Ranking US airlines – a multi-attribute decision making approach

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Abstract: Airline competition has typically been assessed typically using one performance measure, with some exceptions where a combination of a few performance measures has been used. This research presents a multi-attribute decision making approach to assess the competitiveness of airlines in the USA. The performance measures are considered under five competitiveness dimensions including, cost, price, service quality, management and productivity. Input from airline decision-makers was used to assign weights to the performance measures. The analytic hierarchy process (AHP) and technique for order of preference by similarity to ideal solution (TOPSIS) methods were used to conduct a competitiveness analysis of ten US airlines for the year 2015. While the two methods produced slightly different results, the TOPSIS was found to be superior since it returned results in line with previous studies. These results can be used by airline management to benchmark against competitors.

Keywords: airlines; competition; multi-attribute; decision analysis.

Reference to this paper should be made as follows: Gupta, A. and Walton, R.O. (2022) 'Ranking US airlines – a multi-attribute decision making approach', *Int. J. Logistics Systems and Management*, Vol. 42, No. 1, pp.75–88.

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This paper is a revised and expanded version of a paper entitled 'Ranking US airlines – a multi-attribute decision making approach' presented at INFORMS International Conference, Cancan, Mexico, 9–12 June 2019.

1 Introduction

The US domestic passenger airline market experienced rapid growth in both passenger traffic and competition after deregulation. Since deregulation in 1978, the US domestic passenger market has grown from 243 million passengers to over 780 million passengers by 2018 (BTS, 2019; Rutner et al., 1997). In addition, over the last 40 years since deregulation many new airlines have entered and exited the market. To remain competitive and to obtain and hold customers in the current market airlines must understand their relative level of competitiveness and the elements affecting their competitive advantages. Many competitive analysis techniques have been developed in an attempt to understand airlines competitiveness. However, no single technique has emerged as a single best approach for airline competitive analysis. To further complicate things each organisation is different and competitiveness has different meanings to different airlines.

The airline industry experiences more volatile fluctuations than any other industry (Low and Lee, 2014). These volatile fluctuations and the tough competitive environment make long-term profitability very challenging for airlines. Airlines are very capital intensive and can be impacted by outside cost pressures such as fuel price. Aircraft are very expensive to own and operate and to make a profit airlines must operate at a high level of efficiency. In addition, technological advances will continue to create more efficient aircraft which forces airlines to constantly upgrade to newer, more expensive equipment in order to stay competitive.

Cederholm (2014) noted that the availability of aircraft leasing options from banks, investors, and manufactures are part of the contributors to the high number of new airlines. According to the International Air Transport Association (2011), more than 1,300 new airlines have been established in the last 40 years, worldwide. The six major airlines in the USA: Delta Air Lines, United Continental, Alaska Air, JetBlue Airways, Southwest Airlines and American Airlines, account for 94% of the total US market share.

The US airline industry competitiveness grew fierce after the 1978 Airline Deregulation Act. The act deregulated price, route and scheduling controls. The intense competition has created very few success stories. For example, in an effort to retain competitive advantages, American Airlines was the first to offer loyalty programs, use computerised reservation systems and offer other innovations. However, those innovations were short lived, as competitors were able to react quickly and imitate, causing American Airlines to file for bankruptcy protection in November 2011.

The purpose of this study is to presents a multi-attribute decision making approach to assess the competitiveness of airlines in the USA. The number of dimensions and their related performance measures are considered. The dimensions considered include, cost, price, service quality, management and productivity. This study will add to the body of literature on airline competition and provide an alternative method of assessing airline competition. The method being proposed in this paper is reproducible and consistent over time, which makes it more usable when comparing an airline competitiveness over time.

2 Literature review

Competition among the airlines is good for customers; not only does competition decrease customer cost, but it also improves on-time performance. Greenfield (2014) noted how competition has forced airlines to put a strong emphasis on on-time performance. If airlines cannot perform as expected by the customers, in most cases the customer will not have a problem going to a different airline. Customers tend to not have much loyalty to an airline and have no switching costs.

Since deregulation in the USA, the demand for air travel has increased by over 500 million passengers per year. This number will only continue to grow. One of the best ways to improve performance and remain competitive is through benchmarking. It is important for airlines to benchmark against each other to help identify best practices. While this may seem unorthodox, the sharing of performance information with a competitor is necessary in order for airlines to remain competitive (Francis et al., 1999). This research can serve as a benchmark for airlines.

Benchmarking using multiple variables is a multi-criteria problem that can be assessed using multi-attribute decision making models (MADM). By using only quantifiable data and not subjective guesses from decision makers the MADM process is reproducible and a consistent measure that can be used over time (Chang and Yeh, 2001). According to Chang and Yeh (2001, p.406), "MADM has been widely used in ranking a finite number of alternatives characterized by multiple, conflicting criteria or attributes."

Specifically, this study uses the technique for order of preference by similarity to ideal solution (TOPSIS) and the analytic hierarchy process (AHP) to explore the question. TOPSIS is a classic multi-attribute decision making method that is intuitive and easily understood and implemented (Lau et al., 2016). Whereas AHP "involves decomposing complex unstructured multi-criteria decision problem into a hierarchy consisting of various levels in terms of an overall objective" [Singh, (2016), p.773]. AHP has been used to examine a variety of unstructured problems in different industries due to its versatility and practical approach (Lau et al., 2016; Singh, 2016). The four main steps of AHP are:

1 Define the decision program and structure into a hierarchy.

2 Conduct pair wise comparisons for each level.

3 Estimate the relative weightings for each attribute.

4 Conduct a consistency test for the entire hierarchy (Singh, 2016).

Using MADM, this study examined the performance measures of the dimensions of cost, price, service quality, management, and productivity. Though competitiveness can be measured using a variety of qualitative and quantitative performance measures, this study used only quantitative performance measures. The measures were chosen based on the common view of competitiveness as surveyed from professionals in industry and researchers in academia. Ten US airlines which had available data for all performance measures were used in this study.

A hierarchy of performance measures and dimensions was developed to rank the airlines. The hierarchy is needed to conduct pairwise comparisons at each level and section of the hierarchy. The pairwise comparison is typically made for two different categories of factors. For attributes/sub-objectives/objectives or dimensions/performance

measures in this research, the questions asked assess how much more important one factor is than another factor with respect to attributes/sub-objectives/objectives they are associated with. For alternatives or in this research airlines, the questions asked assess how much better one alternative performs than the other with respect to each attribute at the next level of hierarchy.

To identify attributes for a problem, attributes associated with an objective are an obvious choice but in some cases where the objective is not clear cut it can be a challenge to define the attributes. According to Evans (2016), if there are no clear attributes for an objective, then the analyst should either decompose the objective into component objectives or use the constructed attribute for the objective. In addition, if the fundamental objectives are carefully chosen, then the corresponding attributes should be unambiguous, comprehensive, direct, operational and understandable (Keeney and Gregory, 2005). In this research, all of the attributes are associated with fundamental objectives and have the characteristics as cited by Keeney and Gregory (2005).

The first dimension used in this study is cost. Unit operating cost is a good indicator of cost competitiveness of an airline since it provides an indication of efficiency created between cost input and cost output (Chang and Yeh, 2001). The unit operating cost is calculated as direct operating cost minus the fuel cost divided by the available seat-miles. Currently, the cost of fuel has the largest influence on unit operating cost. Over the last decade, fuel prices have been the biggest impact on airline revenue and accounted for 33.2% of the industries cost structure in 2012–2013, but dropped to 18.7% in 2017 (Vayn Aerospace and Defence, 2017). The volatility in the oil market is expected to remain into the near future so it will continue to affect airline's unit operating cost. Available seat-miles indicate how efficiently an airline's capacity is being utilised and is calculated by dividing the total number of revenue passengers by the total number of available seats (Chang and Yeh, 2001).

The second dimension is price. Essentially, the airline market is homogeneous which means that the market is typically governed by price differentiation (Dutta and Santra, 2017). Overall, passengers are sensitive to the cost of air travel and typically price is a consumer's number one determinant. This elasticity of demand varies by price class level (business class vs. economy class), airline and route (Smyth and Pearce, 2008). Total system passenger yield is used in this study. One of the techniques airlines use to maximise profits is by using dynamic pricing. Clark and Vincent (2012) conducted research that identified two factors that determined the airlines dynamic pricing strategy. However, it was also proven that airlines adjust those prices based on the number of seats available by their competitors. Airlines must play this pricing strategy using a very fine balance; the longer an airline waits, the higher the probability the seat will not sell, causing them to lose revenue on an irrecoverable seat.

The third dimension is service quality. Service quality is often measured by customer satisfaction and both are good indicators of the future performance of airlines (Moss et al., 2016). Service quality is important to the travelling public and customer retention and can be linked to airline profitability (Min and Min, 2015; Nasir et al., 2017). According to Singh (2016), service quality is more important than price in customer retention and should be considered a critical success factor for airlines. A customer retention increase of 2% can have the same effect as cutting cost by 10% (Min and Min, 2015). However, the intangible nature of service quality is difficult to measure, therefore difficult to improve (Min and Min, 2015; Singh, 2016). Airline loyalty programs provide a critical competitive tool for airlines in a hyper competitive market (Sandada and

Matibiri, 2015). Other indicators of service quality are on-time arrival and departure performance, mishandled baggage and flight frequency.

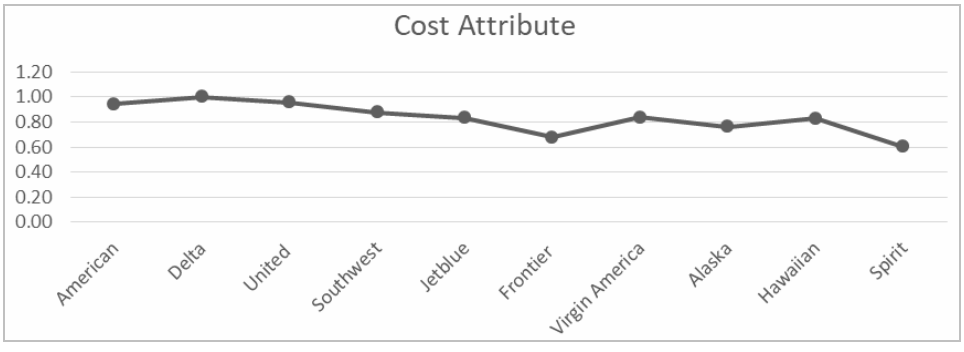
Another dimension used in this study was management. Management's role for any firm is to provide guidance, starting from the strategic level to the tactical level. Financial performance is a core indicator of an airline's success and the net profit margin represents the efficiency of operations in management, either through cost control or improving output (Nasir et al., 2017). In addition to net profit margin, market share is a good indicator of performance.

Finally, productivity was used as the last dimension. In general, productivity is the ratio of output to input, so labour productivity can be defined as the total revenue generated/total employees whereas fleet productivity is the total revenue passenger miles (RPMs)/total fleet. Moss et al. (2016, p.70) noted that "marginal cost per additional passenger is very low to maximizing passengers." Marginal cost is the cost which the airlines incur for every additional passenger. Passenger load factor, labour productivity and fleet productivity are more relevant performance measures for productivity.

3 Comparison of performance measures

As shown in Figure 1, the cost per available seat mile is highest for Delta and lowest for Spirit. Highest cost per available mile for Delta can be attributed to the fact that Delta is a full service carrier and has more cost, whereas Spirit focuses on being a point-to-point low cost carrier (LCC) which tend to have lower marginal cost. In fact, the Big 3 (American, Delta and United) all have the highest cost per available seat mile as compared to the other, mostly LCCs.

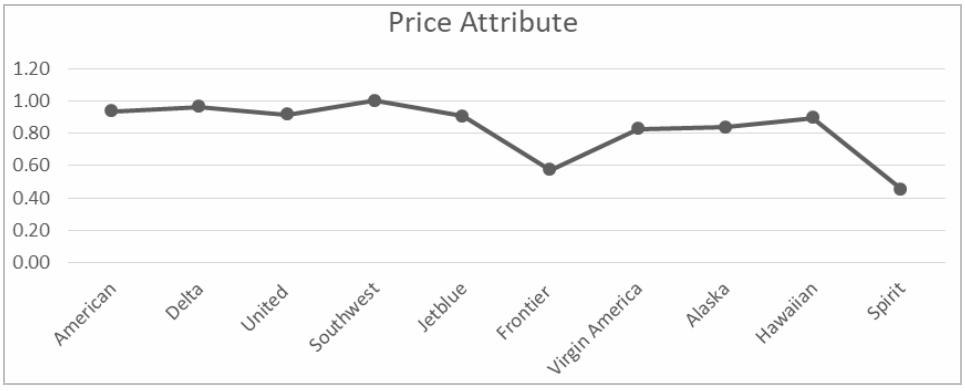
Figure 1 Cost per available seat mile, in cents per mile (2015)



Source: BTS (2019)

Total system passenger yield is the revenue earned per RPM and is highest for Southwest and lowest for Spirit (Figure 2). The best ways to increase yield is to raise ticket prices, increase capacity, or improve efficiency with existing capacity. This data indicates that Southwest has a very efficient system, whereas Spirit's yield is most likely impacted by the fact that it is an ultra-low cost carrier (ULLC) so has very cheap ticket prices which depresses its yield. This is also the case with Frontier, which the second lowest yield.

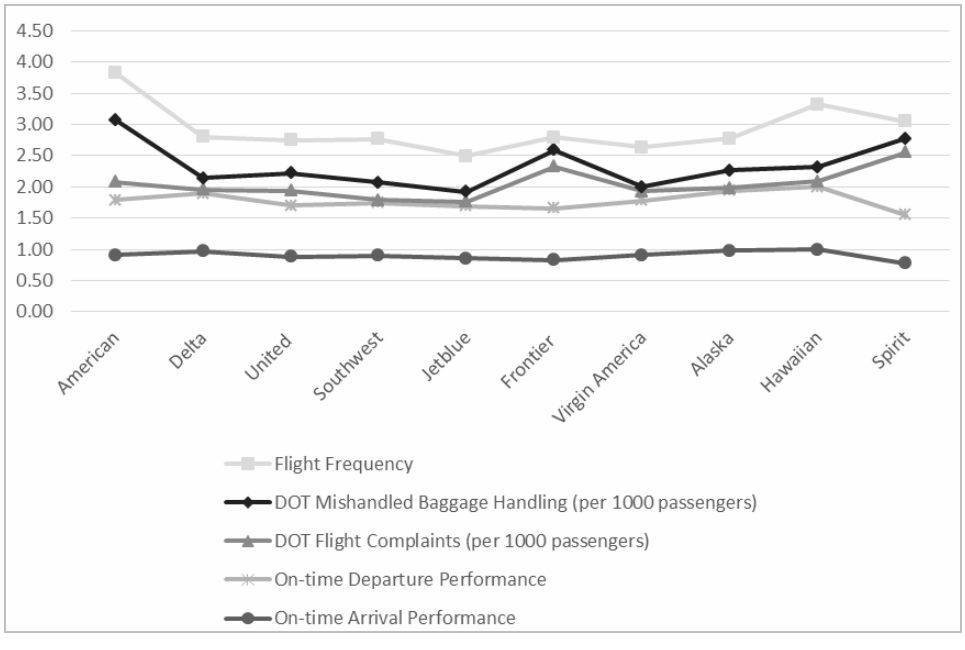
Figure 2 Total system passenger yield, in cents per RPM (2015)



Source: BTS (2019)

Figure 3 outlines the service quality attributes. In 2017, the passenger complaint rate for all domestic airlines was 1.04 per 100,000 passengers, this equates to 8,865 complaints filed with the US Department of Transportation (AQR, 2019). Passenger complaints are only one aspect of service quality so attributes such as on-time performance, and flight frequency should also be considered. The 2015 data shows on-time arrival performance is highest for Hawaiian and lowest for Spirit. On-time departure performance is highest for Frontier and lowest for Hawaiian. DOT flight complaints (per 1,000 passengers) is highest for Spirit and lowest for Alaska.

Figure 3 Service quality attributes (2015)

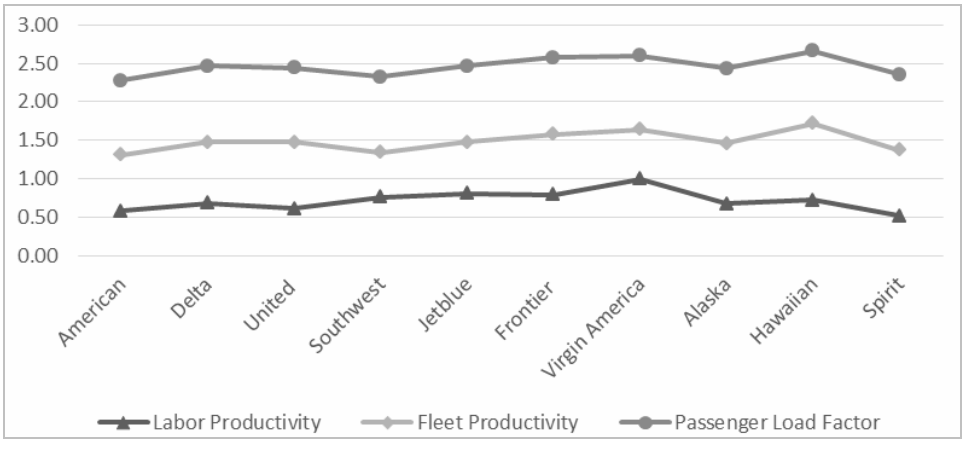


Source: Airline Data Project (2017)

DOT mishandled baggage handling (per 1,000 passengers) is highest for American and lowest for Virgin America, and finally, flight frequency is highest for Hawaiian and lowest for Frontier.

Figure 4 shows the productivity attributes. Productivity is calculated as the available seat mile produced per employee. Labour productivity is highest for Virgin America and lowest for Spirit. Fleet productivity is highest for Hawaiian and lowest for Southwest, and finally passenger load factor is highest for Frontier and lowest for Hawaiian.

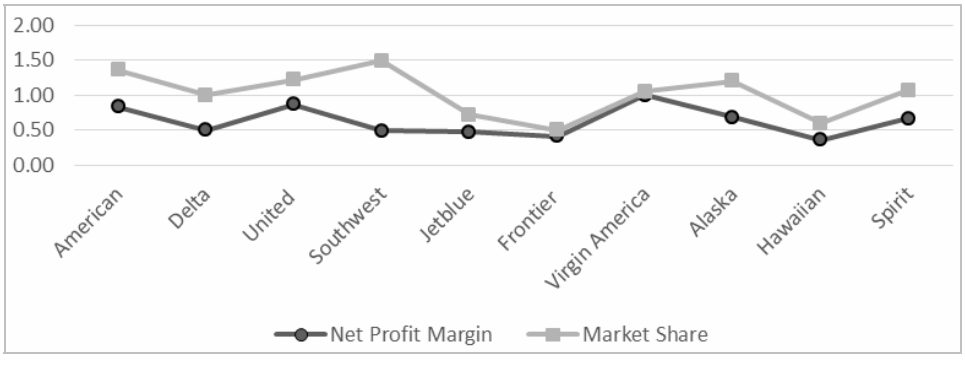
Figure 4 Productivity attributes (2015)



Source: Airline Data Project (2017)

Figure 5 shows the attributes used to examine management. In this case, the airlines net profit margin and market share are shown. Net profit margin is highest for Virgin and lowest for Hawaiian. Whereas, market share is highest for Southwest and lowest for Virgin America.

Figure 5 Management attributes (2015)



Source: Airline Data Project (2017)

4 MADM methodology

Five different dimensions are considered in this study. For each dimension, there are associated performance measures. The performance measures were identified based on the review of the published literature and by consulting the subject matter experts. The subject matter experts were selected from faculty members from Embry-Riddle Aeronautical University and senior level executives from major airline companies. The respective definitions of each of the performance measures are shown in Table 1. The values of performance measures for the year 2015 are shown in Table 2.

Table 1 Dimensions and performance measures

Dimension	*Performance measures*	*Definition*
Cost	Unit operating cost (P1)	(Direct operating cost – Fuel cost) / available seat-miles, cents per available seat mile
Productivity	Labour productivity (P2)	Total passenger revenue / total number of employees
	Fleet productivity (P3)	Total revenue passenger miles / total operating fleet
	Passenger load factor (P4)	Total passengers carried / total seats available (%)
Service quality	On-time arrival performance (P5)	Flights arrived on time / total number of flights landed
	On-time departure performance (P6)	Flights departed on time / total number of flights departed
	DOT flight complaints (per 1,000 passengers) (P7)	Total number of complaints / total number of passengers flown
	DOT mishandled baggage handling (per 1,000 passengers) (P8)	Total number of mishandled baggage / total number of baggage handled
	Flight frequency (P9)	Total number of flights / total number of routes
Price	Total system passenger yield (P10)	Revenue / revenue passenger miles
Management	Net profit margin (P11)	Total net profit / total operating revenue
	Market share (P12)	Total passengers carried / total passengers in the market

AHP and TOPSIS are decision making approaches used under conditions of certainty with a small number of alternatives. With few alternatives, each alternative can be evaluated without the need of a sophisticated optimisation technique. To rank the alternatives in AHP, the following steps were used:

- Develop a hierarchy of factors which represent the decision situation, as shown in Figure 6.
- Perform pairwise comparisons at each level and section of the hierarchy.
- Form a square influence matrix for each set of pairwise comparisons.
- Find the value for a quantity, λmax, the maximum value of λ that solves the system of equations $|A - \lambda I| = 0$.

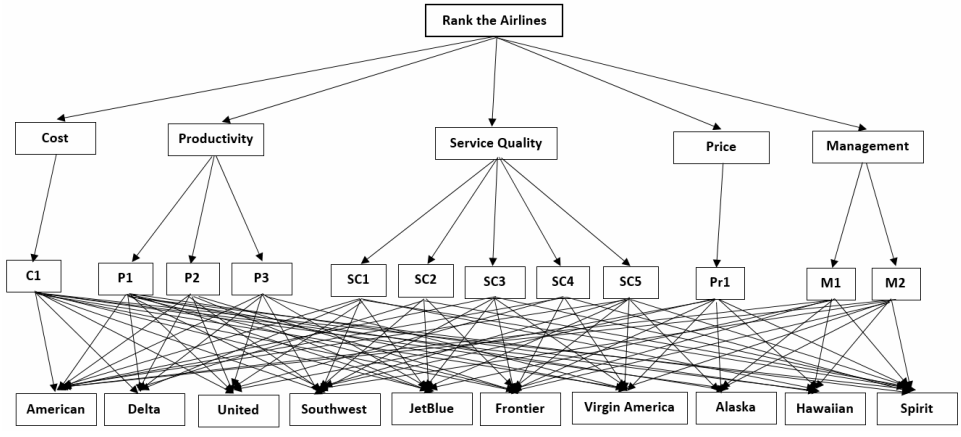
- Determine the local weights for each factor in a section of the hierarchy.
- Determine the global weight for each alternative on each lowest-level criterion in the hierarchy.

Table 2 Data on performance measures (2015)

Perf. measure	*American*	*Delta*	*United*	*Southwest*	*JetBlue*	*Frontier*	*Virgin America*	*Alaska*	*Hawaiian*	*Spirit*
P1	11.97	12.68	12.15	11.1	10.56	8.57	10.61	9.68	10.48	7.64
P2	293.5	344.1	310.6	386.1	408.3	401	504.8	340.3	364.3	262.2
P3	219.43	239.36	259.36	174.76	200.73	235.00	193.28	235.23	300.25	257.09
P4	83	85	83	84	85	86	82	84	81	84
P5	0.80	0.86	0.78	0.80	0.76	0.73	0.80	0.86	0.88	0.69
P6	0.81	0.85	0.75	0.78	0.77	0.77	0.81	0.89	0.92	0.71
P7	3.36	0.74	2.85	0.52	0.86	7.86	1.66	0.5	1.06	11.73
P8	3.98	2.08	3.21	3.31	1.81	3.08	0.84	3.36	2.65	2.57
P9	1,023	903	729	946	783	273	872	687	1,362	371
P10	14.55	14.98	14.25	15.56	14.11	8.92	12.85	13.02	13.95	7.04
P11	0.19	0.11	0.19	0.11	0.11	0.09	0.22	0.15	0.08	0.15
P12	0.39	0.36	0.25	0.72	0.18	0.07	0.03	0.38	0.17	0.29

Source: Airline Data Project (2017)

Figure 6 Hierarchy of factors



Please note that for pairwise comparison, actual data on the performance measures was used instead of asking for input from decision makers. Following the steps in the AHP approach, the global weight of each alternative is calculated as shown in Table 3. Airlines are ranked in the decreasing order of priority.

Table 3 Airline ranking with AHP method

Airline	*Priority*	*Rank*
Southwest	12.8%	1
JetBlue	12.7%	2
Hawaiian	10.5%	3
Frontier	10.4%	4
American	9.9%	5
Alaska	9.7%	6
Virgin America	9.6%	7
Delta	9.0%	8
United	8.2%	9
Spirit	7.2%	10

One weakness of AHP is that it is an aggregation method of the additive type and due to the nature of the method some important information can be lost. With aggregation, there is a possibility of compensation between good scores on some criteria and bad scores on other criteria.

4.1 TOPSIS

In this method compared to AHP, there is relatively less input needed from the decision makers regarding their preferences. The process involves selecting a solution that considers weighted distances from the positive and negative ideals. The method aims to obtain an outcome as close as possible to the positive ideal and as far as possible from the negative ideal, while considering the importance of each attribute (Evans, 2016). To rank the alternatives in TOPSIS, the following steps were applied:

- Outcomes are normalised

$$r_{ij} = x_{ij} \Big/ \sqrt{\sum_{i=1}^{n} x_{ij}^2}$$

The performance measures in Table 2 are used as the input, x_{ij} in this step.

- Weighted value of each alternative i as scored on attribute j are computed

$$v_{ij} = w_j r_{ij}$$

$$\sum_{j=1}^{p} w_j = 1$$

$$0 < w_j, 1 \text{ for } j = 1, \ldots, p$$

- Weighted positive ideal and negative ideals are computed

$$PI = \left(v1^*, v2^*, \ldots, vp^*\right)$$

$$NI = (v1', v2', \ldots, vp')$$

where

vj^* is the maximum value over $\{vij$ for $i = 1, \ldots, n\}$ for $j \in J^*$ and minimum value over $\{vij$ for $i = 1, \ldots, n\}$ for $j \in J'$

vj' is the minimum value over $\{vij$ for $i = 1, \ldots, n\}$ for $j \in J^*$ and maximum value over $\{vij$ for $i = 1, \ldots, n\}$ for $j \in J'$.

- Separation measures for each alternative are computed

$$Si' = \sqrt{\sum_{j=1}^{p} (vj^* - vij)^2}$$

$$Si' = \sqrt{\sum_{j=1}^{p} (vj' - vij)^2}$$

- Relative closeness (Ci) to the ideal for each alternative is computed

$$CI = Si' / (Si^* + Si')$$

Table 4 Airline ranking with TOPSIS method

Airline	*Ci*	*Rank*
Hawaiian	0.870	1
Virgin America	0.707	2
Southwest	0.701	3
Delta	0.680	4
JetBlue	0.638	5
American	0.598	6
United	0.584	7
Alaska	0.571	8
Frontier	0.429	9
Spirit	0.404	10

Table 5 Ranking comparison of AHP and TOPSIS

Rank	*TOPSIS*	*AHP*
1	Hawaiian	Southwest
2	Virgin America	JetBlue
3	Southwest	Hawaiian
4	Delta	Frontier
5	JetBlue	American
6	American	Alaska
7	United	Virgin America
8	Alaska	Delta
9	Frontier	United
10	Spirit	Spirit

Following the steps in the TOPSIS approach, relative closeness to the ideal for each alternative is calculated as shown in Table 4. Airlines are ranked in the decreasing order of relative closeness. Table 5 shows the ranking comparison between the two methods.

5 Discussion

Table 5 shows that the ranking is not consistent between the two methods. In general, AHP is preferred over TOPSIS due to its flexibility and ability to check inconsistencies but requires extensive pair wise comparisons, whereas in TOPSIS both negative and positive ideal solutions are considered. Hence, inconsistencies in the ranking can be expected. The inconsistency can be attributed to the differences in computations used to rank the alternatives.

The results show that the TOPSIS ranking is more consistent with other airline ranking studies, such as the Airline Quality Rating published by Embry Riddle Aeronautical University (Bowen and Headley, 2015). Hence, for this study, it can be concluded that TOPSIS is the preferred method over AHP. It can also be noted that no one airline outperforms in all of the performance measures. For example, Hawaiian and Southwest are ranked among the top three in both of the methods but neither of their performance measures is better than the other.

Airline ranking systems differ based on the method and data used. Competitiveness dimensions often conflict so more than a single dimension must be used to determine the overall competitiveness of an airline. In this study, we used five competitiveness dimensions to compile the ranking. While the results of this study may differ slightly from other rankings systems, this method can be used by airlines to identify competitive advantage attributes and provides a system for benchmarking against competitors. To be able to continually improve an airline must understand their strengths and weaknesses as compared to competitors, and be able to measure and quantify these attributes. This research provides a framework for airline managers to identify areas to improve their competitive strategies.

6 Conclusions

The airline industry operates in a highly competitive market; therefore, it is of strategic importance to understand their relative levels of competitiveness. To assess competitiveness of the US airline industry this study compared and ranked 10 US airlines based on a number of dimensions and their related performance measures for the year 2015. The dimensions considered included, cost, price, service quality, management and productivity. An alternate approach can be to assess competition with each performance measure separately but many of the performance measures are interrelated, so a multi-criteria approach is more suitable.

The analysis presented in this study is valuable for airlines as it helps them to evaluate their competitiveness among their peers. The results of this study can be used as a benchmark for management to monitor their performance in the future. Since the data used in this study is consistent and not subjective to guesses from decision makers, it provides airlines with an objective evaluation to monitor and improve their competitive

position within the industry over time. Future research should examine a larger sample of airlines to verify the results.

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