SERVICE DELIVERY STRUCTURAL DESIGN: AN INDUSTRY STUDY

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ABSTRACT

This paper estimates the empirical significance of key service network design decisions in the domestic airline industry. The model tests the significance design decisions including network centrality, fleet complexity, and operations scale for airline profitability. The empirical significance of these design decisions is based on 9.3 million flight records from 2004 to 2007.

Keywords: structural design choices, network centrality, cost of complexity, economies of scale

INTRODUCTION

The service delivery system, along with the service concept, and the target market constitutes the service strategy triad defined by 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 2007.

**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
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**

![Conceptual Model Diagram]

**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 is 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 benefit from economies of scale. Scale of operations is a structural choice determined by the number of markets served, the frequency of service, and opportunities for mergers with domestic competitors. Larger scale operations benefit from being able to deploy larger scale aircraft which decreases the cost per seat mile of flight operations. A 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).

Control Variables and Adjustments

There are several potentially confounding cost elements that must be controlled to accurately assess the significance of structural design choices. These include the differences in fuel costs between airlines that result from fuel hedging, differences in legacy labor contracts, differences in expenditures for food and beverages served onboard, and differences in advertising and promotional activities.

Jet fuel is a major cost element for the airline industry ranging from 20 -30% of total operating costs. During the four year period of this study fuel costs increased significantly from slightly more than $1 per gallon to over $2 per gallon. More importantly, there is a significant disparity in fuel costs/gallon between airlines as evidenced by data for 2007 in Figure 2 depicting fuel costs per gallon by airline. During 2007, jet fuel cost varied from $1.87 for Southwest Airlines to $2.68 for Delta Airlines. This cost disparity is attributed to fuel hedging strategies with differing proportion of spot market purchases and futures contracts. To correct for the influence of fuel
hedging activities on service profitability, we calculate the average jet fuel cost for all nine airlines quarterly and restate airlines’ fuel costs based on the quarterly average cost per gallon.

**Figure 2**

![Chart showing jet fuel cost per gallon for different airlines]

There are notable differences in salary structures between airlines during this time period. Typically the newer “low cost” airlines have lower salaries for management, pilots, and maintenance while the older “legacy carriers” have significantly higher salary structures. For example, in 2004 the average quarterly pilot salary of AirTran Airlines is $32,000; the Northwest Airlines pilot salary is $60,800. To adjust for the influence of salary structures on service profitability, we determine and average quarterly salary for all airlines for management employees, pilots, and maintenance personnel. The respective employee costs are then restated based on these average airline salaries.

Differences between airlines’ food and beverage costs per passenger reflect two different strategic choices. First, airlines that choose to focus their service delivery network on longer flight segments would incur higher cost for food and beverage service. Secondly, an airline may attempt to differentiate their service offering by increasing their expenditure on food/beverage. To adjust for this cost category, a regression model of food/beverage cost per airline per quarter is regressed on the average flight length by airline by quarter. The resulting regression has an R2
of 0.87 with a slope of 0.0063 dollars per passenger per mile flown. Airline food/beverage costs 
where then restated as a function of average flight length.

Advertising costs were included as a component of operating costs in the financial database. 
These costs were reversed and operating profitability restated to exclude advertising and 
promotion costs.

**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.

\[ V_1 = p_1v_2 V_2 + p_1v_3 V_3 + p_1v_5 V_5 + p_1v_6 V_6 + p_1v_7 V_7 + E_1 \]  
\[ V_2 = p_2v_4 V_4 + E_2 \]  
\[ V_3 = p_3v_4 V_4 + p_3v_5 V_5 + p_3v_6 V_6 + E_3 \]

where

- \( V_1 \) is service profitability, \( V_2 \) load factor, \( V_3 \) number of flight segments, \( V_4 \) service network centrality, \( V_5 \) fleet complexity, \( V_6 \) operations scale, and \( V_7 \) 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 3](image-url)
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 path 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. Jorgeskog & Sorbom, (1989) conclude the chi-square test is frequently not valid in field applications and should be perceived as a general goodness of fit index, not a strict statistical test.

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 3. 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 3 depicts the standardized path coefficients estimated for the conceptual model and the p value reflecting the statistical significance of each estimate. The R2 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 increase 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). 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 (-0.09).

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. 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


