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Multicriteria approach to analyze the relationship between safety and service quality in the US airline industry

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One of the most important concerns of the air transport deregulation is the gradual deterioration of safety and service quality among airlines. Consumers suffer important information asymmetries with respect to safety quality, being the case that when a passenger boards a plane she does not know whether she is choosing a safe or risky airline. However, service quality is more directly perceived by passengers. In this paper, we apply Data Envelopment Analysis (DEA) methodology to synthesize some partial indicators of safety and service quality. We measure these quality variables by using eleven complementary indicators: three corresponding to the safety dimension and eight to the service dimension. The relative performance of each airline is discussed according to the results of these partial indicators, and DEA methodology is used to obtain a better understanding of the overall picture of safety and service quality. As consumers are usually better informed about the service quality of airlines, we will study the interrelationship between these two sides of global quality, trying to anticipate if some of the misinformation regarding air transport safety could be reduced.

Keywords: Data envelopment analysis (DEA), Safety quality, Service quality, Multicriteria Analysis.

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1. Introduction

Safety and service quality are important determinants of demand for air transport. There are several factors related to service quality that can be observed directly by passengers, but concerning safety they suffer important information asymmetries. In fact, reductions in safety expenditures are less visible, in a short term, than reductions in the quality of the service. Moreover, the perception of safety can be highly altered by the occurrence of events motivated by causes not directly related to the air transport sector. The important market convulsions on the airline industry caused by the September 11th terrorist attacks illustrate this issue. The unprecedented fall in passenger traffic in most domestic and international routes, particularly on US destinations, have pushed some American carriers into financial problems.

Other important consequence was the creation of a new airport security act, signed into law on November 18th, 2001. The law was designed to overhaul airport security in the US and promoted a substantive change in every aspect of airlines and airports security. This act has had a carrying effect for the rest of the airports all over the world and similar regulations have been developed in other countries.

Airlines are under intense pressure to improve security at airports and inside the aircraft. They cope with increased cost stemming from new security systems and higher flight insurance premiums, by implementing a variety of cost-cutting measures, making major reductions in flights on unprofitable routes and delivering distinctive customer service as a basic strategic component to retain the declining demand. There are certainly many aspects related to delivering distinctive customer service, but nowadays within the scope of airline's operations and following the arguments stated above it is undeniable that, first and foremost, customer service means safety. In general airlines tend to place one of their higher priorities on safety, but as a direct consequence of recent terrorist attacks, this priority has been put under review and nowadays airlines reinforce their safety management systems to ensure safety through strict security measures that could reduce the possibility of hijackings or other forms of terrorism.

Rose (1992) manifested that some important problems that can exacerbate the barriers to entry in the airline industry, are given by the tendency of consumers to judge safety by service quality, which is more directly observed by the average consumer. This paper will try to examine the relationship between safety and service quality in the airline industry for the major carriers of the United States. The perception of such a link could affect the airline selection that rational consumers make in order to satisfy a travel demand necessity.

The majority of service quality studies rely on subjective surveys of consumer opinion that are not done in a regular period. This subjective approach does not allow comparing the performance of the airlines. Bowen et al. (1991) introduced the Airline Quality Rating AQR, a multi-factor, weighted average approach as an objective method of comparing airline quality on combined multiple performance criteria. We have followed a different approach applying Data Envelopment Analysis (DEA) methodology as a multi-criteria decision manager approach to synthesize some partial indicators of safety and service quality. We study these concepts by using eleven complementary indicators: three corresponding to the safety dimension and eight to the service dimension. The relative performance of each airline is discussed according to the results of partial indicators with respect to different exposure variables, and DEA methodology is used to obtain a better understanding of the overall picture of safety and service quality for each of the dimensions. Finally, we apply a second stage DEA model to obtain a synthetic safety, service quality and overall safety-service quality indicator. As consumers are usually better informed about the service quality of airlines because they directly experiment some of the features, we will study the interrelationship between these two sides of global quality, trying to anticipate if some of the misinformation regarding air transport safety could be reduced.

The rest of the paper is divided into five sections. Section 2 describes the principal economic characteristics of safety and service quality, focusing on their relationship. Section 3 introduces the data and different sources that have been used. Section 4 briefly discusses the DEA methodology, as a way to synthesize the complementary information provided by different safety and service quality indicators. The calculations of these new synthetic indicators and their relationship are shown in section 5. Section 6 summarizes and concludes.

2. Some economic considerations for safety and service quality in airline industry.

Quality is one of the main aspects of the air transport service, as it is also its price. However, contrarily to what happens with respect to the price facet, quality is composed of many different attributes or dimensions. In this sense, quality might be considered as given by a vector of variables. In fact it is possible to distinguish between input and output variables of quality[1]. We might define quality input variables as actions taken by carriers or other agents that diminish the probability of low service quality provision (e.g. adequate levels of frequencies, inboard comfort, equipment maintenance). On the opposite, the output factors are the result of a given level of quality (e.g. number of complaints, mishandled luggage, denied boarding, punctuality). Therefore, in order to measure quality we should take into account as many variables as possible of all candidates. But this is not an easy task. In some cases, it may be complex to find an objective measure, and in other cases, the service quality variables may be difficult to observe. For instance, the number of ticket complaints is an objective measure to study some quality output variable, though for the level of inboard service we might resort to subjective measures like passengers surveys on this matter. On the other hand, some other variables are not directly observable by an average consumer. Maintenance or pilot training expenditures are two possible examples.

The presence of many variables explaining quality allows to distinguish at least three quality dimensions: level of service, safety and external effects. The level of service (frequency, inboard comfort, seat availability) is determined by the airline, and any deficiencies will affect mainly to passengers. Safety levels are regulated by the International Civil Aviation Organization (ICAO), where general safety rules and procedures are decided. The external effects caused by air carriers (noise, congestion, global warming) may be fixed exogenously by other government agencies. Any lack of safety or the production of negative externalities will have consequences upon users and non users of the air transport mode. In these paper, we will study the relationship between the first two dimensions.

From this point of view safety is a part of global quality. In the same sense as stated above, safety input (maintenance, training) and output variables (incidents, accidents, victims) are in place. Quality variables related to safety are among the most difficult variables to observe. When a passengers boards a plane she does not know whether she is choosing a safe or risky air carrier. She might have some beliefs based on previous experiences, but she will never get all the information needed to make proper decisions to this respect, unless some sort of safety signals were present.

The uncertainty faced by passengers arises from two sources: the presence of uncontrollable exogenous factors for carriers and passengers (e.g. bad weather) and their ignorance about the decision made by the airline with respect to safety related expenditures. In this way, the typical airline-passenger relationship is characterized by the existence of an informational asymmetry, given the superior knowledge of the air carrier about its own level of operational safety. Following Chalk (1983), there would be two opposite views of this relationship: the market-failure view and the market-response view. According to the former, airlines face negative financial and safety incentives, suggesting that they could be inclined to reduce their safety expenses in order to increase profits. This is the basic argument that lies at the heart of safety regulations. The second view suggests that since underperformance on safety can be observed in the form of accidents, consumers will use these signals as an indicator of an operator's level of safety, therefore penalizing negligent firms, and possibly forcing them to leave the industry. For the airline sector, there is enough evidence to support both views[2]. The actual industry safety levels seem to be influenced by both the market-failure and market-response views, indicating that safety regulation is necessary, although in practice, it would have been imperfect and complemented by market mechanisms.

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[1] This distinction is not related to the concepts of inputs and outputs that we will use later in DEA methodology.

Nevertheless, the consumers' information asymmetry could be mitigated if some possible signal existed that allow passengers to discern the type of carrier chosen. We may find in the literature several references to the profits variable as an indicator of carriers level of safety (see Golbe, 1986; Rose, 1989, 1990). Those works support the hypothesis that carriers with higher profits would be safer, and hence, that airlines profits would have to be watched closely by civil aviation authorities. The work by Dionne et al. (1997) reaches a similar conclusion. In this case the debt/equity ratio is seen as another possible signal of safety. This is one of the few works that applies the theory on asymmetric information to the airlines industry, modeling the airline effort to reduce accidents. This effort is linked to debt and equity, finding a moral hazard problem for negative values of the debt/equity ratio. Finally, as safety is part of global quality, and other quality variables are more accessible than variables related to safety, quality may be seen as another safety signal. This is the approach adopted by Rhoades and Waguespack (1999) and it is also the one that we try to apply in this paper.

Information on objective measures of input and output safety and quality variables may be given on absolute or relative terms. The use of quality rates or indicators is very useful to build airline rankings, or to make comparisons through the time or among different modes of transport. In general these ratios relate some quality variable to an exposure or output measure. The most used exposure variables, in the case of airlines, are revenue passenger kilometers and departures. Nevertheless, airlines output can also be measured by other variables, such as hours flown, kilometers flown, available passenger kilometers, passenger enplanements and revenue or available tonnes kilometers. Any given indicator has its own advantages and inconveniences and the selection of any exposure variable will have to be made according to each study purposes. The possibility of ratios manipulation is quite obvious. For instance, and for the quality dimension of safety, if one wants to prove that trunk airlines are safer than local air carriers, the advise would be to construct the accident ratio dividing the number of accidents by the revenue passenger kilometers output variable. On the contrary, if the aim is just the

[2] See for instance, Rose (1989), Rose (1990), Chalk (1987), Chance and Ferris (1987), Borenstein and Zimmerman (1988), Mitchell and Maloney, (1989).

opposite, the recommendation would be to make use of the number of departures or landings as the risk exposure variable[3]. From this point of view, other output variables such as the number of hours flown may be considered more neutral. However it is also true that 70% of accidents (Weener and Wheeler, 1992) occurred at take off, initial climb, final approach and landing phases, what will justify the utilization of number of departures or landings as the basis for accident rates indicators.

Nevertheless, the study of indicators is only the first approach in the analysis of air carriers quality and safety levels. In order to be rigorous we need to apply more sophisticated techniques that allow the use of as much information as possible. To this aim Data Envelopment Analysis is a quite proper methodology in order to get a synthetic value for safety and service quality.

3. The data.

Aviation authorities are the principal responsible parties for safety regulations and, jointly with airlines, airports and traffic controllers, for preventing accidents from happening and recurrence of accidents that have happened. However it is clear that aircraft makers and airlines benefit greatly from this prevention, because it helps consumers to be confident on a mode of transport that has been considered as one of the safest modes in the past. Flying in a commercial aircraft, and particularly if this is registered in Europe, Canada or United States, remains a very safe way to travel. However, there are matters of concern that need to be addressed, for example, airline pilots and aircraft maintenance engineers training; the number of incidents when aircraft fly too close to one another, or 'airproxes'; and the proliferation of the number of occasions on which air traffic controllers are not able to cope with their workload.

Accident investigation boards have to prepare reports and recommendations when accidents/incidents occur; regulators collect data on accidents, incidents, aircraft

[3] The same problem arises when we want to compare safety on different transport modes. Traditionally it has been argued that air transport mode is the safest one, however this result is based on a particular way of measuring safety that use revenue passenger kilometers as the output variable. This ratio produces a biased ranking of modes that favors air transport.

defects, near mid air collisions reports, inspection and surveillance data. However aircraft makers, airlines and Aviation Authorities have expressed concern that, because of a lack of a standardized reporting format, there are multiple interpretations of what is required to be reported. Report information is inconsistent from airline to airline and this results in incomplete or incomparable data. But despite all these problems, these air safety data/information sources are a key element in the process of preventing accidents since previous experiences have shown that some accidents can be evitable taking some basic procedure into consideration. Besides this primary goal, these sources are also essential material for safety studies, trend analysis, airlines monitoring and regulations[4].

The air safety information model (fig.1) is based on the Heinrich Pyramid, and shows four types of possible safety events: significant accidents; incidents; aircraft defects; and unreported occurrences. The Heinrich Pyramid (fig.1-left side) shows that for every major accident, there will be 3-5 significant accidents, and 7-10 incidents, but there will be at least several hundred (unreported) occurrences. Adopting this pyramid for the air safety information model, extra layers for other safety events can be added, such as, aircraft defects. The inverted pyramid on the right shows the relative amount of information available for each type of occurrence. This pyramid is easily understandable because mass media pay a lot of attention to major accidents.

(Insert fig 1 about here)

This study includes data on 10 US airlines in operation during the year 2001. These airlines are classified as major carriers (gross revenues over $1 billion). Safety data have been obtained for accidents, incidents and US Near Midair Collisions from different official sources: National Transport Safety Board (NTSB), Federal Aviation Agency (FAA) Incident and Near Mid Air Collision System (NMACS) databases. The NTSB database is probably the best publicly available database related to air industry safety. It contains accidents/incidents since 1962 and information can be searched through a query form. The database is frequently updated and can even be

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[4]In US, both the National Transportation Safety Board (NTSB) and the Federal Aviation Administration (FAA) conduct investigations to determine probable causes of aviation accidents. Among the most important factors, maintenance, manufacturing design defects, operational deficiencies and pilot-errors are frequently quoted. Some studies suggest that all accidents have some form of human error attached to their cause (BASE, 1997; Braitwaite et al., 1998).

downloaded for personal use[5]. The FAA Incident Data System is available as well online and contains events since 1978. The NMACS database can be found through the FAA Office of Accident Investigation website. According to these databases, an accident is defined as an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage. An incident is an occurrence, other than an accident, associated with the operation of an aircraft that affects or could affect the safety of operations and that is investigated and reported. Near mid air collisions are incidents associated with the operation of an aircraft in which a possibility of collision occurs as a result of proximity of less than 500 feet to another aircraft, or a report is received from a pilot or a flight crewmember stating that a collision hazard existed between two or more aircraft.

Service quality data have been primarily collected from the Department of Transportation (DOT)'s Air Travel Consumer Report on the following measures for the 10 major carriers: mishandled baggage, flight complaints, ticket boarding complaints, baggage complaints, customer service complaints, total number of complaints, voluntary denied boarding, involuntary denied boarding, arrivals on time and historical arrivals on time.

The number of mishandled baggage reports by carrier is based on the total number of reports each carrier received from passengers concerning lost, damaged, delayed or pilfered baggage. These baggage statistics are filed with DOT's Bureau of Transportation Statistics (Office of Airline Information) on a monthly basis by U. S. airlines that have at least one percent of total domestic scheduled-service passenger revenues.

Total number of complaints contains aviation consumer complaints filed with the DOT in writing, by telephone, via e- mail, or in person. One of the caveats present in this database is that DOT has not determined the validity of the complaints. However, the figures can be taken as a proxy of the real situation, because

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[5] www.faa.gov.

complaints are usually the result of a maelstrom of anger of consumers that lose part of their time in filing a complaint without any compensation in mind. People's complaints against airlines are usually high. Flights are oversold and people are bumped. Flights are cancelled without notice. People are left in limbo on the phone by customer services. "Air rage" is a common event worldwide. We have also included the individual complaints about flight, ticket boarding, baggage and customer service, as the most important group of consumer complaints. Flight problems complaints are related to cancellations, delays, or any other deviations from schedule, whether planned or unplanned. Reservations, ticketing, boarding complaints are situations where airline or travel agent mistakes in reservations and ticketing; problems in making reservations and obtaining tickets due to busy telephone lines or waiting in line, or delays in mailing tickets. Baggage complaints are situations where consumers claim for lost, damaged or delayed baggage, charges for excess baggage, carry-on problems, and difficulties with airline claims procedures. Finally, customer service complaints are related to rude or unhelpful employees, inadequate meals or cabin service and treatment of delayed passengers.

Voluntary and involuntary denied boarding data are based on the number of passengers who hold confirmed reservations and are denied boarding (bumped) from a flight because it is oversold. These figures include only passengers whose oversold flight departs without them; they do not include passengers affected by cancelled, delayed or diverted flights. The data are reported quarterly to DOT's Bureau of Transportation Statistics (Office of Airline Information). We have included information by carrier on the number of passengers bumped involuntarily and on the number who voluntarily gave up their seat on an oversold flight in exchange for compensation. The number of involuntary denied boardings include both passengers who received denied boarding compensation and passengers who did not qualify for compensation because of one of the exceptions in the over sales rule[6].

[6] There are three exceptions for passenger to not qualify for compensation: 1) passengers are accommodated on another flight scheduled to arrive within one hour of the original flight; 2) passenger fails to comply with ticketing, check-in or reconfirmation procedures; and 3) aircraft of smaller capacity is substituted.

Arrivals on time and historical arrivals on time provide information about airline on-time performance. It is based on data filed by airlines each month with the DOT's Bureau of Transportation Statistics (Office of Airline Information), and it covers nonstop scheduled-service flights between points within the United States by the ten U. S. major air carriers that have at least one percent of total domestic scheduled-service passenger revenues. The rule requires carriers to currently report on operations to and from the 32 U. S. airports that account for at least one percent of the nation's total domestic scheduled-service passenger enplanements. However, all reporting airlines have voluntarily provided data for their entire domestic systems to DOT, and that information is included in this study. A flight is counted as "on time" if it operated less than 15 minutes after the scheduled time shown in the carriers' Computerized Reservations Systems.

Exposure risk variables, such as, departures, hours flown, miles flown, revenue passengers kilometers, passengers enplanements, freight tons kilometers, and work load units kilometers were collected from the Bureau of Transportation Statistics. These output variables were used to normalize the safety and service quality measures, obtaining in this way a partial indicator of safety and service quality for each airline.

Table 1 presents a summary of the variables included in the study.

(Insert table 1 about here)

Pearson correlation coefficients of the safety, service quality and risk exposure variables vs. safety and service quality variables, respectively, indicate that, in general, there exists a higher correlation in the service quality variables than in the rest of the variables; and this statement is especially true when the group of variables addressing the complaints is analyzed. However, there is an exception to this rule, involuntary denied boarding variable presents a different behavior and it is not strongly correlated with the complaints variables, which indicates that maybe the airlines with a higher number of complaints apply a less-lax overbooking policy. Finally, it is interesting to remark that arrivals on time and historical arrivals on time variables are negatively correlated with the complaint variables, which is clearly intuitive because complaint variables produce disutility or discomfort to consumers, meanwhile arrivals on time increase consumers' satisfaction.

Partial indicators were calculated for each of the safety and service quality variables for all airlines in order to include as much information as possible. Regarding the safety partial indicators, we calculate 21 different ratios. For example, we have obtained the number of incidents divided by the total number of departures for each airline in the year 2001. In a similar way, we have proceeded to calculate a total number of 70 different partial service quality indices.

The whole set of partial safety indicators represents a measure of insecurity and can be interpreted as a number of safety problems per exposure variable. For instance a S1_EX1 (partial indicator of number of incidents per departures) of 0.00235 would translate into 2.35 incidents per 1000 departures. The set of partial service quality indicators does not point out into the same direction of performance, because some ratios, such as arrivals on time and historic arrivals on time indicate a positive level of performance, meanwhile the rest of the ratios correspond to measures of consumers' disutility. For instance, a SQ1_EX2 (partial indicator of number of mishandled baggage per hours flown) of 0.0017 would translate into 17 baggage problems per 10000 hours flown. Spearman rank correlations coefficients were also computed and some selected results are shown in tables 2-5.

(Insert tables 2-5 about here)

It is interesting to note that partial indicators cannot be used robustly in order to rank the safety and service quality performance of the airlines during the year 2001. Had each airline's rank been identical, independently of which partial safety or service quality indicator had been employed to rank the airlines, then the Spearman rank correlation coefficient would have been a perfect 1. The lower the Spearman rank correlation coefficient is, the greater the difference between the safety or service quality ranking for the airlines is. However some patterns can be clearly established. Partial safety and service quality indicators per hours flown and miles flown tend to classify similarly the airlines performance. This result is based on the fact that these two risk exposure variables are related by the speed of the aircraft used in the operations of the airlines, but major carriers use a similar fleet and for this reason the speed of the aircraft does not vary greatly in the sample[7]. Other partial safety and service quality indicators that are highly ranked correlated are the relative indices per departures and passengers enplanements. In this case, the two risk exposure measures are related by the size of the aircraft and the load factor of each of the airlines.

However, besides the existent relationship among some of the partial safety and service quality indicators there still exists a great number of partial indicators that produces a very distinct picture of overall airlines' performance with respect to these two important dimensions: safety and service quality. For this reason, next section tries to provide a synthetic index of performance for all the safety and service quality variables included in the study.

4. A Multi-criteria approach (DEA) to analyze safety and service quality.

Although the interpretation of partial safety and service quality indicators could be done without any difficulties, previous section has shown that this method will not provide a synthetic and a global comparison of the performance of the airlines. However, there exists a great interest in the industry to determine "good" and "bad" airlines regarding safety and service quality performance. Other issue that is not well resolved with the aforementioned analysis is the relationship between safety and service quality, that is whether or not airlines have a better service quality present a better performance concerning safety.

Safety and service quality embraces many different dimensions. If we study safety using partial indicators, like the ones shown in the previous section, we could use 21 different partial indicators and the group of goodies and baddies would greatly depend on what partial indicator is used. For this reason, we think it is necessary to evaluate the performance of each airline at multiple criteria, trying to synthesize all the information provided by partial indicators. In this sense, it would be advisable to obtain an order in the set of the major carriers for each safety variable included in the

[7] In this sense, it is highlighted that partial indicators of near mid air collisions, flight complaints, baggage complaints and total complaints per miles flown and hours flown produce the same relative order of airlines' performance.

study. To illustrate the kind of problem that must be resolved we propose the following multiple objective problem regarding at the number of incidents:

$$
\begin{aligned}
&MOP\\
&\min_j \{incidents\ per\ departures\} = \min_j \{S1\_EX1\}\\
&\min_j \{incidents\ per\ hours\ flown\} = \min_j \{S1\_EX2\}\\
&\min_j \{incidents\ per\ miles\ flown\} = \min_j \{S1\_EX3\}\\
&\min_j \{incidents\ per\ revenue\ passengers\ kilometers\} = \min_j \{S1\_EX4\}\\
&\min_j \{incidents\ per\ passenger\ enplanements\} = \min_j \{S1\_EX5\}\\
&\min_j \{incidents\ per\ freight\ tonnes\ kilometers\} = \min_j \{S1\_EX6\}\\
&\min_j \{incidents\ per\ work\ load\ units\ kilometers\} = \min_j \{S1\_EX7\}
\end{aligned}
\tag{1}
$$

where j=1 to 10 varies for all the airlines included in the study. We may observe that the trivial case is excluded, where an airline simultaneously optimize the seven partial indicators included in the multiple objective problem.

The results shown in the previous section remark the idea that the different partial incident indicators can be considered complements instead of substitutes, and they present a different picture of the performance of the carriers regarding at the number of incidents. In the trivial case, we would have obtained a matrix of 1 or -1, depending on the type of the objective function employed. The ideal way to solve a multiple objective program would be to find out a general agreement about a protocol to evaluate a consumers' utility function *U* that depends on the partial incident indicators:

$$U(S1\_EX1_j, S1\_EX2_j, \ldots, S1\_EX6_j, S1\_EX7_j) \tag{2}$$

where j has the same meaning as before. Then, it would be possible to synthesize the partial information according to the values of the function *U*. Data envelopment analysis (DEA) methodology provides a single unit-less overall index of incidents efficiency. This index will summarize the multifaceted partial incidents indicators in a single synthetic measure for comparison purposes.

The same approach will be applied for the rest of safety and service quality variables included in the study in a straightforward way.

4.1 A DEA model to synthesize partial indicators

Charnes et al. (1978), in their seminal paper, described the DEA methodology as a "mathematical programming model applied to observed data that provides a new way of obtaining empirical estimates of extreme relationships such as the production functions and/or efficiency production possibility surfaces that are the cornerstones of modern economics"[8]. Since then, numerous applications employing the DEA methodology have been presented and involve a wide area of contexts: education, health care, banking, armed forces, sports, transportation, agriculture, retail stores and electricity suppliers. Seiford (1994) cited more than 400 articles in a comprehensive bibliography and stated that DEA methodology is an important analytical tool whose acceptance is no longer in doubt. Emorouznejad and Thanassolis (1997) provide a list of 1500 applications of DEA.

The method was originally designed to evaluate data management units (DMUs), which use multiple inputs to produce multiple outputs, without a clear identification of the relation between them. However, DEA has progressed throughout a variety of formulations and uses to other kind of industries and applications. DEA has been applied to scenarios where the data cannot be strictly interpreted as inputs or outputs or there is no direct functional relationship between the variables. In such situations, a general guideline to the classification of the variables is that variables for which lower levels are better are considered inputs, while outputs are those variables for which higher amounts are better.

A good introduction to DEA notation, formulation and geometric interpretation can be consulted in Charnes et al. (1994), Ali and Seiford (1993), Lewin and Seiford (1997), Coelli et al. (1998) and Cooper et al. (2000). These references provide a good coverage of all the topics that are going to be used in this section. We can employ different envelopment surfaces or orientation in order to develop a data envelopment analysis model. The nature of our problem has determined the employment of VRS (variable returns to scale) because there exists a great heterogeneity among the

[8] The model proposed in this seminal paper is commonly referred to as a CCR model (due to the initials of the authors). The model assumes constant return to scale. Banker et al.(1984) presented a revised efficiency model that is commonly refereed to as a BCC model based on variable returns to scale. In models assuming VRS, the DMUs are not penalized for operating at non-optimal scale as it is the case when constant returns to scale are assumed.

major carriers of US; and an output orientation once the reciprocal of the first three partial incident indicators have been obtained.

The model is used to seek which ones of the 10 major carriers determine the frontier of the envelopment surface, and are deemed efficient with respect to the incident dimension of safety. The airlines that do not lie on the frontier are inefficient and the measurement of the grade of incident inefficiency is determined by the resolution of the model.

In our analysis, we evaluate the grade of performance of the incident dimension of *n* airlines, using *S1_EX4, S1_EX5, S1_EX6,* and *S1_EX7* as inputs, and the reciprocal of the rest of the partial indicators as outputs. Specifically, in production parlance, the *o'th* production unit consumes x_{io} units of input *i (i= 1 to 4)* and produces y_{ro} units of output *r (r=1 to 3)*. The *o'th* production unit can now be described more compactly with the vector (X_o, Y_o), which denote, respectively, the vectors of input values and output values for each airline included in the study.

Next, we consider the dominance comparisons for each airline using the set of all the airlines as a reference. DEA consider the dominance of the linear combinations of the 10 airlines, i.e. $(\sum_{k=1}^{10} \lambda_k X_k, \sum_{k=1}^{10} \lambda_k Y_k)$, with the scalar restricted to be non-negative[9]. Airline *o* is dominated, regarding at the incident dimension, if at least one linear combination of the rest of the airlines shows that some partial incident indicator can be improved without worsening off the rest of partial incident indicators.[10].

Thus, the method serves to segregate a set of airlines into two subsets: the incident-efficient airlines and the incident-inefficient ones. The method also serves to calculate the level of incident-inefficiency of a given airline that will be interpreted as the synthetic incident-DEA index.

Formally, the incident-DEA efficiency index for each airline *o* is calculated through the following linear programming problem:

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[9] The different assumptions about the scalar produce distinct envelopment surfaces: VRS, CRS or extensions of these basic models.

$$\max_{\phi,\lambda,s^+,s^-} z_0 = \phi + \varepsilon \cdot \vec{1}s^+ + \varepsilon \cdot \vec{1}s^-$$
$$\begin{aligned} & s.t. \\ & Y\lambda - s^+ = \phi Y_o \\ & X\lambda + s^- = X_o \\ & \vec{1}\lambda = 1 \\ & \lambda, s^+, s^- \geq 0 \end{aligned} \qquad (3)$$

where, X and Y are the input and output partial incident matrixes, respectively. X_o and Y_o are the input and output incident partial vectors of the airline *o*, respectively. ϕ and λ are parameters calculated in the model, and represent the maximum proportional output that can be attained and the linear convex combination of airlines that dominates the *o'th* airline, respectively. ε and *s* are the Archimedian constant and the slack variables, respectively. The model compares the airline *o* with all the convex linear combinations of the rest of the airlines. Due to the existence of different size of major carriers, a VRS approach is used.

5. Safety and Service Quality DEA indicators for the airline industry

The linear programming problem discussed in the previous section is solved for every airline included in the study in order to obtain an incident-DEA index that embraces all the partial incident indicators calculated as normalized ratios by different risk exposure variables. The incident-DEA index obtained is deemed as the synthetic incident-DEA indicator and is calculated as the inverse of the maximum proportional output that can be obtained for some inputs.

Similarly, we have resolved an equivalent linear programming problem expressed in equation 3 for each variable of safety and service quality. The results of these problems appear in tables 6 and 7, in which we have separated the efficient (goodies) and inefficient (baddies) airlines.

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10 This procedure can be done with all the partial incident indicators and it is quite common when we try to built or approximate some utility function *U*.

(Insert tables 6 and 7 about here)

Table 6 shows the safety-DEA indicators for US major carriers for the year 2001, and it can be seen that there does not exist any airline that can be considered efficient under all the variables considered studying the safety dimension. For example, Alaska airlines shows a good performance under incidents and accidents variables, but has the lowest level under the near mid air collisions. Among the rest of the carriers, we would like to remark that American, Northwest, Southwest and Continental are the only airlines that can be considered efficient for two out of the three variables studied in the safety dimension.

Table 7 shows the service quality DEA indicators for all the variables considered in the study but arrivals on time and historic arrivals on time. Northwest is an efficient airline for seven out of eight different service quality variables. This company is not efficient only for flight complaints but its service quality DEA indicator is really close to one. It can be seen that Southwest is an efficient airline for six out of eight different service quality variables. This company is not efficient only for involuntary denied boardings and mishandled baggage. American is only efficient for two SQ variables, namely mishandled baggage and involuntary denied boardings. Alaska is efficient for mishandled baggage and customer service complaints, and finally US-Airways is only efficient for involuntary denied boardings. The rest of the airlines are inefficient for all the service quality variables.

Southwest obtains a very bad performance for mishandled baggage and involuntary denied boardings. We will see below that mishandled baggage can be out of the direct management of airlines. However, overbooking policy is under a direct control of executives of the airlines. Overbooking means that airlines accept more reservations than a particular airplane capacity on a given flight. Airlines overbook to compensate for passengers who neither cancel reservations nor show up for their confirmed flights. Airlines usually accept a small percentage of extra reservations because, historically, they know that some confirmed passengers, without notice, did not show up for the flight[11]. The problem is that airlines usually overbook a flight trying to maximize profits without internalizing all the externalities that are produced as a consequence of this policy. However, it happens sometimes that confirmed consumers check in on time and the capacity of the plane cannot accommodate all of them. The passengers have different and important reasons to travel and many of them can be quite inflexible insofar as their departure and arrival times are concerned. In fact, airlines usually argue that the majority of overbooked flights still depart with empty seats because the overbooking policy is carefully applied and quite conservative. However, the results of Southwest can induce to think that it is not so conservative as they say[12]. In fact, Suzuki (2002) suggested the idea that airlines seeking to increase short-term profits may decide to implement more aggressive overbooking policies. Other studies analyzing optimal overbooking policies can be found in the operations research literature (see Karaesman and van Ryzin (1998); Chatwin (1998,1999); and Subramanian et al.(1999)).

It seems that the best performance regarding at service quality dimension is obtained by Northwest and Southwest airlines. We will be back to this issue below when we discuss the second stage DEA models to evaluate safety, service quality and global safety-service quality indicators.

Another important issue that we would like to remark is that it seems looking at tables 6 and 7 that the performance of safety is more homogenous through the whole set of airlines than the performance of service quality. Service quality among the major US carriers varies more than safety. There can be two possible explanations for this result; first since safety quality is more strictly regulated than the service quality we can conclude that airlines have the correct incentives to maintain some standards of safety and for this reason these standards create a common reference state that apparently homogenizes safety performance for airlines; and

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[11] Smith et al. (1992) showed that airlines that do not practice overbooking may suffer a comparative disadvantage with respect to its competitors that practice overbooking because the flights whose seats have been completely sold out can experience approximately 15% of seats vacant after the departures.

[12] Southwest handles its seat inventory differently from its rivals. It only participates in one computer reservation system and prefers to sell most of its tickets directly to customers over the phone or Internet. So, overbooking may be an intentional Southwest directive. However, it is necessary to have in mind that Southwest obtained efficiency for many other aspects of service quality, namely flight complaints, ticket complaints, baggage complaints, customer service complaints, total complaints and voluntary denied boardings. Southwest is world known for being ranked number 1 for baggage handling, customer service, on-time performance, price and safety.

second service quality can be part of the marketing strategies of the company and some separating equilibrium can exist in the market, where some airlines of “high quality segments” coexist with some others of “low quality segments”. Airlines could effort in creating a “brand” image that will distinguish its performance from its rivals’ getting some market power over its loyal customers.

Finally, we apply a second stage DEA model to obtain a synthetic safety, service quality and overall safety-service quality indicator. The linear programming problem to calculate the safety-DEA indicator has been resolved using the three different dimensions of safety studied in this paper, namely incident-DEA, accident-DEA and near mid air collisions DEA indicators. Similarly, the linear programming problem to calculate the service quality-DEA indicator has been resolved using the ten different dimensions of service quality studied in this paper. In this case we have employed the eight different dimensions of service quality discussed in table 7 and we have also included arrivals on time and historic arrivals on time as outputs. Finally, we have employed the thirteen different indicators conjointly to evaluate the global safety-service quality DEA indicator. The results of these problems appear in table 8.

(Insert table 8 about here)

Table 8 shows that Southwest, Northwest and American are the safest airlines for the year 2001. The same set of airlines including Alaska has the best overall performance regarding at service quality. On the opposite side, we can observe that TWA, America West and Delta are the airlines that present the worst performance with respect to safety and service quality. There exists empirical evidence that suggest the linkage between financial stability performance and safety and service quality performance. Rose (1990) showed that a 5 percent increase in operating profit margin causes a 15 percent decline in accidents and incidents rate in the following year. For this reason, it is not strange the position that TWA achieved during year 2001 and its cease in operation during December 2001. Graham and Bowes (1979) and Lee (1996) stated that unprofitable airlines would reduce costs in maintenance, safety and service quality when they face economic hardships, and pursuing lower cost they usually are confronted with more consumers’ complaints.

Berry et al. (1994) have outlined the following ten critical lessons for improving service quality: listening, reliability, basic service, service design, recovery, surprising customers, fair play, teamwork, employee research, and servant leadership. Rhoades et al. (1998) suggested that US airlines as a group have yet to fully learn these lessons. Without in-depth qualitative study of airline operations, the authors cannot address their performance on a number of these lessons but their study suggest that airlines as a whole have serious problems with three of the lessons outlined by Berry et al. (1994), namely reliability, basic service, and service design. Our results point out into the same direction.

Data on on-time performance, denied boarding, and mishandled baggage suggest serious problems with reliability and basic service provision for some carriers. While airport congestion and the hub-and-spoke system can be blamed for some of the problems with on-time performance and flight problems (delays), airlines still have an adequate panoply of measures that can help to mitigate these problems, namely traffic managers can reroute some traffic to secondary airports, expand facilities and infrastructure to increase capacity, and refuse to hold flights longer than a certain time waiting for incoming flights.

Other problems can be alleviated improving the information systems. Denied boardings and complaints about fares, refunds, ticketing, and credit can frequently be attributed to a mismanagement of data. Airline industry is characterized by an extensive use of revenue management techniques; however besides some important resources have been put into the arena there is still great variation in the sophistication of these systems.

Finally, the issue of mishandled baggage must be addressed at all levels of the airline. Since the level of mishandled baggage varies by month and day depending on traffic volumes, as well as, by airports; any effort to correct the problem requires extensive study of the process involved at each site including the training of personnel, tagging and loading, movement of baggage from check-in to loading, tracking of baggage, etc.

Finally, we would like to answer the question of whether the airlines that present a better performance with respect to service quality dimension, they also present a better performance with respect to safety dimension. If we segregate the companies under the efficient criteria using our service quality DEA, we can evaluate how likely is that the performance on safety dimension would be significantly the same. In order to answer this question we will work out the probability that the two different sets of airlines obtain the same average performance on safety records. The results that we obtain applying a t-test allow us to conclude that average safety performance is significantly higher in service quality efficient airlines (mean=0.996) than in service quality inefficient airlines (mean=0.644)[13]. Thus we can conclude that passengers traveling on a major US airline during the year 2001 could have reduced the misinformation problem on safety dimension looking at the overall level of service quality, and they have good reasons in using service quality as a proxy for safety. So it is arguable if consumers are more price sensitive than service quality, because our results have shown that service quality is a signal for safety and the interaction of this relationship has to be measured carefully.

6. Summary and Conclusions

Safety and service quality are important determinants of demand for air transport. However, the perception of safety has been altered by the occurrence of the September 11th terrorist attacks, events motivated by causes not directly related to the air transport sector. The airline industry is now experiencing time of great turbulence and uncertainty and some market convulsions, such as an unprecedented fall in passenger traffic in most domestic and international routes, particularly on US destinations, have pushed some American carriers into financial problems.

Under these circumstances, airlines need to regain the consumers' confidence in order to recover the precedent levels of demand, consolidating their market share and profitability. However, the marginal benefits of marketing strategies become gradually decreasing because most of the airlines act similarly. Recognizing this limitation of the marketing strategies, some of air carriers now tend to focus on the commitment of improving customer service quality.

[13] The t-test and the Welch approximation for small samples produce the following results (different variances t= 3.068; df=5; p= 0.028; equal variances t= 2.455; df=8; p= 0.040). In any case we would reject the null hypothesis that the true difference in means is equal to 0.

Airlines provide a range of services to consumers including ticket reservation, purchase, airport assistance, on-board service and the service at the destination airport. Airline service also consists of the assistance associated with disruptions such as mishandled-baggage and service for delayed or denied boarding passengers. For this reason, service quality can be regarded as a composite of various attributes.

In this paper, we apply a multicriteria approach (DEA) to synthesize some partial indicators of safety and service quality. First we have introduced different indicators to study a complex phenomenon such as safety and service quality. In this sense, different partial indicators have been obtained dividing the main information variables by some different risk exposure variables. In total, we have used 21 partial indicators of safety and 56 partial indicators of service quality.

We have seen that the indicators used in this study respond to different conceptualizations of the topic we are trying to analyze; and offer a complementary vision that needs to be embraced. We have also shown that the selection of the partial indicator plays a crucial role in determining a different picture of the performance of each major US airline for the year 2001. For this reason, we have proposed a multicriteria DEA approach to synthesize all the complementary information provided by different partial indicators and we have calculated a synthetic safety, service quality and safety-service quality indicators using a second stage DEA model.

We have highlighted that the performance of safety is more homogenous through the whole set of airlines than the performance of service quality, i.e. service quality among the major US carriers varies more than safety. The explanation to this result is twofold: first since safety quality is more strictly regulated than the service quality we can conclude that airlines have the correct incentives to maintain some standards of safety and for this reason these standards create a common reference state that apparently homogenizes safety performance for airlines; and second service quality policy is determined principally by the marketing strategies of the company and some separating equilibrium can exist in the market, where some airlines of “high quality segments” coexist with some others of “low quality segments”. Airlines could effort in creating a “brand” image that will distinguish its performance from its rivals’.

It has been seen that Southwest, Northwest and American are the safest airlines for the year 2001. The same set of airlines including Alaska has the best overall performance regarding service quality. On the opposite side, we can observe that TWA, America West and Delta are the airlines that present the worst performance with respect to safety and service quality.

We have shown that average safety performance is significantly higher in service quality efficient airlines than in service quality inefficient airlines. Thus, we can conclude that passengers traveling on a major US airline during the year 2001 could have reduced the misinformation problem on safety dimension looking at the overall level of service quality, and they have good reasons in using service quality as a proxy for safety.

In summary, safety and service quality is a multi faceted concept that is difficult to analyze. Different patterns can be obtained depending on which partial indicator is being used to study this issue. Some comments must be done here in order to obtain synthetic safety and service quality indicators that combine all the information provided by the multiple partial indicators. It would be ideal to solve the multiple objective program according to some average consumer's utility function that depends on partial indicators. However, we do not have an explicit knowledge of this function, and we really need to find out somehow the space of tradeoffs among the different partial measures. This is not an easy task because the space of tradeoffs is not small. DEA methodology can help as an interesting and powerful tool in searching these tradeoffs. In this fashion, we have found the airlines that can be considered safety and service quality DEA efficient, where the vector of partial indicators (its performance) is not dominated by a convex linear combination of the rest of the airlines included in the study, i.e., it is not possible to improve some partial indicator without worsening at least one of the others.

Finally, this study presents some limitations. The variables of service quality have been obtained from the Air Travel Consumer Report, and the information presented there deals primarily with issues of basic service, such as flight problems, overbooking and some complaints, but it does not address other important issues that can be important factors determining the level of service, such as, seat space, comfort, friendliness of flight attendants and in-flight amenities. Other important caveat is that we cannot separate the study of service quality by different type of consumers and it is evident that a different perception of service quality between business-class and coach-class may exist for each of the airlines analyzed in the study. The results of the analysis would be more robust if a longer period of time is studied. However, the lack of adequate data precludes us to evaluate this important issues that can be object of promising future research.

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Figure 1.Air Safety Information Model. Heinrich Pyramid.

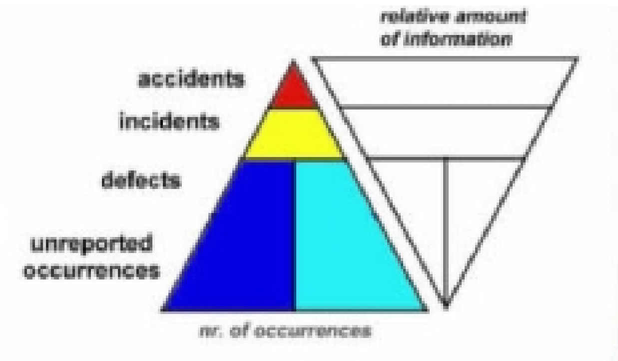

Table 1. Safety, Service Quality and Risk Exposure Variables Included in the Study.

Type of variable	Variable
Safety	Number of Incidents (S1) Number of accidents (S2) Number of near mid air collisions (S3)
Service Quality	Mishandled baggage (SQ1) Flight complaints (SQ2) Ticket Boarding complaints (SQ3) Baggage complaints (SQ4) Customer service complaints (SQ5) Total number of complaints (SQ6) Voluntary denied boarding (SQ7) Involuntary denied boarding (SQ8) Arrivals on time (SQ9) Historical arrivals on time (SQ10)
Risk exposure variables	Departures (EX1) Hours flown (EX2) Miles flown (EX3) Revenue passengers kilometres (EX4) Passengers enplanements (EX5) Freight tonnes kilometres (EX6) Work Load Units kilometres (EX7)
Sources: Bureau of Transport Statistics.	

Table 2. Spearman Rank Correlation Coefficient of Incidents Ratios

	S1_ EX2	S1_ EX3	S1_ EX4	S1_ EX5	S1_ EX6	S1_ EX7
S1_ EX1	0.794	0.592	0.321	0.964	0.103	0.309
S1_ EX2		0.932	0.648	0.818	0.358	0.588
S1_ EX3			0.831	0.605	0.567	0.768
S1_ EX4				0.321	0.891	0.988
S1_ EX5					0.055	0.297
S1_ EX6						0.915

S1: Number of Incidents
EX1: Departures
EX2: Hours flown
EX3: Miles flown
EX4: Revenue passengers kilometres
EX5: Passengers enplanements
EX6: Freight tonnes kilometres
EX7: Work Load Units kilometres

Table 3. Spearman Rank Correlation Coefficient of Near Mid Air Collisions Ratios

	S3_ EX2	S3_ EX3	S3_ EX4	S3_ EX5	S3_ EX6	S3_ EX7
S3_ EX1	0.935	0.935	0.805	0.951	0.789	0.821
S3_ EX2		1	0.935	0.984	0.886	0.919
S3_ EX3			0.935	0.984	0.886	0.919
S3_ EX4				0.919	0.951	0.984
S3_ EX5					0.919	0.935
S3_ EX6						0.984

S3: Number of near mid air collisions
EX1: Departures
EX2: Hours flown
EX3: Miles flown
EX4: Revenue passengers kilometres
EX5: Passengers enplanements
EX6: Freight tonnes kilometres
EX7: Work Load Units kilometres

Table 4. Spearman Rank Correlation Coefficient of Mishandled Baggage Ratios

	SQ1_ EX2	SQ1_ EX3	SQ1_ EX4	SQ1_ EX5	SQ1_ EX6	SQ1_ EX7
SQ1_ EX1	0.733	0.588	0.430	0.903	0.224	0.394
SQ1_ EX2		0.964	0.806	0.855	0.576	0.770
SQ1_ EX3			0.855	0.721	0.588	0.794
SQ1_ EX4				0.576	0.855	0.976
SQ1_ EX5					0.394	0.552
SQ1_ EX6						0.927

SQ1: Mishandled baggage
EX1: Departures
EX2: Hours flown
EX3: Miles flown
EX4: Revenue passengers kilometres
EX5: Passengers enplanements
EX6: Freight tonnes kilometres
EX7: Work Load Units kilometres

Table 5. Spearman Rank Correlation Coefficient of Flight Complaints Ratios

	SQ2_ EX2	SQ2_ EX3	SQ2_ EX4	SQ2_ EX5	SQ2_ EX6	SQ2_ EX7
SQ2_ EX1	0.952	0.952	0.818	0.988	0.139	0.745
SQ2_ EX2		1.000	0.927	0.964	0.285	0.842
SQ2_ EX3			0.927	0.964	0.285	0.842
SQ2_ EX4				0.842	0.515	0.964
SQ2_ EX5					0.212	0.770
SQ2_ EX6						0.624

SQ2: Flight complaints
EX1: Departures
EX2: Hours flown
EX3: Miles flown
EX4: Revenue passengers kilometres
EX5: Passengers enplanements
EX6: Freight tonnes kilometres
EX7: Work Load Units kilometres

Table 6. Safety-DEA Indicators for US Major Carriers.

Incidents	Accidents	Near mid air collisions
American (1.000)	**Northwest (1.000)**	**Continental (1.000)**
Northwest (1.000)	**Southwest (1.000)**	**TWA (1.000)**
Southwest (1.000)	**Alaska (1.000)**	**American (1.000)**
US-Airways (1.000)	**United (1.000)**	**America West (1.000)**
Alaska (0.985)	**Continental (1.000)**	Northwest (0.767)
United (0.982)	Delta (0.950)	Southwest (0.472)
Continental (0.632)	US-Airways (0.886)	United (0.436)
Delta (0.508)	TWA (0.252)	US-Airways (0.265)
America West (0.352)	American (0.226)	Delta (0.146)
TWA (0.345)	America West (0.011)	Alaska (0.009)

Airlines in bold type are efficient and ϕ is in brackets.

Table 7. Service Quality-DEA Indicators for US Major Carriers.

Mishandled Baggage	Flight Complaints	Ticket Complaints	Baggage Complaints	Customer Service Complaints	Total Complaints	Voluntary Denied Boardings	Involuntary Denied Boardings
Continental (1.000)	**Southwest (1.000)**	**Southwest (1.000)**	**Southwest (1.000)**	**Southwest (1.000)**	**Southwest (1.000)**	**Southwest (1.000)**	**Northwest (1.000)**
American (1.000)	Northwest (0.959)	**Northwest (1.000)**	**Northwest (1.000)**	**Northwest (1.000)**	**Northwest (1.000)**	**Northwest (1.000)**	**US-Airways (1.000)**
Northwest (1.000)	Continental (0.722)	American (0.827)	US-Airways (0.719)	**Alaska (1.000)**	Continental (0.659)	US-Airways (0.893)	**American (1.000)**
Alaska (1.000)	American (0.342)	Alaska (0.672)	Continental (0.704)	American (0.677)	American (0.619)	Continental (0.869)	America West (0.586)
United (0.719)	United (0.213)	Continental (0.603)	Alaska (0.664)	Delta (0.576)	Alaska (0.578)	American (0.823)	Delta (0.226)
US-Airways (0.625)	Delta (0.172)	US-Airways (0.547)	Delta (0.664)	Continental (0.416)	Delta (0.428)	United (0.587)	Continental (0.163)
Delta (0.619)	Alaska (0.140)	Delta (0.514)	American (0.467)	US-Airways (0.339)	United (0.389)	TWA (0.581)	United (0.122)
America West (0.392)	US-Airways (0.090)	United (0.450)	United (0.388)	United (0.295)	US-Airways (0.302)	Delta (0.492)	Alaska (0.048)
Southwest (0.291)	TWA (0.038)	TWA (0.047)	TWA (0.191)	TWA (0.112)	TWA (0.075)	Alaska (0.332)	Southwest (0.039)
TWA (0.181)	America West (0.006)	America West (0.036)	America West (0.068)	America West (0.059)	America West (0.026)	America West (0.263)	TWA (0.026)

Airlines in bold type are efficient and ϕ is in brackets.

Table 8. Global Safety-SQ-DEA Indicators for US Major Carriers.

Safety	Service Quality	Safety-Service Quality
Southwest (1.000)	**Southwest (1.000)**	**Southwest (1.000)**
Northwest (1.000)	**Northwest (1.000)**	**Northwest (1.000)**
American (1.000)	**American (1.000)**	**American (1.000)**
Alaska (0.985)	**Alaska (1.000)**	**Alaska (1.000)**
United (0.982)	Continental (0.869)	**Continental (1.000)**
US-Airways (0.886)	US-Airways (0.719)	**US-Airways (1.000)**
Continental (0.808)	United (0.422)	United (0.982)
Delta (0.483)	Delta (0.382)	Delta (0.631)
TWA (0.355)	America West (0.230)	America West (0.392)
America West (0.352)	TWA (0.111)	TWA (0.362)

Airlines in bold type are efficient and ϕ is in brackets.