimated at $1.58 per bag search, based solely on time-related losses. These findings show the part of the operational and economic loss posed by prohibited items. As global air travel expands, it is crucial to incorporate multiple perspectives into aviation security policies to maintain safety and efficiency, especially by considering sustainability as essential for reducing aviation's environmental footprint and supporting the industry's long-term viability. Such integration supports long-term resource management and strengthens overall security resilience.

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Introduction

Aviation security is essential for protecting passengers, employees, and the overall aviation industry. Over time, evolving security threats have led to stricter regulations and expanded screening measures to prevent unlawful activities. For instance, following a foiled terrorist plot involving liquid explosives in 2006, authorities imposed restrictions on the quantity of liquids allowed on international flights (Wong & Brooks, 2015). Security measures are essential for protecting people and property from attacks and cannot be compromised for any reason. However, screening for a large number of prohibited items requires additional human and material resources and introduce operational challenges, potentially delaying screening processes and increasing passenger inconvenience and complaints.

The aviation industry is recovering from the significant impacts of COVID-19 (IATA, 2024), and passenger numbers are projected to increase from 4.6 billion in 2019 to an estimated 12.4 billion by 2050 (ICAO, n.d.-b). This ongoing increase in air traffic could lead to more prohibited items being intercepted at airport security checkpoints, potentially causing operational delays if proper preparations are not made. To facilitate the security process, authorities and operators keep improving screening procedures through technological advances and inform passengers about prohibited items via media campaigns and public awareness initiatives. Despite these efforts, the effectiveness of such measures remains uncertain, as a substantial number of prohibited items continue to be intercepted. Therefore, the aviation industry must proactively prepare for future challenges related to prohibited items and their impact on security operations to accommodate the rising volume of air travelers.

However, research on the implications of confiscated items for security checkpoint operations remains limited. One of the main challenges in studying this issue is the lack of accessible data on confiscated items, which may stem from security concerns regarding public disclosure or from the logistical difficulty of tracking the large volume of items confiscated daily. Despite these limitations, this study gathered several years of publicly available data from the U.S. Transportation Security Administration (TSA) and Incheon International Airport in South Korea. According to the U.S. Bureau of Transportation Statistics, over 54 million prohibited items were intercepted at U.S. airports between 2002 and 2008 (U.S. Bureau of Transportation Statistics, n.d.). The Transportation Security Administration (TSA) discontinued the collection of data on prohibited items (except firearms) after 2010, and there is currently no official comprehensive dataset available detailing the total number of prohibited items intercepted at U.S. airports. Although the Republic of Korea does not publish data on prohibited items, information from Incheon International Airport regarding prohibited items from 2013 to 2023 was available through sources provided by the airport authority. Datasets from two countries were used to perform statistical analyses aimed at examining the relationship between passenger volume and the number of confiscated items at screening checkpoints.

Given that restrictions on certain items remain a critical and non-negotiable aspect of aviation security policy, it is essential to examine the impact of prohibited items on airport operations in order to enhance the procedures for handling and disposing of confiscated items while maintaining high levels of security. These impacts stem from various factors, including socio-economic, operational, and environmental considerations, which are closely aligned with

the EONS framework, a recognized sustainability model. EONS stands for Economic Vitality, Operational Efficiency, Natural Resources, and Social Responsibility (ACI-NA, 2006). This framework has been widely adopted by the airport community to support strategic improvements, enhance operations, and facilitate sustainable growth (Martin-Nagle & Kluber, 2015). While sustainability has not yet received significant attention in the field of aviation security, it is crucial for future preparedness. Integrating sustainability considerations into various operational aspects of aviation security, such as managing and discarding prohibited items or optimizing screening effectiveness, may not only enhance aviation security but also improve airport efficiency, enrich the passenger experience, and optimize resource management.

This paper first examines the relationship between passenger traffic and the number of confiscated items. The first research question is *What is the relationship between the amount of passenger traffic and the number of confiscated items?* The corresponding null hypothesis is that there is no statistically significant correlation between passenger traffic volume and the number of confiscated items at airport security checkpoints; the alternative is that there is a significant correlation between these two variables. The second research question is *What are the estimated economic losses from routine security operations, excluding those resulting from security incidents?* This question seeks to provide quantitative and qualitative analyses into the implications of these items for the sustainable operation of security checkpoints, with a particular focus on economic impacts. The research specifically analyzes economic losses from routine security operations caused by prohibited items, excluding those resulting from security incidents. By exploring these aspects, this study aims to offer new perspectives to enhance aviation security policies, optimize checkpoint efficiency, and develop sustainable methods for managing confiscated items while maintaining high security standards.

Literature Review

The Evolution of Restrictions on Items Aboard Aircraft

In aviation security history, the period from 1968 to 1972 is often called the "Golden Age of hijacking" due to a sharp increase in unlawful interferences. During this time, more than a hundred U.S.-registered aircraft were hijacked (Koerner, B. I., 2013). To combat hijackings, countries including the U.S. started to screen passengers who were selected using metal detectors and implemented 100% passenger and carry-on luggage screening from January 5, 1973 (Klenka, 2019; Ravich, 2005). Also, ICAO adopted the new International Standards and Recommended Practices on Aviation Security (Annex 17) in 1974, which mandates that the Contracting State implement screening for passengers and their cabin baggage (ICAO, n.d.-c). The purpose of screening is to detect items that can be used to harm other people. Metal detectors are typically used to detect metallic items carried by individuals, such as firearms, which can be used for unlawful purposes. However, the 9/11 hijackers concealed weapons such as box cutters and knives on their person or in carry-on luggage and used those to take control of four aircraft (TSA, 2022). According to the 9/11 Commission Report, at the time of the attack, knives with blades under four inches long were allowed in carry-on luggage (U.S. Government Publishing Office, 2004). Therefore, even if box cutters had been detected during the screening procedure, these passengers would have been permitted onboard with the box cutters (Schaper, 2021). Undoubtedly, security measures and the level of security have greatly enhanced since the

9/11 attacks. Various types of sharp objects including box cutters and razors were banned and the list of prohibited items on board aircraft significantly extended (Schaper, 2021).

In addition to the 9/11 attack, various other notable security threats and incidents have prompted heightened security measures. For example, in 2006, UK authorities arrested 21 suspects linked to a plan to target multiple commercial flights from the UK to the US using liquid explosives (Klenka, 2019). Following this, the UK and US governments tightened regulations on liquids, aerosols, and gels (LAGs), and ICAO urged all Contracting States to implement security controls on those items. The guideline restricts passengers to one quart-sized (one-liter) plastic bag filled with liquid containers of no more than 100 ml (3.4 ounces) each (ICAO, 2007). This rule is now enforced on all of the international flights, and domestic flights in some countries.

Generally, certain materials, such as explosives, sharp objects, and blunt weapons, are commonly restricted on aircraft in most countries. However, specific regulations vary by national authorities and may change over time under the circumstances. For instance, the U.S. initially permitted passengers to carry no more than two lighters per person. However, to comply with U.S. Department of Transportation hazardous materials regulations, lighters were added to the prohibited items list and banned from aircraft from March 1, 2005 (National Archives and Records Administration, 2005). Following a threat assessment by U.S. TSA, the restriction was amended in August 2007, allowing passengers to carry one lighter each. (National Archives and Records Administration, 2007).

Frequent changes and implementations in item restrictions aboard aircraft may cause inconvenience to passengers and stakeholders, including security personnel and airlines. Nevertheless, restrictions on certain items remain essential for aviation security. However, they can also reduce operational efficiency at screening checkpoints, potentially affecting overall security effectiveness. Detecting and handling prohibited items prolongs screening times, increases the workload for security personnel, and inconveniences passengers. According to U.S. TSA data, a manual bag search takes an average of 92 seconds, which is approximately 17 times longer than an X-ray screening (5.25 seconds) (Van Boekhold et al., 2013). In addition to the screening, screeners may be required to record and dispose of confiscated items following established procedures, which may add to the workload of the screeners and pose a delay in the process.

Depending on internal policies, confiscated items are typically discarded, donated, or resold. For instance, most liquids intercepted at the U.S. TSA screening checkpoints are discarded, including drinks, cosmetics, and food. Hazardous materials like aerosols are handled through specialized processes, while certain items, such as knives and firearms, are resold through government auctions and sales (Harmon-Marshall, 2025; Newsweek, 2025). In particular, the disposition of those items is directly related to environmental sustainability. To offset some of these expenses, U.S. airports and the U.S. TSA can use the Passenger Facility Charge (PFC) and Security Fee. These fees are collected by airlines from passengers and are included in ticket prices:

1) Passenger Facility Charge (PFC): Up to $4.50 per flight, capped at $18 per round trip. Airports use these funds to support FAA-approved projects that enhance security, safety, airport capacity, noise mitigation, or increase airline competition (U.S. FAA, n.d.).
2) TSA Security Fee: $5.60 per one-way trip, up to $11.20 per round trip. This fee has been collected since the 9/11 attacks to support security operations and efficiency improvements (U.S. TSA, n.d.-b).

Sustainability in Airport and Aviation Security

Sustainable growth has garnered global attention over time, emerging as a critical factor for long-term business success. The concept of sustainable development was brought into the core of the business, triggered by the *Brundtland report*, also called *Our Common Future* (Cole et al., 2014). This report was published by the UN in 1987, which defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987, p. 41). Since then, the international and national attention to sustainable growth has continued, and the UN developed "The 2023 Agenda for Sustainable Development" in 2015, which contains the 17 Sustainable Development Goals (SDGs). These 17 Goals require an urgent call to all Countries (United Nations, n.d.). The SGDs affects many industries and organization including the aviation industry. Subsequently, the concept of the Triple Bottom Line (TBL), proposed in 1994, emphasizes environmental value alongside the social and economic dimensions, highlighted in the Brundtland Report (Elkington, 1994).

As the aviation industry continues to evolve, sustainability has become one of focus for researchers, policymakers, and industry leaders. Especially, the expansion of aviation sustainability initiatives, research projects, and funding since the early 2000s indicates significant growth in these efforts (U.S. National Academies of Sciences, Engineering, and Medicine, 2016). According to the Air Transport Action Group (ATAG), aviation sector contributed 2.05% of global human-generated carbon dioxide (CO_2) emissions in 2023 (ATAG, 2024). However, this estimate accounts only for emissions from jet fuel combustion. It excludes emissions related to airport operations, which generate substantial waste streams such as municipal solid waste, hazardous materials, and construction debris. Security operations are part of these airport activities and therefore contribute indirectly to overall emissions. Data from San Francisco International Airport in 2018 and 2020 indicate that greenhouse gas (GHG) emissions from aviation such as flights and airport activities were distributed in an 85% to 15% ratio, respectively. Even though it is based on one airport's example, it still provides insight into the environmental impact of airport operation. (Greer et al., 2020).

Airports, as critical components of the aviation ecosystem, have a considerable socio-economic and environmental footprint, necessitating sustainable development frameworks to address stakeholder concerns regarding airport operations (Jordao, 2009). To define sustainability in this context, many airports have adopted the EONS framework—Economic Vitality, Operational Efficiency, Natural Resources, and Social Responsibility which was developed by Airports Council International–North America (ACI-NA) (ACI-NA, 2006). This framework extends operational efficiency from the triple bottom line concept (Martin-Nagle & Kluber, 2015). Research on aviation sustainability often emphasizes environmental factors, such

as emissions reduction and energy efficiency (Sreenath et al., 2021). These efforts have resulted in progress and improvements. For instance, the development of sustainable aviation fuel (SAF) has shown the potential to reduce CO_2 emissions by up to 80% compared to conventional fuels (ATAG, 2024). Sustainability considerations extend beyond environmental concerns; however, not all aspects of aviation address sustainability in the same way.

While various dimensions of aviation security may align with the EONS framework, research on sustainability in this field remains scarce. The primary objective of aviation security is to protect civil aviation from unlawful interference through a combination of human and material measures (ICAO, 2022). Due to its nature, aviation security primarily focuses on threat mitigation and safeguarding the aviation industry rather than addressing sustainability concerns. As a specialized agency of the United Nations (UN), ICAO links its Strategic Objectives on aviation security and facilitation activities to nine of the 17 UN Sustainable Development Goals (SDGs). For example, ICAO suggests that enhancing global aviation security contributes to SDG 8 (Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all). Given that the 9/11 attacks resulted in estimated economic losses of approximately $2 trillion, strengthening aviation security can help prevent significant financial and economic disruptions (ICAO, n.d.-a).

However, ensuring the highest level of security remains a challenge (Jain et al., 2012). Therefore, while considering limited resources and the inconvenience and costs imposed on passengers and operators, it is essential to adopt a rational and acceptable approach to aviation security that maintains effective security measures without compromise (Jackson et al., 2012). This approach requires balancing security with operational efficiency, yet determining the appropriate level remains a complex challenge. A key example is the screening process for prohibited items, such as liquids and sharp objects. While detecting these items is crucial for preventing unlawful use and mitigating security risks, the process often leads to rescreening process and passenger complaints regarding enforcing regulations (Redden, 2021).

Methodology

The methodology seeks to answer two research questions: What is the relationship between the amount of passenger traffic and the number of confiscated items? What are the estimated economic losses from routine security operations, excluding those resulting from security incidents? By exploring these aspects, this study aims to suggest the necessity of adopting new perspectives to enhance aviation security policies, optimize checkpoint efficiency, and develop sustainable methods for managing confiscated items while maintaining high security standards. To answer the questions, the researchers collected data from publicly available sources. The data are from the United States Bureau of Transportation Statistics and published articles containing data provided by Incheon International Airport authority in the Republic of Korea. The collected data are analyzed using statistical techniques that reveal descriptive and inferential characteristics.

Data Collection

Countries tend to not share the detailed numbers and kinds of confiscated items at the airports with the public for various reasons, which is a challenge in this type of data collection. Fortunately, the U.S. Bureau of Transportation Statistics (BTS) provides the U.S. TSA data since 2003 on prohibited items intercepted at airport screening checkpoints (see Table 1). These items are categorized into seven groups: firearms, knives, box cutters, other cutting instruments, clubs, incendiaries, and others, which include tools, self-defense items, lighters, etc. (U.S. Bureau of Transportation Statistics, n.d.). To enhance comparability across years and account for variation in passenger numbers, normalized values were calculated and added for the number of intercepted firearms, expressed as firearms per one million passengers. The firearm detection rate increased from approximately 1.7 firearms per million passengers in 2002 to over 8 firearms per million passengers in 2023, with the highest rates occurring during the COVID-19 period (2020–2021). However, there are two issues with these data. The first issue is that the TSA ceased collecting data on all prohibited items, except for firearms, as of 2010. Moreover, major regulation changes had significantly affected collected data from 2002 to 2009 (e.g., the prohibition of lighters from April 2005 to August 2007 and relaxing regulations on scissors less than 4 inches and tools less than 7 inches from December 2005). The second is that the TSA did not collect data on LAGs (Liquids, Aerosols, Gels). The restriction on LAGs was implemented in 2006, but the data do not reflect this category. The TSA's data on confiscated firearms have been collected consistently. These data have the potential to reveal trends and provide valuable insights in conjunction with other data.

In addition to the U.S. TSA data, the number of confiscated items at Incheon International Airport (ICN) in the Republic of Korea from 2013 to 2022 was collected from publicly available sources, which were provided by the Incheon airport authority (Edaily, 2023; People Power Party, 2018) (see Table 2). Normalized values for prohibited items were calculated and included in the table to enable year-over-year comparison and observe fluctuations, expressed as items per 1,000 passengers. The detection rate ranged from about 41 to 145 items per 1,000 passengers across the years studied, with significantly higher rates in 2021 and 2022, possibly due to the impact of COVID-19. However, since the detailed category descriptions were not provided, it may constrain the data analysis. For instance, between 2013 and 2022, there were no significant changes in Korea’s regulations regarding prohibited items, apart from restrictions on Lithium-ion batteries. The restriction on spare Lithium-ion batteries—those not installed in electronic devices—took effect in April 2016 (ICAO, 2016). This regulation may have contributed to an increase in confiscated items. However, the data does not specify which category includes lithium batteries, making it difficult to assess the exact impact of this regulation. Nevertheless, the data provides recent figures and categorizes prohibited items from 2013 to 2017, enabling an analysis of the most commonly confiscated categories. Using U.S. and Korean data, researchers analyzed the relationship between the number of passengers and confiscated items over time.

Table 1

Prohibited Items Intercepted at Airport Screening Checkpoints in the United States

Year	Total Domestic Passengers	Total Prohibited Items	Firearms [b]	Knives [c]	Box cutters	Other cutting instruments [d]	Clubs [e]	Incendiaries	Other [f]	Firearms per Million Pax
2002	551,899,643	3,775,345 (Apr. to Dec.)	927	1,036,697	32,788	1,846,207	11,131	79,341	768,254	1.68
2003	583,293,766	6,114,612	683	1,961,849	20,991	2,973,413	25,139	494,123	638,414	1.17
2004	629,769,616	7,089,599	650	2,058,652	22,350	3,567,731	28,813	693,649	717,754	1.03
2005	657,261,487	15,886,039	660	1,822,752	21,315	3,276,691	20,531	398,830	10,345,260	1.00
2006	658,362,620	13,710,505	821	1,607,125	15,999	163,419	12,296	113,700	11,797,145	1.25
2007	679,185,450	6,515,409	803	1,056,687	11,908	101,387	9,443	89,623	5,245,558	1.18
2008[a]	651,710,182	972,834	926	626,182	6,284	59,459	6,447	116,200	157,336	1.42
2009	618,067,255	129,548	976	N	N	N	N	127,176	1,396	1.58
2010	629,537,593	N	1,123	N	N	N	N	N	N	1.78
2011	638,247,667	N	1,320	N	N	N	N	N	N	2.07
2012	642,289,482	N	1,556	N	N	N	N	N	N	2.42
2013	645,677,554	N	1,813	N	N	N	N	N	N	2.81
2014	662,826,955	N	2,212	N	N	N	N	N	N	3.34
2015	696,016,894	N	2,653	N	N	N	N	N	N	3.81
2016	719,996,828	N	3,391	N	N	N	N	N	N	4.71
2017	741,735,098	N	3,957	N	N	N	N	N	N	5.33
2018	777,972,787	N	4,239	N	N	N	N	N	N	5.45
2019	811,545,260	N	4,432	N	N	N	N	N	N	5.46
2020	335,607,840	N	3,257	N	N	N	N	N	N	9.70
2021	605,935,323	N	5,972	N	N	N	N	N	N	9.86
2022	750,535,394	N	6,542	N	N	N	N	N	N	8.72
2023	819,333,204	N	6737	N	N	N	N	N	N	8.22

Note. Adapted from U.S. Bureau of Transportation Statistics, (2023, August 18). *Prohibited Items Intercepted at Airport Screening Checkpoints* 2002 – 2022. https://www.bts.gov/content/prohibited-items-intercepted-airport-screening-checkpointsa and TSA. (2025, January 15). *TSA intercepts 6,678 firearms at airport security checkpoints in 2024*. https://www.tsa.gov/news/press/releases/2025/01/15/tsa-intercepts-6678-firearms-airport-security-checkpoints-2024

[a] Data for 2008 are up to August, except for Firearms and Incendiaries.

[b] Firearms includes any weapon (including a starter gun) that is designed to or may readily be converted to expel a projectile by the action of an explosive, as well as spear guns, BB guns, flare pistols, compressed air guns, and stunning devices.

[c] Knives include any length and type except round-bladed, butter, and plastic cutlery.

[d] Other cutting instruments include scissors, swords, meat cleavers, and ice axes.

[e] Clubs includes baseball bats, night sticks, and billy clubs.

[f] Other refers to tools, self-defense items, compressed gas cylinders, bleach, lighters, and certain sporting goods.

Data Analysis

The first research question is *What is the relationship between the amount of passenger traffic and the number of confiscated items?* The corresponding null hypothesis is that there is no statistically significant correlation between passenger traffic volume and the number of confiscated items at airport security checkpoints; the alternative is that there is a significant correlation between these two variables. The Pearson correlation coefficient was used to analyze the correlation between annual passenger volume and intercepted items at U.S. TSA airports and Incheon International Airport (ICN) in the Republic of Korea. As data on other categories has not been collected since 2009, only the number of confiscated firearms was analyzed for TSA. To use a Pearson's correlation coefficient, both variables must be quantitative normally distributed random variables with no outliers, and a relatively linear relationship. A Graphical Summary was generated using commercially available Minitab© Statistical Software to verify these assumptions. Following this verification, the Pearson correlation coefficient formula was applied to evaluate the strength and direction of the relationship:

$$r = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2} \times \sqrt{\sum(Y-\bar{Y})^2}}$$

where X is the annual passenger volume (PAX), Y is the total prohibited items detected, and $\bar{X}$ and $\bar{Y}$ are the means of X and Y, respectively.

The strength of the relationship is determined by the resulting r score. The coefficient ranges from -1 to 1:

1) r close to 1 shows a strong positive correlation; as passenger volume increases, intercepted items also rise.
2) r close to 0 signifies no correlation, with no clear relationship between the variables
3) r close to -1 indicates a strong negative correlation; as one variable increases, the other decreases.

Table 2

Prohibited Items Intercepted at Airport Screening Checkpoints at Incheon International Airport

Year	Total passengers	Total prohibited items	Firearms	Knives/ scissors	Tools	Incendiaries/ chemicals/ lighters	Inert ammunition	Liquids, aerosols, gels and others	Prohibited Items per 1,000 PAX
2013	40,864,272	1,968,200	590	212,448	27,049	178,109	3,052	1,546,952	48.16
2014	44,900,257	2,092,937	3,603	171,384	20,867	160,820	5,570	1,730,693	46.61
2015	48,663,242	2,048,036	5,238	179,721	21,590	195,250	2,548	1,643,689	42.09
2016	57,040,615	3,071,821	8,237	206,361	29,058	256,695	517	2,570,953	53.85
2017	61,362,514	2,568,764	9,413	208,039	31,197	219,250	79	2,100,786	41.86
2018	67,535,463	3,339,654	N	N	N	N	N	N	49.45
2019	70,467,146	3,527,883	N	N	N	N	N	N	50.06
2020	11,938,096	876,391	N	N	N	N	N	N	73.41
2021	3,164,280	459,543	N	N	N	N	N	N	145.23
2022	17,747,747	1,659,883	N	N	N	N	N	N	93.53
2023 (Jan. to Jul.)	29,558,316	2,283,524	N	N	N	N	N	N	77.25

Note. Adapted from Edaily, (2023, September 21). 공항보안검색서 놓친 '칼' 꺼내도 처벌 못한다? [Knives missed during airport security screening—Can they be penalized?]. https://www.edaily.co.kr/News/Read?newsId=03683446635742416&mediaCodeNo=257&OutLnkChk=Y and People Power Party. (2018, November 5). *최근 5 년간 인천공항의 위해물품 적발건수 2,860 건, 기내반입금지물품은 1,385 만건에 달해!* [Over the past 5 years, Incheon Airport detected 2,860 hazardous items and 13.85 million prohibited carry-on items]. https://www.peoplepowerparty.kr/news/lawmaker_inspection_view/80492

Correlation Analysis: Annual Passenger Volume and Intercepted Items at Korea ICN

To examine the relationship between passenger volume and intercepted prohibited items at Incheon International Airport (ICN), a regression analysis was conducted. The resulting model, shown in Figure 1, presents a strong positive correlation between total enplanements (millions) and prohibited items (millions), with an R-squared (R^2) value of 87.8%. This indicates that approximately 87.8% of the variation in the number of prohibited items can be explained by changes in passenger volume. The correlation coefficient (r) is approximately 0.937, and the associated *p*-value is < .001, confirming that the relationship is statistically significant at the 0.05 alpha level. This suggests that as passenger traffic increases, the number of confiscated items also rises proportionally (see Figure 1). The regression equation is:

$$\textit{Prohibited Items (millions)} = 0.5660 + 0.03899 \times \textit{Total Enplanements (millions)}$$

In the scatterplot, the solid black line through the middle of the chart represents the fitted regression line. The dashed red lines show the 95% confidence interval for the mean prediction, while the dashed green lines indicate the 95% prediction interval for individual new observations. Each red dot represents an observed data point.

Figure 2 presents the four-in-one residual plot. The residuals appear to be randomly scattered around zero in the "Versus Fits" and "Versus Order" plots, and the normal probability plot suggests that the residuals are approximately normally distributed. These diagnostics support the assumption of constant variance and normality, validating the use of linear regression for this dataset. Although the model fits the data well, caution is warranted when making predictions beyond the range of the observed data. Nonetheless, the findings clearly suggest that as passenger volume increases, the number of intercepted prohibited items also rises. These underscores the importance of reviewing and enhancing the procedures for prohibited items and the strategies used to raise public awareness. The findings in the regression analysis and correlation analysis are also consistent with expectations, and therefore, indicates face validity.

Figure 1

Correlation Analysis – Incheon International Airport

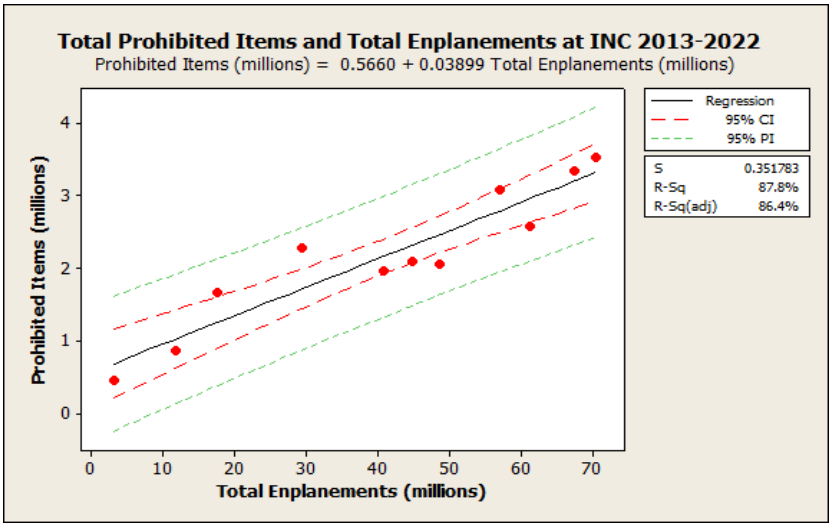
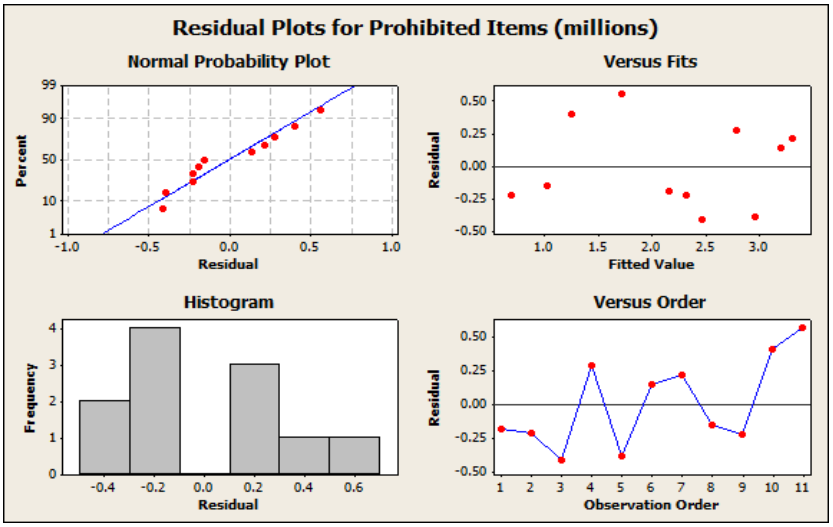


Figure 2

Residual analysis chart – Incheon International Airport



Further analysis of item composition revealed that the category "LAGs (Liquids, Aerosols, and Gels) and others" constituted an average of 81.94% of all intercepted items, implying that LAGs are the most frequently confiscated category (See Table 3).

Table 3

Prohibited Item Composition at Incheon International Airport

Total Prohibited Items	Firearms	Knives/ Scissors	Tools	Incendiaries/ Chemicals/ Lighters	Inert ammunition	LAGs and others
13,853,77	35,375	1,131,985	152,302	1,169,786	12,905	11,351,42
100%	0.26%	8.17%	1.10%	8.44%	0.09%	81.94%

Correlation Analysis: Annual Domestic Passenger and Intercepted Firearms at US TSA

Due to limited data availability, this analysis focused exclusively on the number of confiscated firearms at U.S. TSA checkpoints. The regression analysis for the full dataset spanning 2002–2023 (Figure 3) shows a correlation coefficient of r=.423 with p = .050, and a low R^2 value of 17.9%, suggesting that only a small portion of the variation in firearm confiscations can be explained by total passenger volume. The corresponding residual plots reveal non-constant variance and potential outliers, especially in the later years, indicating that the regression assumptions may not be fully met across the entire period (see Figure 4).

Figure 3

Correlation Analysis – TSA Data (2002-2023)

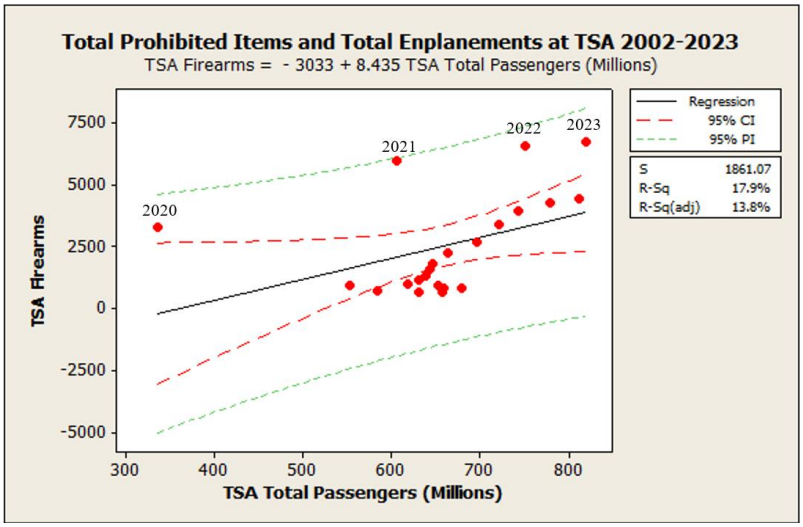


Figure 4

Residual analysis chart – TSA Data (2002-2023)

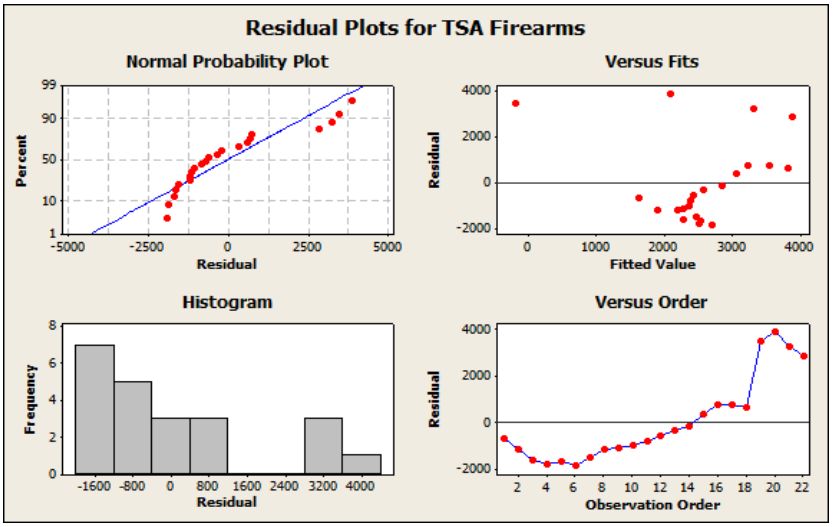
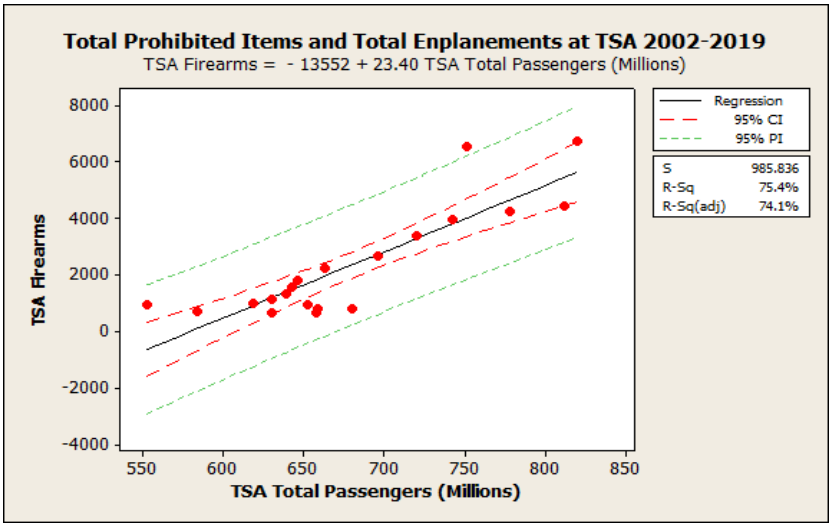


Figure 5

Correlation Analysis – TSA Data (Excluding 2020-2023)



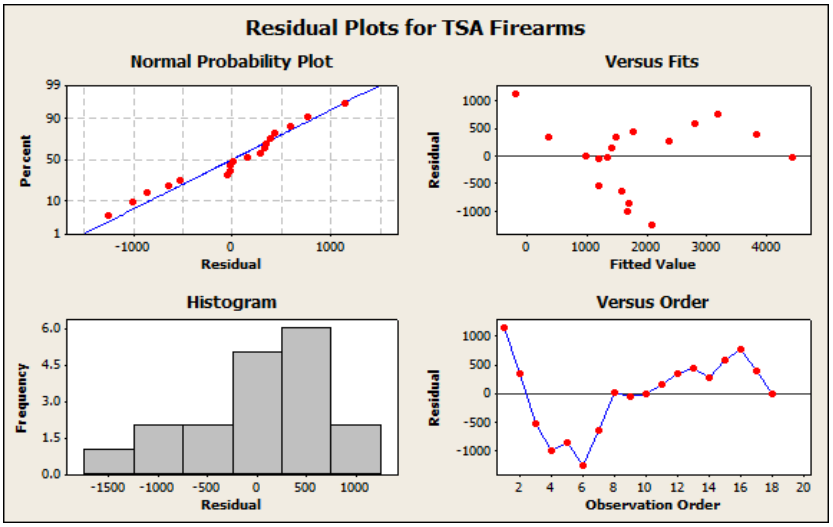
While the ICN dataset showed no noticeable distortion, the TSA data demonstrated unusually high firearm detection rates during the COVID-19 pandemic. This anomaly was likely due to a combination of unknown factors and significantly reduced passenger volumes, both of which substantially affected the correlation analysis. To ensure methodological rigor and mitigate these effects, two additional analyses were conducted alongside the full dataset evaluation:

- Excluding the years 2020–2023 (post-COVID impact)
- Excluding only 2020–2021 (peak pandemic years)

In the filtered analysis excluding 2020-2023 (Figure 5), the Pearson correlation coefficient improves substantially to r = .868 with $p < .001$, indicating a strong and statistically significant positive correlation between domestic passenger volume and firearm interceptions. This suggests a more stable relationship in normal travel conditions.

Figure 6

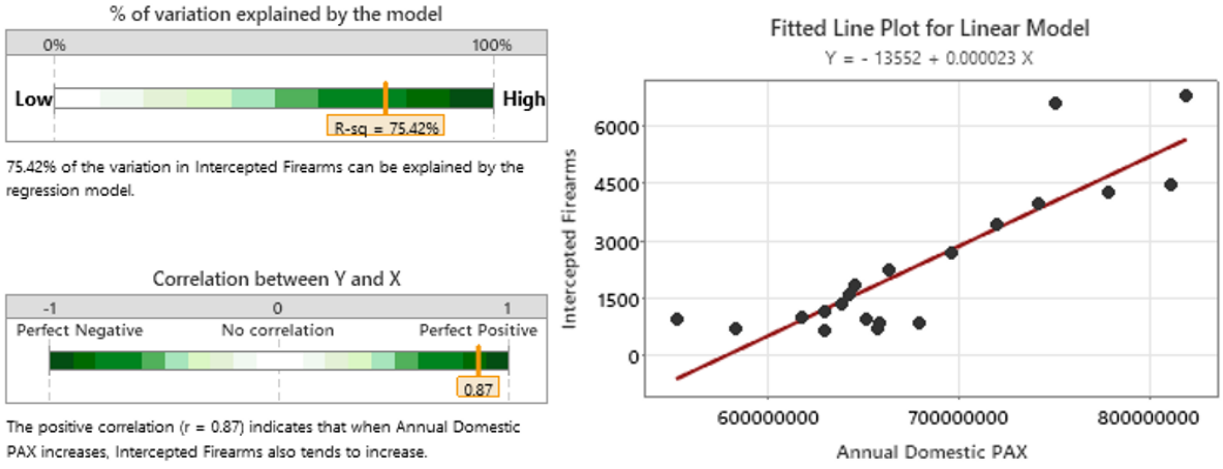
Residual analysis chart – TSA Data (Excluding 2020-2023)



To further validate the robustness of this trend, another analysis was conducted, excluding only 2020 and 2021. This analysis yielded a similar result (r=.87). This consistency suggests that passenger volume may have a stable relationship with the number of intercepted firearms, irrespective of the COVID-19 pandemic (see Figure 7).

Figure 7

Correlation Analysis – TSA Data (Excluding 2020-2021)



Economic Loss Estimation

The next step is to examine the second research question: *What are the estimated economic losses from routine security operations, excluding those resulting from security incidents?* To estimate the economic impact of confiscated items on sustainable airport security operation, this study identifies five potential contributors to financial loss. These include:

1) Time lost due to additional screening procedures for both passengers and security personnel.
2) Costs incurred for discarding or disposing of confiscated items.
3) Expenses related to informing the public about prohibited items and upgrading or installing relevant screening facilities.
4) Replacement costs for intercepted items, as passengers may need to repurchase confiscated belongings.
5) Administrative and miscellaneous costs related to the processing and handling of confiscated items by security authorities.

While all five factors are relevant, the current analysis focuses solely on the first factor, time loss, due to the availability of measurable data. Specifically, the study estimates the economic cost of time spent on manual bag searches involving prohibited items by calculating wage-based opportunity costs for both passengers and security personnel. The other factors are discussed as areas for future research. This approach provides a conservative estimate of the economic burden imposed by routine security operations involving prohibited items. The calculation was performed by multiplying the average search time (converted to hours) by the standard hourly wages of both Transportation Security Officers (TSOs) and passengers. As presented in Table 4, the estimated economic loss per manual bag search is $1.58. This figure assumes: (1) both security personnel and passengers incur time-related costs during the screening process, and (2) on average, each searched bag containing a prohibited item results in the confiscation of one item.

Table 4

Estimated Economic Loss per Manual Bag Search of the U.S. Airport

	Average hourly wage (A)	Manual bag search time [c] (B)	Labor cost per manual bag search (A × B)
Passengers[a]	$35.93	92 seconds = 0.02556 hours	$0.92
TSOs[b]	$25.91		$0.66
Total economic loss per search		$1.58	

Note. [a] Estimated hourly wage of passengers: Estimated based on data from the U.S. Bureau of Labor Statistics (U.S. Bureau of Labor Statistics, 2025).
[b] Estimated hourly wage of TSOs: Derived from recent TSA job postings across 33 states (U.S. TSA, n.d.-a).
[c] Time for a manual bag search: Averaged at 92 seconds (0.0256 hours), based on prior research (Van Boekhold et al., 2013).

It is important to note that this estimate excludes additional costs such as manual bag searches that do not result in confiscation, pat-down searches, and random searches conducted in compliance with regulatory requirements, all of which also contribute to economic loss. In addition to time lost due to screening, extra costs are associated with the disposal and management of confiscated items, public awareness campaigns, infrastructure investments, administrative expenses, and more. Furthermore, passengers who surrender their belongings at security checkpoints may need to repurchase similar or the same items, and therefore, they incur personal financial losses. Therefore, given that U.S. passenger traffic reached 1.58 billion in 2023 (Airports Council International-North America, 2024), along with other factors, the actual economic loss would be significantly higher.

Results

The methodology of this study addresses two primary research questions: (1) What is the relationship between passenger traffic volume and the number of confiscated items? and (2) What are the estimated economic losses resulting from routine security screening procedures, excluding those related to actual security incidents? To answer these questions, data were collected from publicly available sources: (1) statistics published by the United States Bureau of Transportation Statistics and (2) published articles referencing data from Incheon International Airport authorities in the Republic of Korea. The analysis revealed statistically significant correlations of passenger volume and confiscated item volume at the 0.05 alpha level for both Incheon International Airport (ICN) and U.S. TSA checkpoints. Specifically, the Pearson correlation coefficient indicated a strong positive relationship between passenger volume and the number of intercepted items at ICN ($r = .94$), as well as between passenger volume and firearm confiscations at TSA checkpoints ($r = .87$). These findings suggest that higher passenger traffic is associated with an increased number of prohibited items being intercepted. To address the second research question, the study estimated economic losses based on average search times and hourly wage data for both Transportation Security Officers (TSOs) and passengers. The resulting calculation estimated the economic loss per manual bag search to be approximately $1.58, applicable only to instances in which a prohibited item was found and confiscated from the bag.

Discussion

This study explored the relationship between passenger traffic and the number of confiscated items at airport screening checkpoints, and examined the economic implications of these items. The results revealed a statistically significant and strong positive correlation at both Incheon International Airport (ICN) and U.S. TSA checkpoints for passenger volume correlating to the volume of confiscated items. These findings suggest that as passenger volume increases, the likelihood of prohibited items being intercepted also rises. In other words, despite ongoing public awareness campaigns, signage, and regulatory enforcement, passengers continue to bring restricted items to security checkpoints. This trend may point to gaps in communication strategies, limited passenger understanding of current security regulations, changing nature of security regulations and screening techniques, passenger inadvertent non-compliance, or a lack of willingness to comply, among other gaps.

From an economic perspective, this study also demonstrates how confiscated items contribute to measurable financial losses. By converting screening time into economic value—based on the duration of manual bag searches and average hourly wages—the analysis provides a conservative yet compelling estimate of costs, calculated at approximately $1.58 per manual search involving a confirmed prohibited item. For example, at Incheon International Airport (ICN) in 2019, the estimated financial loss exceeded $5.5 million (*3,527,883 Confiscated Items/Year) × $ 1.58/search = $5,574,055/year)*, based solely on the time expended addressing prohibited items relative to passenger volume. Importantly, this estimate excludes additional costs such as pat-down procedures, administrative processing, random searches, and searches that do not result in confiscation, suggesting that the true economic burden is likely substantially higher.

These findings underscore the necessity of pursuing more efficient and sustainable strategies for managing prohibited items. The handling and disposal of prohibited items, particularly liquids, aerosols, and gels (LAGs), raises environmental concerns given their substantial proportion among intercepted items. Disposal often results in landfill accumulation or the need for hazardous materials processing, both of which contribute to the ecological footprint of airport operations. Moreover, the logistical and administrative demands associated with donation, resale, or specialized disposal may further strain security operations. Although sustainability has become an increasingly important consideration in the aviation industry, efforts have mainly focused on alternative fuels and emissions reduction. However, airport operations, including security procedures, also significantly contribute to waste generation and energy consumption. Therefore, it is crucial to incorporate sustainability principles into aviation security policies and practices. By broadening passenger awareness beyond mere regulatory compliance to encompass sustainability and operational efficiency, airport authorities may reduce the volume of intercepted items and support more effective, environmentally responsible security practices.

A key limitation of this study is the lack of up-to-date and comprehensive data on confiscated items at airports. Many security authorities either do not systematically collect such data or choose not to disclose it publicly due to operational or security-related concerns. Additionally, the available datasets often lack detailed item classifications, which constrains the depth and accuracy of analysis. Future research is recommended to investigate additional factors contributing to the economic impact of airport security operations, conduct a more comprehensive study on sustainability and assessment of the environmental effects from confiscated items, and explore strategies to enhance public awareness and compliance with security regulations. By expanding the scope of passenger awareness to include sustainability considerations, airport authorities can contribute to both reduced item confiscation and more sustainable aviation security practices.

Conclusion

This paper is the first to examine the relationship between passenger traffic and the number of confiscated items at airport screening checkpoints. Using data from the United States and the Republic of Korea, the findings revealed a strong positive correlation between passenger volume and the number of confiscated items, particularly at Incheon International Airport (ICN), where the correlation coefficient reached 0.937. A similar pattern was observed in U.S. TSA

firearm data, with a correlation of 0.868 (excluding COVID-affected years), reinforcing the robustness of this trend. The results suggest a need to strengthen existing policies or develop new strategies aimed at reducing the number of prohibited items brought to airport security checkpoints.

Beyond the correlation analysis, the study also quantified part of the economic losses associated with additional screening procedures required to detect prohibited items. The estimated cost of $1.58 per manual bag search, based on the time spent by both security personnel and passengers, translates to an economic loss exceeding $5.5 million at ICN in 2019 alone. This figure does not include further costs such as pat-downs, administrative processing, or waste management. These findings underscore the operational and financial burdens that prohibited items impose on airport security systems, an issue often overlooked in discussions of aviation sustainability.

This research suggests the necessity of adopting new approaches to reduce the presence of prohibited items at airports. As global air traffic continues to grow, integrating sustainability principles into aviation security policies will be essential to ensure safe, efficient, and sustainable operations. By broadening airport security strategies to include sustainability considerations, the aviation industry can better manage long-term resource use, reduce environmental impact, and support future-ready security operations, and this ultimately increasing the overall security.

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