SERVICE DELIVERY MODELS AND PROFITABILITY: AN INDUSTRY STUDY INSTRUCTIONS FOR PREPARING PROCEEDINGS

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ABSTRACT

This paper presents a model for the estimation of structural design choices to explain profitability for an industry. The model is based on the architecture of service delivery systems is empirically tested with 9.3 million flight records from the domestic operations of the US airline industry from 2004-2007.

INTRODUCTION

The service delivery system, along with the service concept, and the target market constitutes the service strategy triad (Roth & Menor, 2003). Their service delivery system includes structural, infrastructural, and integration strategic design choices. Structural choices are those decisions that define physical aspects of the service delivery system including facilities and layout, delivery networks, technology and equipment, aggregate capacity planning, and the services product-process interfaces (Roth and Menor, 2003). Goldstein et al. (2002) refer to the design of service delivery systems as an area of operations management receiving growing emphasis in the literature. They characterize the service delivery system as a collection of strategic and operational choices ranging from facility location, system design, and workforce training. In a search of the primary journals for service operations management, we find little empirical-field research on service system design and the effect of structural service design choices on business performance. The few exceptions are denoted in the following paragraph.

Giloni et al. (2003) investigate service delivery choices in the property and casualty insurance industry during a time when changing external forces are compelling firms to rethink their service system design, and in particular their distribution channel strategies. Apte and Mason (2006) report service improvement from a hub-and-spoke service delivery configuration in the operations of the San Francisco Public Library. Another public sector study investigates the performance of the South Carolina Department of Motor Vehicles (Karwan and Markland, 2006). The authors find that integrating service design principles and information technology improves delivery performance and productivity in public sector operations.

The objective of this study is to contribute to the body of service operations knowledge with an industry study investigating structural service delivery decisions and service operations profitability. This study is a single industry case study of the impact of structural service design choices on operational profitability in the domestic airline industry. Our research framework is that proposed by Roth and Mentor (2003) for service design. The empirical results are based on longitudinal and cross sectional data covering 16 quarters of operations for nine domestic airlines from 2004 through 2006.

SERVICE DELIVERY DESIGN STRATEGIES OF THE US AIRLINE INDUSTRY

To our knowledge, Tsikriktsis (2007) is the only study that links service operations and profitability in the airline industry. This is a longitudinal study of operational performance for two segments of the US airline industry, focused airlines with regional or national service and full service airlines with international routes. Two main conclusions of this study are that operational performance and profitability is contingent on the operating model, and that capacity utilization is a stronger driver of profitability for full-service airlines than for focused airlines. Our study differs from Tsikriktsis' (2007) in several significant ways. First, we make no attempt to segment the industry, instead choosing to evaluate metrics of service network design for each airline. Tsikritis' (2007) full service airlines included international flights, which have higher margins and economies of scale from long flight lengths. We exclude international flights, as they involve different service delivery processes, including longer setup times and longer flights. We also find that many of the airlines we would conceptualize as focused airlines today violate the characteristics of fast turnaround time and the avoidance of congested hub and spoke airports. For example, America West operates from a hub in Phoenix and has turnaround times that are on average 30 minutes longer than Southwest. Air Tran and Jet Blue (neither are subjects of the Tsikriktsis (2007) study) operate from hubs at Atlanta and JFK, New York, both congested airports.

The design of the structural components of the service delivery system in the airline industry includes the choice of facility locations (airports) and the selection of a network of origins and destinations referred to as a flight schedule, a major determinant of an airline's cost structure (Barnhart, 2004). The degree of network centrality is a key metric of an airline's service delivery system. An appreciation of network centrality is gained by examining the two extremes. The lowest possible centrality value for an airline's service delivery network is achieved when all passengers are routed directly from origin to destination. This strategy would create a frequency of activity at each facility location in the service delivery network that would approximate the local demand at the location. It has the advantage of direct flights with fast passenger throughput times. This service delivery strategy has the highest customer value and minimizes waste in the customer's consumption process (Womack and Jones, 2005). The highest degree of network centrality is a service delivery strategy with a single hub-and-spoke design. Rosenberger et al. (2002) defines the hub-and-spoke strategy for an airline as a flight network with a large percentage of the flight segments into or out of a small subset of stations called hubs. In this service delivery network, all passengers originating at non-hub locations are routed first to the hub where passenger loads are aggregated, and re-routed to outbound destinations. The only passengers receiving direct service in the hub-and-spoke design strategy are those whose travel originated at the hub location or those with the hub as a destination. The hub network strategy creates the operational wastes of longer passenger throughput times (diminishing the lean consumption value) and the physical waste of multiple flight segments. The benefits of service networks with hubs include aggregation of demand and a flight schedule with higher frequency of service to destination cites (Gillen and Adib Kanafani, 2005, Adler, 2001, Bruekner and Zhang, 2001, Nero, 1999, Dobson and Lederer, 1993). It is also recognized that hub airports have become increasingly congested with waves of arriving flights followed by waves of outbound flights scheduled at convenient travel times for passengers (Button, 2002, Ritveld and

Brons, 2001). This creates airport demand variability, which lowers airline productivity by increasing the degree of variation.

DATA DESCRIPTION AND EXPERIMENTAL METHODOLOGY

The conceptual model, depicted in the figure below, defines the strategic service design decisions as determinants of service profitability.

Figure 1
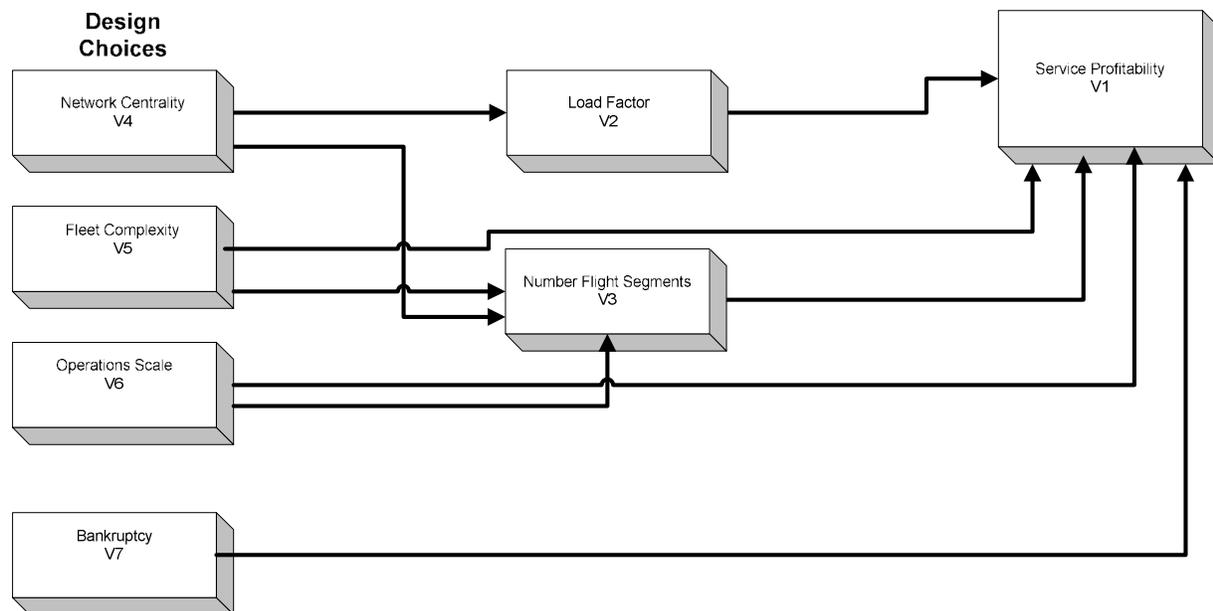
Service delivery system design

The specific structural service design decisions we investigate in this research are the structure of the service delivery network, the complexity of the aircraft fleet deployed, and the scale of the service delivery operations. The choice of the service delivery network requires the identifications of service locations (airports in this industry) and the definition of network paths from origins to destination. Service delivery networks can differ significantly in the "degree of directness." A highly centralized network would route all flights though hub airports (low degree of directness) allowing for the consolidation and redirection of passengers. Apte and Mason (2006) encountered a highly centralized service network in the San Francisco Library. By contrast, a decentralized network design would route flights directly from origin to destination (high "degree of directness"). Higher network centrality creates economic advantages by aggregating passenger demand at hub locations and thereby enabling higher schedule frequency. Passenger aggregation at hubs creates larger aircraft load factors (proportion of aircraft fleets with revenue paying passengers) which increases operational profitability. These advantages are estimated by paths V4-V2 and V2-V1 in the conceptual model. The disadvantages of centralized networks are the longer distances traveled from origin to destination and the longer travel time for passengers. Aircraft utilization is frequently reduced by the longer aircraft turnaround times associated with congested hub airports. To be effective, the benefits realized from centralized

networks must compensate for the higher costs of transporting passengers longer distances and the necessity of using multiple service encounters (measured by the number of flight segments). This is estimated by path V4-V3.

There is also a value and revenue effect on profitability generated by the design of the service delivery network. The service delivery design decision directly influences value from the customers' perspective in the following way. First, the degree of network centrality is a proxy measurement for the directness of the passengers' paths from origin to destination. Service delivery systems with low centrality will, on average, provide shorter, more direct paths, while networks with high centrality will have longer and slower paths. Service networks with higher centrality create more indirect routing for passengers, thereby increasing the wastes of waiting and longer flight times Womack and Jones, 2005). While airline passengers are generally segmented into time sensitive business passengers and cost sensitive leisure travelers, we argue that both segments value shorter and more direct routing. The passenger's value for shorter flights is measured in the conceptual model by the average number of flight segments required to travel from origin to destination. The average number of flight segments variable is a proxy to measure both the increased costs incurred in less direct flights and the reduced value of longer throughput times to the passenger. The joint effect of these forces are estimated by path V3-V1.

Hypothesis 1a. Differences in the structural choice of the service delivery network centrality (V4) will be positively correlated with load factors (V2); higher load factors will increase operational profitability (V1).

Hypothesis 1b. Differences in structural choice of the service delivery network centrality (V4) will be positively correlated with the number of flight segments (V3); increasing the number of flight segments will decrease operational profitability (V1) by the joint effect of increasing travel distance and costs, and reducing customer value.

The selection of the aircraft fleet is a second key structural service design decision. There are a variety of commercial aircraft with differing capacities and economic performance that can be deployed in the service delivery network. The structural choices range from standardizing on a single "best compromise" aircraft from one supplier (low fleet complexity) to deploying as many as 12 different aircraft from as many as 3 different suppliers (high fleet complexity). Offsetting this advantage are the costs of fleet complexity including the need to train pilots, crew and mechanics on multiple platforms, scheduling constraints, and the management of more complex maintenance and repair programs. Path V5-V1 estimates the direct costs of investing in fleet complexity. These costs include the need to train pilots, crew, and mechanics on multiple aircraft platforms, scheduling constraints that require aircraft certification, and the management of more complex maintenance and repair programs. The advantage of a more complex fleet for the service organization is the ability to more closely match aircraft operating characteristics to the demand patterns of specific flight segments. This in turn allows more direct flights, reducing the number of flight segments. This is estimated by path V5-V3 in the conceptual model.

Hypothesis 2a. Differences in the fleet complexity structural service design (V5) will be negatively correlated with operational profitability (V1).

Hypothesis 2b. Differences in the fleet complexity structural service design (V5) will be negatively correlated with the number of flight segments (V1).

It is reasonable to expect that the airline industry will exhibit economies of scale. Structural choice of scale: number of markets served (new routes, new gates) frequency of service, mergers with domestic competitors. This results from the ability of larger scale operations to benefit from deploying larger scale aircraft. Increasing the number of seats on an aircraft lowers the cost per seat mile of flight operations. Larger operational scale also allows the amortization of fixed costs (management, scheduling, operations control, advertising, maintenance overhead etc.) over a larger economic base. The final strategic service design decision is the choice of operational scale. The effect of the structural decision regarding operations scale on service profitability is estimated by path V6-V1.

Hypothesis 3. Differences in operational scale structural service design (V6) will be positively correlated with operational profitability V1. Increased scale will increase operational profitability.

The role of bankruptcy interventions

Bankruptcy is modeled as an exogenous variable in this research. The airline industry is a brutally competitive industry with price and convenience being the major considerations in consumer purchasing decisions. With low switching costs and low marginal costs per seat, real revenue per seat mile has been declining for decades. As a result, bankruptcy reorganizations have been common in this industry. Bankruptcy reorganization improves the competitive position of the airline and will have a positive impact thereafter on service profitability. Bankruptcy events are modeled by path V7-V1.

Hypothesis 4. Bankruptcy events (V7) will increase service profitability (V1).

Data Sample

This study uses operational data from all domestic flights for nine major US carriers in the period 2004-2007, a total of 9.3 million flights. The timeframe 2004-2007 was chosen for two basic reasons. First it is a period with a reasonably uniform and stable economic environment. This reduces the potential of confounding the experimental results with external economic disturbances. The 2008 banking crises significantly altered the economy resulting in a recession and severe economic pressures on the domestic airline industry. Subsequent to the financial crises, there were several mergers in the airline industry which reduced the number of potential participants and the amount of data available for this analysis. These include United Airlines merging with Continental and Delta with Northwest Airlines.

The operational data is available from The Office of Airline Information of the Bureau of Transportation Statistics. This data mart contains a table of scheduled and actual departure and arrival times reported by certified US air carriers that account for at least one percent of domestic scheduled passenger revenues (www.transtats.bts.gov) and provides such additional information as origin and destination airports, flight numbers, scheduled and actual departure and arrival times, cancelled or diverted flights, air time, and non-stop distance. The nine major US carriers

investigated in this study are American, Jet Blue, Continental, Delta, Air Tran, Northwest, United, US Air, and Southwest. Commuter airlines, international flight segments of domestic carriers, and charter operations were excluded from this analysis. The operational data was paired with quarterly financial performance data from the same source as the operational data. The financial data allowed us to isolate measures of profitability, including operating income for domestic operations and assets employed in domestic operations.

Venkatraman and Ramanujam (1986) validated the use of financial and operational secondary source data for single industry studies. This technique has been used previously by Tsikritsis & Hineke (2004) and Tsikritsis (2007). We therefore feel the data is appropriate for this research. We also note that the use of single industry airline data has the advantage of uniformity, since there is little difference in the competitive environment of the domestic airline industry. None of the major airlines have been able to differentiate their offerings with value added services; they all essentially compete on price. In a pure price competition environment, differences in service profitability are largely caused by differences in service network design and execution of operational processes.

Model Estimation

A major US airline's domestic operation is the unit of analysis for this research. The data for each of the nine airlines consists of explanatory variables measured over 16 successive quarters of operations.

A structural equation model of the following specification was fit to the airline industry data.

$$V1 = pv1v2\ V2\ +\ pv1v3\ V3\ +\ pv1v3\ V3\ +\ pv1v5\ V5\ +\ pv1v6\ V6\ + pv1v7\ V7 + E1 \qquad (1)$$

$$V2 = pv2v4\ V4\ + E2 \qquad (2)$$

$$V3 = pv3v4\ V4 + pv3v5\ V5 + pv3v6\ V6 +\ E3 \qquad (3)$$

where

V1 is service profitability, V2 load factor, V3 number of flight segments, V4 service network centrality, V5 fleet complexity, V6 operations scale, and V7 the presence of a bankruptcy event during the time of the study.

DISCUSSION OF EXPERIMENTAL RESULTS

The SAS CALIS procedure with maximum likelihood estimation was used to estimate the structural equation model depicted in the figure below. The following subsections describe aspects of the model fit and implications of the model estimates.

Figure 2
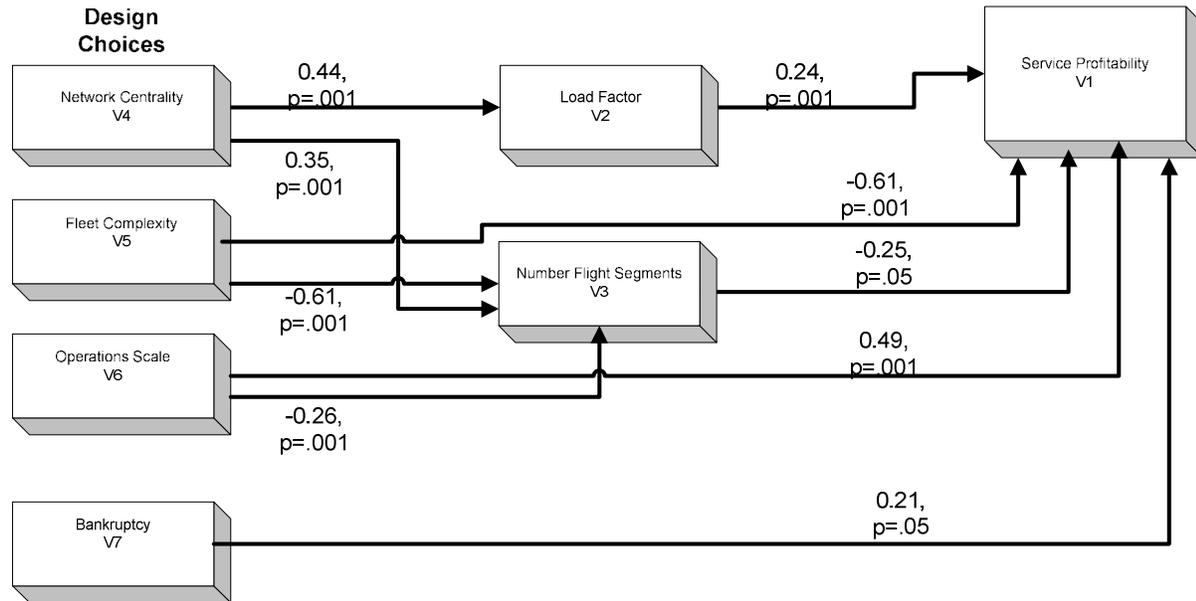
Discussion of Model Fit

Evidence of a reasonable fit between the model and data is assessed by several statistical outputs of PROC CALIS. These include the normalized residual matrix, a chi-square test, several fit indices, and the statistical significance of patch coefficients.

The model residual matrix is calculated from the differences between the elements of the covariance matrix of the data sample and the predicted covariance matrix from the model path coefficients. If the model fit is acceptable, the predicted covariance matrix should be nearly identical to the original covariance matrix. A commonly accepted criterion for structural equation model residuals is that the absolute values of the normalized residual matrix should not exceed 2.0. The residuals from this model satisfy that criterion, the magnitude of the largest residual is 1.68.

The chi-square statistic tests the null hypothesis that the conceptual model fits the data versus the alternative hypothesis that the data are from a multivariate normal distribution with unconstrained covariance matrix. A successful fit results in a small chi-square value and a relatively large p value. The specified model in this research rejects the null hypothesis of good model fit (chi-square = 22.3, p=.001). There are several reasons the chi-square result should be treated with caution. First, the chi-square test is sensitive to data distributions that are not multivariate normal. Several violations of normal distributions were reported in subsection 3.3. In those cases, variable transformations were applied to improve the distributions but significant deviations from normality remain. A second limitation is that the sample size of 144 only slightly exceeds the minimum standard of 100 and the ratio of observations to model parameters of 7 is marginally greater than the minimum recommendation of 5.

Bentler and Bonett [1980] propose a normed fit index (NFI) as an alternative to the chi-square test. The index gauges the percentage of observed-measure co-variation explained by the structural model. Values over 0.9 are evidence of acceptable model fit. The NFI value for the conceptual model is 0.9578. A variation of the NFI index is the non-normed fit index (NNFI) which is intended to be more robust over a wider range of sample sizes (Bentler and Bonett, 1980). The NNFI index for the conceptual model is 0.888 with 0.9 suggested as evidence of good model fit. A later test by (Bentler and Bonett, 1980), the comparative fit index (CFI) is viewed as more precise than NNFI again with values over 0.9 suggesting good fit. The CFI index for the conceptual model is 0.9679.

It is also necessary to review the statistical significance test for estimates of path coefficients in the conceptual model. For the t test to be significance at the 0.05 level the statistic must exceed 1.96. Path estimates and significance levels for the conceptual model are given in Figure 2. Inspection reveals that all path estimates are highly significant varying from 0.001 to 0.05.

The preponderance of evidence suggests the proposed model provides an acceptable fit to the empirical data. The next sub-section discusses results and implications of this model.

Implications of Model Estimates

Figure 2 depicts the standardized path coefficients estimated for the conceptual model and the p value reflecting the statistical significance of each estimate. The R^2 results of this model provide strong evidence that service delivery design choices have considerable effect on service operations profitability. For this model, 35.4% of the variance of service profitability is explained by the antecedent variables in the conceptual model including the structural design choices of service delivery network structure, aircraft fleet complexity, and operations scale. The choice of network centrality explains 20% of the variance in aircraft load factor. Other influences of load factor include revenue management processes and overbooking policies that are beyond the scope of this study. It is also noteworthy that 81% of the variance in the number of flight segments is explained by the three antecedent variables network centrality, fleet complexity, and operations scale.

The network centrality metric measures the degree of directness of the airlines' service delivery network. High degrees of centrality are networks that consolidate passengers at hub locations before directing them to their final destinations. Low centrality reflects service networks that emphasize direct routes from origin to destination. The model's results suggest that service networks with higher degrees of centrality increase aircraft load factors with a standardized path coefficient of 0.44 (p=0.001) and higher load factors increase service profitability with a coefficient of 0.24 (p=0.001). These path results confirm hypothesis 1a. The costs of network centralization are revealed in the tendency for more centralized networks to increase the number of flight segments passengers travel from origin to destination (0.35, p=0.001) The more centralized service delivery networks result in more indirect paths for consumers. Indirect paths increases costs and decreases operations profitability with a path coefficient of -0.25 (p=0.05) for the path between the number of flight segments and service profitability (confirming hypothesis 1b). We would also argue the more indirect paths reduce the value of the service to the consumer thereby reducing the revenue per passenger mile and profitability (Womack and Jones 2005). We

could not isolate passenger value in the model since the data does not track individual customer's experiences. It is however, reasonable to expect passenger value is reflected in the path estimate of flight segments on service profitability. The net effect of network centrality on service profitability (0.02) is the small difference between the benefits from higher load factors (0.11) and the costs the longer indirect flights (-.09).

The service structural design decision defining aircraft fleet complexity has two paths that influence profitability. First, the cost of maintaining more diverse aircraft fleets increases operations costs through maintenance, repair items and pilot training/certification. This effect significantly reduces service profitability with a path coefficient of -0.61 (p=0.001) and confirms hypothesis 2a. The benefits of higher fleet complexity are seen in the reduction of the number of flight segments (-0.61, p=0.001), confirming hypothesis 2b. Higher fleet complexity provides more options to match aircraft capacity and route demand on specific flight segments. The improved matching of supply and demand reduces the need to consolidate passenger at hubs and enables more direct flights from origin to destination. The net effect of the fleet complexity metric on service profitability is a reduction of service profitability with a standardized coefficient of-0.46.

The model results provide strong support for the prominence of economies of scale in this industry. Structural design decisions that focus on larger scale operations directly increase service profitability with a scale coefficient of 0.49 (p=0.001), confirming hypothesis 3a. Mention direct economies of scale from literature i.e. who else found this. A second benefit of increased scale is the ability to decrease aircraft fleet complexity (-0.26, p=0.001) confirming hypothesis 3b. With increased scale, organizations have the ability to fill aircraft without relying on aggregating passengers at hubs and without the need for a complex array of aircraft capacities. A simple example may help understand the dynamics of this path. Assume there is a hypothetical route between origin A and destination B served by 2 competing airlines. If each airline is serving 60 passengers on this route, it is likely designed to transport the passengers to one of their hub locations where each airline could consolidate the passengers flying A to B with 60 other passengers to achieve an approximate 75% load factor to the final destination. If the A to B scale could be increased, possibly by merger of the two competing airlines, the 120 passengers would represent a 75% load factor on a direct flight between A and B. The net impact of operations scale on service profitability including the direct scale effects and the ability to schedule more direct flights is 0.54, the largest of the three strategic design variables.

The occurrence of a bankruptcy event is included in the model as a control variable because several organizations' declared bankruptcy during the 2004 to 2007 timeframe of this investigation. Bankruptcy gives the organization the ability to restructure contractual relationships and reduce operating costs. The model results estimate that bankruptcy increases service profitability in the industry with a path coefficient of 0.21 (p=0.05) confirming hypothesis 4.

REFERENCES

Adler, N., 2001. Competition in a deregulated air transportation market. European Journal of Operational Research 129 (2), 337-345.

Apte, A., Apte, U.M.,Venugopal, N., 2007. Focusing on customer time in field service: A normative approach. *Production and Operations Management* 16 (2), 189-202.

Apte, U.M., Mason, FM., 2006. Analysis and improvement of delivery operations at the San Francisco Public Library. *Journal of Operations Management* 24 (4), 325-346.

Barnhart, C., Cohn, A., 2004.Airline schedule planning: Accomplishments and opportunities. *Manufacturing & Service Operations Management* 6 (1), 3-22.

Bentler, PM., Bonett, DG., 1980. Significance tests and goodness-of-fit in the analysis of covariance structures. *Psychological Bulletin* 88, 588-606.

Brueckner, JK., Zhang Y., 2001. A model of scheduling in airline networks: How a hub-and-spoke system affects flight frequency, fares and welfare. *Journal of Transport Economics and Policy* 35, 195-222.

Button, K., 2002. Debunking some common myths about airport hubs. *Journal of Air Transport Management* 8 (3), 177-188.

Dobson, G., Lederer, P.J., 1993. Airline scheduling and routing in a hub-and-spoke system. *Transportation Science* 27 (3), 281-297.

Gillen, D., Adib Kanafani, KK., 2005. The Evolution of Networks with Changes in Industry Structure and Strategy: Connectivity, Hub-and-Spoke and Alliances. *Research in Transportation Economics*: JAI, 49-73.

Giloni, A., Seshadri, S., Kamesam, P., 2003. Service system design for the property and casualty insurance industry. *Production and Operations Management* 12 (1), 62-78.

Goldstein, S.M., Johnston, R., Duffy, J., Rao, J., 2002. The service concept: The missing link in service design research? *Journal of Operations Management* 20 (2), 121-134.

Karwan, K.R., Markland, R.E., 2006. Integrating service design principles and information technology to improve delivery and productivity in public sector operations: The case of the South Carolina DMV. *Journal of Operations Management* 24 (4), 347-362.

Nero, G., 1999. A note on the competitive advantage of large hub-and-spoke networks. *Transportation Research Part E: Logistics and Transportation Review* 35 (4), 225-239.

Rietveld, P., Brons, M., 2001. Quality of hub-and-spoke networks; the effects of timetable co-ordination on waiting time and rescheduling time. *Journal of Air Transport Management* 7 (4), 241-249.

Rosenberger, J.M., Schaefer, A.J., Goldsman, D., Johnson, E.L., Kleywegt, A.J., Nemhauser, G.L., 2002. A stochastic model of airline operations. *Transportation Science* 36 (4), 357-377.

Roth, A.V., Menor, L.J., 2003. Insights into service operations management: A research agenda. *Production and Operations Management* 12 (2), 145-164.

Tsikriktsis, N., Heineke, J., 2004. The impact of process variation on customer dissatisfaction: Evidence from the U.S. domestic airline industry. *Decision Sciences* 35 (1), 129-142.

Tsikriktsis, N., 2007. The effect of operational performance and focus on profitability: A longitudinal study of the U.S. airline industry. *Manufacturing & Service Operations Management* 9 (4), 506-517.

Womack, J.P., Jones, D.T., 2005. Lean consumption. *Harvard Business Review* 83 (3), 58-**68.**