

The Economic Analysis of Thermal Runaway on Commercial Passenger Planes in the United States

A UL Standards & Engagement Report



Executive Summary

Lithium-ion batteries power rechargeable devices used every day, including phones, laptops, and portable chargers. If damaged, improperly charged, poorly manufactured, or counterfeit, these batteries can present a significant risk of thermal runaway — a state of overheating that can result in fire or even explosion.

With more products powered by rechargeable lithium-ion batteries and airline passengers routinely bringing these types of devices on flights, there has been an increase in the frequency of thermal runaway incidents on airplanes, which threatens the safety of passengers and results in economic losses.

To further understand the economic impact of thermal runaway on commercial passenger flights, UL Standards & Engagement conducted an analysis of the thermal runaway incidents that resulted in significant flight disruption on commercial passenger flights within the U.S. from 2021 to 2025. A significant disruption is classified as an incident that results in a diversion, cancellation, delay, or missed connection. ULSE calculated a cost estimate for this economic analysis. Thermal runaway incidents that caused significant flight disruption led to incremental costs, irrespective of those who absorbed these costs.

The cost to airlines from thermal runaway incidents with significant flight disruptions is **\$1.8 million per year and growing.**

ULSE estimated the overall cost of significant flight disruptions due to thermal runaway from lithium-ion batteries on commercial passenger airplanes in the U.S. from 2021 to 2025. This estimate includes:

- Travel disruption for passengers
- Impact on the airlines
- Injuries resulting from thermal runaway incidents

Analysis of ULSE’s Thermal Runaway Incident Program data shows 507 flights that experienced thermal runaway on passenger commercial flights from 2021 to 2025. Of those flights, about 18%, or 92 flights, experienced significant flight disruption. ULSE estimates that significant flight disruptions from thermal runaway incidents on commercial passenger flights have conservatively cost about \$8.8 million in damages and loss. This translates to about \$1.8 million per year, or \$96,000 per incident.



According to the International Air Transport Association, North American flights earned an estimate of \$11.10 in net profit per passenger in 2025. With approximately 119 seats on a typical U.S. domestic flight, airlines generate about \$1,321 in net profit per flight — meaning each thermal runaway incident with significant flight disruption costs more than 73 times the net profit of an average flight (beyond profit from the cargo space).

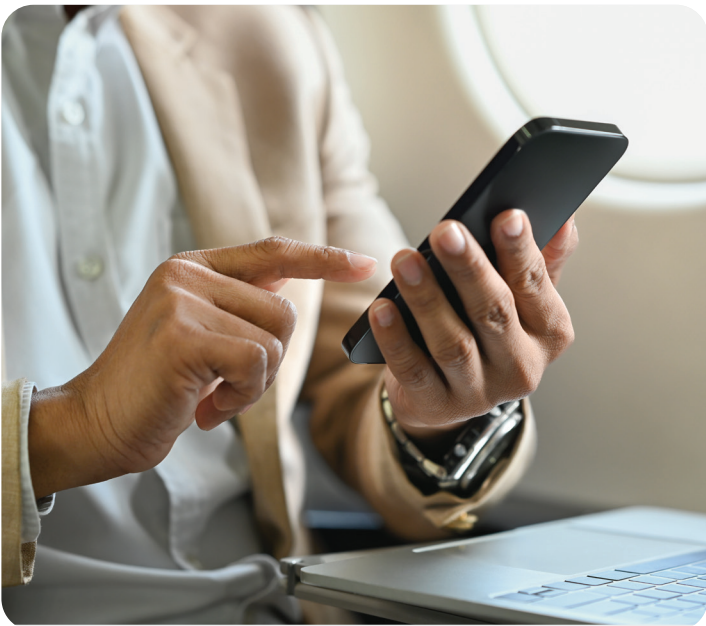
The Cost of Thermal Runaway in U.S. Commercial Aviation

Lithium-ion batteries power many of the devices that passengers rely on during air travel, including smartphones, laptops, portable chargers, and e-cigarettes. While generally safe, these batteries can go into thermal runaway if damaged, improperly charged, poorly manufactured, or counterfeit. Thermal runaway is an uncontrollable release of stored energy that can result in smoke, fire, toxic gas release, or explosion.

Within the confined environment of an aircraft at 30,000 feet in the air, thermal runaway incidents can escalate within seconds, creating significant safety risks and operational challenges. Even a single event can trigger costly diversions, delays, cancellations, missed connections, emergency response procedures, schedule disruptions, passenger impacts, and aircraft repairs.

Air travel is a widely utilized mode of transportation, serving millions of passengers annually. The Federal Aviation Administration estimates that over 3 million passengers fly in and out of U.S. airports every day, with about 45,000 flights daily and 16.2 million flights per year.ⁱⁱ Because of the incredible number of passengers traveling by air, there is also a large volume of lithium-ion batteries on each aircraft, increasing the potential risk of thermal runaway incidents.

The risk only continues to increase as passengers travel with more rechargeable battery-powered devices. Research by UL Standards & Engagement



found that the average airline passenger carries approximately four lithium-ion batteries onboard. Yet awareness of risks remains low.ⁱⁱⁱ

This knowledge gap can contribute to unsafe handling and storage practices that increase the likelihood of thermal runaway. While catastrophic events remain rare, their consequences can be severe. In 2025, a portable charger stored in an overhead bin went into thermal runaway aboard an Air Busan aircraft preparing for departure in South Korea. Although all passengers and crew evacuated safely, the fire and smoke rapidly spread, resulting in a total loss of the aircraft.

ULSE's Thermal Runaway Incident Program is a voluntary aviation reporting system designed for the aviation industry to better understand the extent of the problem and prepare for and help prevent future incidents. Through TRIP, participants from more than 40 passenger and cargo airlines provide detailed information on incidents within their operation. The information is anonymized and shared with aviation industry and safety organizations, offering insights to improve the safe transport and usage of lithium-ion batteries and the devices that rely on them. The TRIP database operates as a surveillance tool, helping capture data

on the frequency, characteristics, and consequences of incidents for thermal runaway incidents in passenger and cargo operations.

TRIP data shows that thermal runaway incidents continue to occur regularly and have been increasing. Between 2021 and 2025, 507 domestic passenger flights experienced thermal runaway, averaging roughly 101 incidents per year. In 2024, there were about 2.05 incidents per week and in 2025, the rate increased to 2.36 incidents per week. Research indicates that portable chargers and vapes/e-cigarettes are the leading causes of passenger-flight thermal runaway incidents.

Most thermal runaway incidents are successfully managed on board, but a significant portion lead to operational disruption. Between 2021 and 2025:

-  **18% of incidents** involving thermal runaway (1 in 5) resulted in significant flight disruption, including diversions, delays, cancellations, or missed connections.
-  **92 flights** experienced significant disruption, averaging about 18 per year.
-  **10,948 passengers** were estimated to be affected by these disruptions^{iv}

Because TRIP relies on voluntary reporting, actual incident totals could be higher.

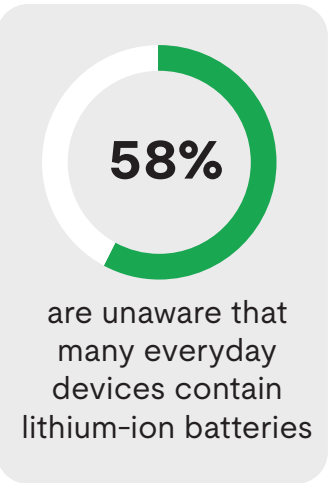
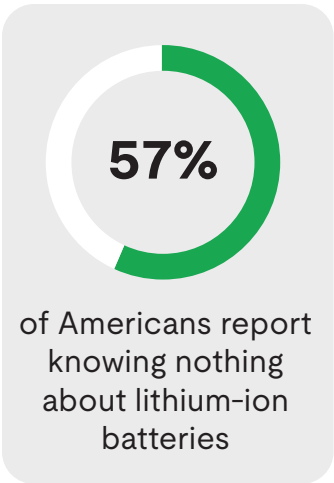
Economic Impact

ULSE estimates that thermal runaway incidents causing significant flight disruption cost the U.S. commercial aviation industry and passengers approximately \$8.8 million between 2021 and 2025 in damages and losses, equivalent to:

\$1.8 million annually, or \$96,000 per significant incident.^v

These costs include passenger travel disruption, airline operational impacts, and injury-related expenses. This economic analysis is based on conservative assumptions that could understate the true costs of these incidents due to data limitations. Therefore, the true costs may vary.

The financial burden is substantial when viewed against airline economics. IATA estimates that North American airlines earned approximately \$11.10 in net profit per passenger in 2025, or roughly \$1,321 per domestic flight. At an estimated cost of \$96,000 per significant thermal runaway event, a single disruption can cost more than 73 times the net profit generated by an average flight (beyond profit from the cargo space).



Conclusion

From 2021 to 2025, significant flight disruptions due to thermal runaway on commercial passenger airplanes may have resulted in at least 92 significant flight disruptions and seven cases of injury.^{vi} ULSE estimates that significant flight disruptions from thermal runaway on commercial passenger flights have conservatively cost about \$8.8 million in damages and loss in total, or about \$1.8 million per year, or \$96,000 per incident.^{vii} This is just an estimate, and the true cost may vary considerably depending on the nature of the incident and the airline's operation.



Methodology

ULSE estimated the impact of thermal runaway incidents that caused significant flight disruption on passengers' travel disruption that resulted in diversions, delays, cancellations, or missed connections by utilizing various data sources. The analysis was conducted by focusing on the costs for the passengers, airlines, injuries, and spillover effect impacts and then aggregated to a higher level to generate a cost. The actual cost per incident may differ substantially depending on the severity of incident and airline operation.

Impact on Passenger

ULSE used the following data sources:

- TRIP data to determine the number of significant flight disruptions that occurred from 2021 to 2025 due to thermal runaway; categorized by either delays, cancellations, missed connections, or diversions.
- Bureau of Transportation Statistics (BTS) passenger data to determine the average number of seats per domestic flight; 119 seats per flight.^{viii}
- Various historical airline data^{ix} for delays categorized by amount of time and disruption type.
- Census Bureau for the median household income to calculate Department of Transportation's (DOT) Hourly Values of Travel Time Savings (VTTS) for intercity air travel adjusting the dataset to 2025 dollars to account for inflation; \$90.09 per hour per passenger.^x
- General Service Administration (GSA) for the average hotel and meals and incidental expenses (M&IE) costs and BTS for the average flight costs for rebooking flights; \$164 per night for hotel, \$81 per M&IE, and \$387 per flight for roundtrip (or \$194 per segment, rounded).^{xi}

ULSE calculated the impact of flight disruption by taking the average delay time by the disruption type then multiplying it by the number of flights impacted, then by the average number of passengers per flight, and then by the values of travel time savings of the passengers.

Depending on the type of disruption and the length of disruption, ULSE calculated additional travel costs for the passengers, such as cost for hotels, meals, and airfare. Adapting the analysis from DOT's report "Air Help: Cost of Disrupted Flights to the Economy, ULSE assumed that 30% of passengers that experienced significant flight disruption would require a hotel and meals.^{xii} Seventy-five percent of passengers that experienced significant flight disruption would require rebooking of their flight. These additional costs may be covered by the airlines, travel insurance companies, and/or the passengers. However, ULSE does not distinguish who is responsible for these additional costs, because ultimately, it is an additional cost regardless of who pays for it.

The Impact on Passenger analysis includes the number of significant flight disruptions categorized by disruption type, the amount of delay time by disruption type, average number of seats per domestic flight, and value of travel time savings per hour. Depending on the type of disruption and the length of disruption, there may be additional travel costs for passengers, such as hotels, meals, and airfare. Impact on the airlines includes costs for fuel, maintenance, aircraft ownership, crew wages and benefits, airport landing costs, equipment replacement, and the spillover effect.

A significant disruption is classified as an incident that results in a diversion, cancellation, delay, or missed connection.

Impact on Airline Industry

Significant flight disruption due to thermal runaway can have a deep impact on passengers, airlines, airports, and other sectors of the economy. There are various costs associated with flight disruptions depending on the type of disruption and the length of the disruption.

To estimate the impact on the airlines for significant flight disruption due to thermal runaway, ULSE used the following data sources:

- TRIP narratives to determine the types of equipment damage, the number of equipment damages, and the number of flights impacted.
- Various historical airline data for the cost of delays categorized by amount of time and disruption type. Airlines also provided cost data related to clean up, additional maintenance, airport landing, equipment repairs, repositioning of aircraft, and/or unexpected additional wages for airline crew. These data points were adjusted for inflation using BLS CPI data to 2025 dollars.^{xiii}
- Airlines for America’s U.S. passenger carrier delay costs in 2025, total direct operating costs. This dataset includes the cost for crew (pilots and flight attendants), fuel, maintenance, aircraft ownership, and others; \$98.41 per minute.^{xiv}

ULSE estimated the impact on the airlines based on the best information available. These costs are estimated and could vary depending on the extent of the aircraft damage, length of delay, fuel cost, and number of airline crew onboard. Therefore, the operational realities of flight delays can vary widely.

Injuries Related to Thermal Runaway Incidents

Fortunately, there have been no fatalities due to thermal runaway on U.S. commercial passenger airplanes. Injuries related to thermal runaway incidents in situations where there was significant flight disruptions have been minor. Based on the TRIP dataset, there have been 7 minor injuries related to thermal runaway events from 2021 to 2025.

VSL Fractions Applicable to Injuries by Severity Level

Injury Severity Level	Fraction of VSL
Minor	0.003
Moderate	0.047
Serious	0.105
Severe	0.266
Critical	0.593
Unsurvivable	1.000

Source: U.S. Department of Transportation, Relative Disutility Factors by Injury Severity Level (MAIS)

DOT’s Value of Statistical Life (VSL) is based on a comprehensive assessment to quantify the monetary value of reducing fatalities.^{xv} It is designed to be used in analyses that assess the economic benefits of preventing fatalities. For 2025, DOT estimated the VSL for each life was \$14.2 million. ULSE used VSL to estimate the cost of injuries caused from thermal runaway incidents as these injuries could impact a passenger’s quality of life, including pain, suffering, and lost income. ULSE calculated the range of injury costs based on a fraction of the VSL, depending on the severity of the injury. There is some uncertainty about these costs as non-fatal injuries are subject to more variation. ULSE used the narratives within the TRIP database to determine the severity of injuries. Since TRIP data is inputted by the end users, the details of the passenger injury can vary. ULSE conservatively categorized for each injury scenario based on the information available. ULSE used the recommended DOT VSL fractions of injury severity on the Maximum Abbreviated Injury Scale, which is a standardized medical scale commonly used to assess and categorize injury severity.

Spillover Effects

The spillover effect encompasses the indirect impact on other sectors of the economy that occur beyond the event. DOT study, AirHelp, conducted a study of the cost of disrupted flights to the economy.^{xvi} They utilized an FAA/US Senate report that assumed that there is a 0.5 USD spillover cost for every 1.0 USD direct airline cost of delays. ULSE used this same assumption and ratio to estimate the spillover effect of thermal runaway incidents with significant flight disruption. This ratio is used to measure the indirect impact that is difficult to measure, such as lost demand, reputational damage, passenger costs, and broader societal effects.

Behind the Disruption: Hidden Costs

Variable Hidden Operational Impacts

A single flight disruption can have a cascading impact on the airline and at the airports. Each segment of a flight is planned throughout the day. A single aircraft can have multiple routes and transport hundreds of passengers. Airports have planned arrivals and departures flights mapped out so therefore one flight cancellation or delay could cascade into multiple cancellations and/or delays. There are hidden operational impacts that can occur with flight disruptions.

Flight disruptions can create unexpected costs for airlines. For example, airlines will need to adjust the aircraft’s schedule and manage potential crew duty-time limitations. Airlines could incur costs due to the emergency landing, additional ground service, additional fuel, refueling operations, security coordination, and reassigned resources. While the crew can experience lost wages, per diem earnings, and/or overnight accommodation. These unexpected expenses can escalate quickly.

There can be operational complications that could result from significant flight disruptions. For example, in a scenario where a flight disruption results in an unusable aircraft, some airlines may be able to quickly substitute the unusable aircraft with a ready-to-fly aircraft. However, if an extra aircraft is not available at a specific location, the airline may have to fly in an aircraft from another city with just the airline crew. This would be a significant cost to the airline and a time burden on passengers.

Airlines can also experience revenue displacements and emergency service costs. The overall cost estimate of this economic analysis does not include these costs as they can be incurred in a case-by-case scenario depending on the severity of the scenario.

Revenue Displacement

ULSE assumed that rebooking a flight would cause revenue displacement costs for the airlines as rebooking a passenger on another flight due to flight disruption takes away a seat that could have been purchased by a paying passenger. On average, a single aircraft typically has 2 to 4 segments per day. ULSE estimates that if one aircraft is out of service and there is no replacement aircraft available and the airline must cancel all the flights that the aircraft is planned to service, it could cost the airline up to \$230,860 in revenue displacement due to reaccommodation and impact up to 476 passengers per day. One flight cancellation could impact about 119 passengers and cost about \$23,086.

Emergency Service Cost

Another example with a complicated operational scenario would be if an airplane were to be diverted to another airport due to a thermal runaway event. The airline would incur additional landing fees at that airport. Once the airplane lands, the airport may need to divert all ground traffic away from the aircraft as emergency personnel handle the incident on the ground. This would have an impact on the airport traffic flow. If there was an active fire on the aircraft, the airport may have to shut down the airport’s landing space and divert all other flights to other nearby airports. Airlines may incur additional fees if they need an emergency service, such as the Aircraft Rescue and Fire Fighting (ARFF). *In 2025, emergency services responded to 7.3% of thermal runaway incidents that experienced significant flight disruption.* This could lead to a logistical challenge as all the other flights would need to reroute, and all the passengers would need to reschedule their flights so that they arrive at their intended destination.

Cargo

The primary purpose of commercial passenger aircraft is to transport passengers between destinations, while also carrying air freight in the aircraft’s lower cargo holds. The cost impacts for thermal runaway incidents with significant disruption for cargo would be assessed and measured differently from passenger cost impacts. Cargo revenue is typically measured on a per-kilogram basis, while passenger revenue is not. It is important to note that thermal runaway incidents on commercial passenger aircraft can affect cargo revenue; however, these impacts are outside the scope of this economic analysis.

Variable used	Time period
Thermal Runaway Incident Program (TRIP)	
Count of flights that experienced thermal runaway and significant flight disruption	2021-2025
Count of flights that were delayed due to thermal runaway	2021-2025
Count of flights that were cancelled due to thermal runaway	2021-2025
Count of connecting flights missed due to thermal runaway	2021-2025
Count of flights diverted due to thermal runaway	2021-2025
Count of injuries due to thermal runaway by injury type	2021-2025
Count of damage on airplanes by damage type	2021-2025
Bureau of Transportation Statistics (BTS)	
Average number of seats on domestic flights	2021-2025
On-time arrival performance	2021-2025
Average annual domestic passenger enplanements	2021-2025
Annual U.S. Domestic Average Itinerary Fare in Current and Constant Dollars	2025
Department of Transportation (DOT)	
Hourly Values of Travel Time Savings (VTTS), Air travel, Intercity, All purpose	2025
Percentage of passengers that require hotel and meal compensation	
Percentage of passengers that require rebooking for flights	
Value of Statistical Life (VSL)	2025
Spillover costs, AirHelp	
Relative Disutility Factors by Injury Severity Level (MAIS)	
Federal Aviation Administration (FAA)	
Number of passengers that fly in and out of U.S. airports per day	
Number of flights daily	
Number of flights per year	
U.S. Bureau of Labor Statistics (BLS)	
Consumer Price Index (CPI)	2025
Occupational Employment and Wage Statistics	2025
Employer Costs for Employee Compensation	2025 Q1
U.S. Census Bureau	
U.S. Median Household Income	2025
General Service Administration (GSA)	
Average Lodging Rates	2025
Average Per Diem Rates	2025
International Air Transport Association (IATA)	
North America, Net profit (estimated) (net margin) per passenger	2025
Airlines for America (A4A)	
U.S. Passenger Carrier Delay Costs, total direct operating costs	2025
Airline Provided Data	
Average delay time (in minutes)	
Average time lost per passenger for cancellation (in minutes)	
Average time lost for passengers for missed connections (in minutes)	
Average time lost for passenger for flight diversion (in minutes)	
Average cost for damage on airplane by damage type	

Uncertainty Analysis

There are variable costs that can impact the cost of the disruption of a commercial passenger flight within the U.S. due to thermal runaway. This economic analysis relied on the TRIP data to gather the number of incidents, the injuries sustained from the thermal runaway incidents, and the severity of the significant flight disruption. The details provided within the TRIP database vary depending on the incident. As TRIP data is self-reported, the true number of thermal runaway incidents with significant flight disruption could be higher than what was analyzed in this economic report.

Additionally, airline costs can vary depending on the airline, aircraft, and airport. ULSE received anonymous data from several airlines and integrated their costs into this analysis. However, ULSE recognizes that the costs per incident can vary widely depending on the scenario. The operational realities of each airline can be highly variable as the extent of the disruption can differ in each scenario.

Data Sources Used in ULSE’s Analysis

Overall, limited detailed data exists on thermal runaway incidents on commercial aircraft. However, ULSE used various data sources to conduct an economic analysis to determine an estimate of the impact of thermal runaway events that caused significant flight disruption from 2021 to 2025. The primary sources available for the analysis are below.

ULSE Insights U.S. consumer survey series of a cumulative 6,046 U.S. adults, conducted between January 2026 and August 2026. The modeling and results presented here are based on information provided by ULSE and third parties, upon which USLE has relied in producing a report and estimates in good faith. Any subsequent revision or update of those data will affect the assessments and projections shown.

To derive the estimates of thermal runaway incidents with significant flight disruption and associated costs, ULSE considered several indicators collected by TRIP, DOT, BTS, etc.

Due to the lack of data, ULSE could not fully quantify the cost of damage associated with the spillover effect of thermal runaway.

ⁱ International Air Transport Association (IATA), Airline Profitability to Strengthen Slightly in 2025 Despite Headwinds, <https://www.iata.org/en/pressroom/2025-releases/2025-06-02-01/>

ⁱⁱ Federal Aviation Administration, Air Traffic By the Numbers, https://www.faa.gov/air_traffic/by_the_numbers

ⁱⁱⁱ UL Standards & Engagement, 2025 Data Review Lithium-Ion Battery Incidents in Aviation, https://ulse.org/wp-content/uploads/2026/08/TRIP-Report-July-2026_FINAL.pdf

^{iv} Bureau of Transportation Statistics (BTS) data analysis shows that from 2021 to 2025, the typical U.S. domestic flight has about 119 seats per flight. Therefore, over the 5-year period, ULSE estimates that about 10,948 passengers experienced significant flight disruption due to thermal runaway.

^v ULSE adjusted all data points for inflation to 2025 dollars using Bureau of Labor Statistics (BLS) Consumer Product Index (CPI) data.

^{vi} Data based on TRIP, which is self-reported from the airlines.

^{vii} ULSE’s estimates are conservative because all the economic impacts could not be quantified due to data limitations.

^{viii} Bureau of Transportation Statistics, Passengers, 2021 to 2025, <https://data.bts.gov/stories/s/Passengers/itj6-vfiw>

^{ix} Anonymous data was collected from various airlines for this economic analysis. These airlines operate domestically within the U.S. All data has been aggregated, and all airlines have been deidentified.

^x Analysis was conducted by taking the Valuation of Travel Time formula and updating it with 2025 Census Bureau data and 2025 Bureau of Labor Statistics data.

U.S. Department of Transportation, Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis, 2016, <https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20Travel%20Time%20Guidance.pdf>

U.S. Census Bureau, Median Household Income, 2025, <https://www.census.gov/library/visualizations/2026/comm/median-household-income.html>

Bureau of Labor Statistics, Employer Costs for Employee Compensation, https://www.bls.gov/news.release/archives/ecec_06132025.htm

^{xi} U.S. General Services Administration, Per diem rates, Hotel and Meals and Incidental Expense (M&IE), 2025, https://www.gsa.gov/system/files/FY2025_PerDiemMasterRatesFile.xlsx

U.S. Department of Transportation, Annual U.S. Domestic Average Itinerary Fare in Current and Constant Dollars, 2025, <https://www.bts.gov/content/annual-us-domestic-average-itinerary-fare-current-and-constant-dollars>

^{xii} Department of Transportation, Air Help: Cost of Disrupted Flights to the Economy, https://downloads.regulations.gov/DOT-OST-2024-0062-0001/attachment_7.pdf

^{xiii} U.S. Bureau of Labor Statistics, Consumer Price Index (CPI), Annual average from 2021 to 2025, <https://www.bls.gov/cpi/>

^{xiv} Airlines for America, U.S. Passenger Carrier Delay Costs, 2025, <https://www.airlines.org/dataset/u-s-passenger-carrier-delay-costs/>

^{xv} U.S. Department of Transportation, Departmental Guidance on Valuation of a Statistical Life in Economic Analysis, 2025, <https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis>

^{xvi} U.S. Department of Transportation, Air Help: Cost of disrupted flights to the economy, https://downloads.regulations.gov/DOT-OST-2024-0062-0001/attachment_7.pdf



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