Transportation Safety and the Allocation of Safety Improvements

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Introduction

Commercial air carriers are commonly regarded as one of the safest modes of transportation, largely due to oversight from organizations such as the Federal Aviation Administration (FAA), European Aviation Safety Agency (EASA), and the National Transportation Safety Board (NTSB.) Yet, many people are still apprehensive about air travel, and there is a continued effort by these regulatory agencies to improve the safety records of airlines [1]. In comparison, other modes of transportation, such as private automobiles, are much more dangerous, but arouse less anxiety and receive less attention from regulators. In this paper, the authors will first review the safety records of various modes of transportation in recent years and compare that to the number of investigations performed by the NTSB. This comparison will be used to determine whether resources are being allocated to areas with the worst safety record, and the authors will discuss reasons why demand for safety may be different in various modes of transportation.

Data Selection

Data for miles traveled, accidents, injuries, and fatalities for various modes of transportation is available from the 2011 National Transportation Statistics report [2]. This report provides data for aviation travel distinguished by mode of operation: Code of Federal Regulations (CFR) Part 121, 135 and 91. CFR Part 121 is the regulation governing scheduled commercial airliners; CFR Part 135 governs on-demand air taxis and scheduled commuter carriers, such as business jets and regional airlines; and CFR Part 91 governs general aviation. Statistics for each of these three modes is collected for comparison. Additionally, the transportation statistics report contains safety statistics for highway transport from which the authors consider private automobiles (cars, SUVs, light trucks, and motorcycles) as well as buses. In order to reduce the effects of year-to-year variation, data is collected for years 2002-2009. Yearly average data for each mode is provided for both vehicle and passenger miles traveled, hours flown for aviation, departures, accidents, injuries, and fatalities. Passenger miles are determined for a given trip by multiplying the total number of passengers by the distance traveled. Since the number of passengers involved in private transport is not explicitly known, we rely on survey estimations. The 2009 National Household Travel Survey [3] offers estimates of number of passengers and average distance traveled, from which we can determine passenger miles and total departures. Similarly, the annual FAA General Aviation and Part 135 Activity Survey [4] provides an estimation of the total number of departures for

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both general aviation and air taxi operations. However, there is no data regarding the average number of passengers on these trips, and as such we are not able to compute passenger miles traveled for these modes. A summary of the data collected is available in the appendix.

Societal and Individual Safety Measures

Travel safety can be measured from society's standpoint or from the standpoint of an individual passenger. Society is concerned with the risks associated in transporting a passenger a given distance, while an individual is concern with his risk travelling the same distance. For example, accidents involving buses often lead to fatalities of non-passengers. This will affect society's measures of bus safety, but not the measures of the individual passenger.

The most commonly used measure of transportation safety from society's viewpoint is accidents per passenger mile. This would be the perception of regulatory agencies, who seek to ensure the largest number of people have safe travel over the same distance. Data for accidents and fatalities per passenger mile is shown in Table 1. We see that airlines would be judged to be the safest, followed by buses and finally private automobiles. Estimates do not exist for passenger load on general aviation and Part 135 operations.

Table 1. Risk Per Billion Passenger Miles

	Air Carrier	Commuter and Air Taxi	General Aviation	Private Automobiles	Bus
Accidents	0.064	---	---	1343	323
Fatalities	0.038	---	---	9.09	0.26

However, an individual's perception of safety may be more accurately reflected by accidents per vehicle mile traveled. That is, an individual will consider only whether they will arrive at their destination safely, regardless of how many others they may travel with. Accident and fatality rates per vehicle mile are shown in Table 2. We see that airlines are still the safest mode, while commuter and air taxi and general aviation are the least safe. Note, however, that while the chance of an air carrier accident per billion passenger miles is about 20,000 lower than of a private automobile, per billion vehicle miles it is only about 400 times lower. If we consider the risk of dying, the Table 1 entry is more relevant to an individual than that of Table 2, because the higher value for an air-carrier represents the fact that a single accident will kill many passengers.

Table 2. Risk Per Billion Vehicle Miles

	Air Carrier	Commuter and Air Taxi	General Aviation	Private Automobiles	Bus
Accidents	5.65	161	453	2231	8075
Fatalities	3.40	103	158	15.1	6.54

From the above metrics, it would be assumed that people would prefer airline or bus travel to driving their own car. While this is difficult to quantity, there is a common belief [1] that people are more anxious about flying than driving a personal automobile. Additionally, we would expect that regulations and other efforts to improve safety would be focused on private automobiles and would pay less attention to airlines and buses. It will be shown in the following section that this is not necessarily the case.

Regulatory Emphasis

In order to quantify regulatory demand for increased safety, the authors have surveyed accident investigations performed by the NTSB from 2002-2009 and classified each by the specific mode of transport it is intended to address. An investigation was deemed to address a certain mode if either the probable cause of accident or at least one resulting recommendation specifically referenced that mode. The authors propose that this can be used as a simple metric to compare the desire to improve levels of safety for different modes of transportation. A total of 60 investigations from 2002-2009 were found to deal with a specific mode, with 15 for air carriers, 11 for commuter and air taxi, 12 for general aviation, 4 for private automobiles, and 18 for buses. Due to the relatively small number of investigations performed each year, data is aggregated over the span of 2002-2009. Tables 3 and 4 show the number of investigations per accident and per fatality, respectively.

Table 3. NTSB Investigations Per Thousand Accidents

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
52.8	21.3	0.926	8.28E-05	0.046

Table 4. NTSB Investigations Per Thousand Fatalities

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
91.5	32.5	35.5	0.012	57.0

It can be seen that accidents involving buses are hugely more likely to receive attention from the NTSB than accidents involving private automobiles. The difference in investigation per fatality, which is by about a factor of 5,000 is astonishing. An air carrier accident can be expected to receive more attention than a general aviation or commuter or air taxi accident, but the difference in investigations per fatality is much milder. In the following section, several factors are considered that may cause people to demand varying levels of safety in different modes.

Reasons for a Safety Disparity

The authors propose that there are three effects that contribute to the demand for varying levels of safety in different modes of transportation. First, the news-worthy nature of some accidents like airline crashes means that they get more attention than the same number of deaths due a large number of smaller accidents. Second, when people feel they are in control of their own safety, they may be willing to accept more risk on the basis of trusting their own abilities. Finally, people are more likely to over-estimate risk in systems they have less understanding of.

The news-worthiness or unusual nature of an accident has a large psychological influence on an individual's assessment of risk. In systems like airlines, where accidents are rare but catastrophic, people are more likely to overestimate the probability of an accident compared to a system such as private auto travel. This bias is addressed by prospect theory [5-6], which claims people weigh changes in probabilities that make an impossible event possible disproportionately high. Specifically, people may consider that while the chances of an accident on an airline are low, the survivability of an accident is also very low as compared to automobiles, and so people may seek higher risk of a less fatal accident in order to avoid even a low risk of a certainly fatal one. It can also be seen that a single accident killing many people is much more likely to receive public attention than many accidents that result in the same number of deaths. As such, people may be more aware of these rare occurrences and overestimate their probability.

We can attempt to quantify this news-worthiness by considering the lethality of an accident, or the number of fatalities per accident. This metric is shown in Table 6. We see that aviation accidents are much more lethal than highway accidents, and will be more likely to receive attention. Though buses have a low number of fatalities per accident, a review of the accident investigations reveals that bus accidents investigated commonly involved a large number of fatalities.

Table 6. Fatalities Per Hundred Accidents

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
60.2	64.2	34.9	0.677	0.081

The second factor in varying levels of safety is peoples' level of personal responsibility for their own well being. In private transportation, people tend to trust their own abilities to keep themselves safe. However, on public transport such as buses or airlines, people are relying on someone else to make sure they get to their destination. This causes a demand for increased safety in response to the lack of control over the situation.

Traditional economic theory assumes that decisions are dictated largely by the fact that people are risk averse, and that risk is determined by expected utility of an uncertain prospect. Risk aversion implies that people prefer certain outcome to a lottery with the otherwise equal expected value. For instance, a risk-averse person will prefer $50 for sure to a lottery giving her an equal chance of receiving either $100 or $0. However, several theories have challenged this assumption, stating that people making decisions often times seek risk in certain conditions [5-6]. This is particularly true in uncertain decisions, or situations where exact probabilities are not known. In these cases, people tend to distribute probability uniformly across all possible outcomes and then adjust based on their knowledge [7]. This leads to a bias, known as an ignorance prior, towards a uniform distribution, which is largely dependent on an individual's prior knowledge. Consequently, there will be an over-estimation of rare events in a system that is not well understood. Additionally, people display ambiguity aversion, or preference for risk over uncertainty [8] (i.e., people tend to prefer situations with known probabilities to prospects with unknown probabilities.) This phenomenon is driven largely by comparison with other events where uncertainty and risk are more or less unknown. This comparative ignorance indicates that an individual may prefer a known risk to an unknown uncertainty, even if they judge the probabilities of both events to be approximately equal.

One metric to determine an individual's knowledge or exposure to a given mode is the total number of departures. Since the number of departures is much higher for private modes of transport, people are may be more familiar with the associated risks. Therefore, in Table 5 we consider accident and fatality rates per departure. It can be seen that by this measure, one may consider private automobiles to be safer than airlines, and that the risk of general aviation and bus accidents is very small. This may help explain why familiarity with a system may result in people misjudging risk.

Table 5. Risk Per Million Departures

	Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
Accidents	3.81	36.0	0.015	22.1	10.42
Fatalities	2.14	23.4	0.0054	0.150	0.008

Based on the allocation of accident investigations, it is considered that rare or news-worthy accidents may place increased pressure on regulatory agencies, leading to a disparity in their efforts to improve safety. The authors consider that a lack of knowledge may be the primary factor contributing to an individual's decision to use a transportation mode that is less safe, rather than one they do not understand as well. Personal responsibility may be a contributing factor for both individuals and regulatory agencies, in that people place too much faith in their own abilities and subsequently resist regulation requiring them to change their behavior.

Conclusions and Future Work

It has been shown that depending on what metrics are used, different conclusions may be drawn regarding transportation safety for different modes. Using NTSB accident investigations to quantify demand for increased safety, a theory has been considered that people expect different levels of safety from different modes. This may be due to a comparative lack of knowledge, effects of personal responsibility and over-confidence, and the news-worthiness or rare nature of certain occurrences.

The full paper will address the potential effects of a misallocation of efforts to increase safety. One potential consequence could be that increasing safety disproportionately in a single mode may increase costs to the point that people begin to switch to cheaper, less safe modes of travel. This effect implies that increases in safety in one mode could result in increased fatalities overall. Consideration will be given to multiple sources of oversight from organizations other than the NTSB, such as the National Highway Traffic Safety Association, who may work in parallel on more specific topics. Additionally, attempts will be made to quantify the costs associated with safety improvements and determine their effectiveness in saving lives, including studying safety trends over a longer range of dates. This will allow us to determine if the value of statistical life varies across different modes and see if attention to safety could be allocated more efficiently. The consideration for effects of the news-worthy nature of an accident, personal responsibility, and ignorance will also be explored in more detail.

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Appendix

Transportation Usage Data:

Transportation Use and Safety[1]

	Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
Vehicle Miles Traveled (Millions)	6,340	400	3,500	2,707,000	6,900
Passenger Miles Traveled[2] (Millions)	558,000	---	---	4,501,000	206,400
Hours (Thousands)	18,500	2,700	24,000	---	---
Departures (Millions)	9.6	1.8[4]	30[4]	273,000[5]	5,400
Accidents[3]	36	65	1,620	6,040,000	55,700
Injuries	20	15	280	2,620,000	7,300
Fatalities	21	42	560	41,000	45

[1]Average per year, 2002-2009. Source (unless otherwise noted): U.S. Department of Transportation, 2011 National Transportation Statistics [2]

[2]Passenger miles for a given trip are equal to vehicle miles traveled multiplied by the number of passengers

[3]The Department of Transportation defines an accident as an event resulting in a serious injury or fatality AND/OR substantial vehicle or property damage [2]

[4]Estimated using FAA General Aviation and Part 135 Activity Survey, years 2002-2009 [4]

[5]Estimated using U.S. Department of Transportation, 2009 National Household Travel Survey [3]

Various Safety Metrics:

Accidents Per Billion Vehicle Miles

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
5.65	161	453	2231	8075

Accidents Per Billion Passenger Miles

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
0.06	---	---	1343	323

Accidents Per Million Hours

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
1.92	24.2	67.9	---	---

Accidents Per Million Departures

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus

3.81	36.0	0.015	22.1	10.42

Fatalities Per Million Departures

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
2.14	23.4	0.0054	0.150	0.008

Fatalities Per Hundred Accidents

Air Carrier	Commuter and Air Taxi	General Aviation	Private Vehicle	Bus
60.2	64.2	34.9	0.677	0.081

Fatalities Per Million Enplanements

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
0.03	---	---	0.091	0.008

Fatalities Per Injury

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
1.03	2.89	2.0	0.016	0.006

Injuries Per 100 Accidents

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
57.6	22.2	17.1	43.3	13.2

NTSB Investigations Per Thousand Accidents

Air Carrier	Commuter and Air Taxi	General Aviation	Private Auto	Bus
52.8	21.3	0.926	8.28E-05	0.046

NTSB Investigations Per Thousand Fatalities

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