ABSTRACT

This paper estimates the empirical link between four structural service design choices and service profitability in the context of the U.S. domestic airline industry. The empirical study is based on panel data of 12.35 million flight records of nine domestic carriers from 2004 to 2007. The flight records were accessed from a database maintained by the U.S. Department of Transportation. The empirical results provide evidence that the structural design choices of (1) the network routing structure; (2) the complexity of the aircraft fleet deployed; (3) the operations scale and (4) the extent of market rivalry explain approximately 80% of the differences among airlines in operational profitability.

KEYWORDS: structural design choices, service profitability, economies of scale.

INTRODUCTION

The service delivery system, along with the service concept, and the target market constitute 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 based 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.

The objective of this study is to contribute to the body of service operations knowledge with an empirical industry study linking structural service delivery choices to service operations profitability. The contributions of this study are to: (1) provide empirical evidence of the significance of structural design choices on operational profitability for a major industry; and (2) provide insight into the effectiveness of specific structural design choices in the US domestic airline industry. We believe this is the first study to relate service design choices directly to service profitability. The empirical analysis underscores the potential for using "big data" and business analytics to better understand links between strategic design choices and business performance.
In the following section we summarize research theories on the structural design of the service delivery network. We then describe our experimental methodology including operational data, metrics, and model estimation procedures. Finally, we discuss the empirical findings relating to our hypotheses, and conclude with key contributions and limitations.

**LITERATURE REVIEW**

In this section we review studies that examine the significance of structural choices in the service delivery system and current service design strategies and practices of the domestic airline industry.

The Service System Triad (Roth and Menor 2003) consists of three constructs: service delivery system design choices, the target market that defines who the right customers are, and the service concept specifying the product bundle offered. The service delivery system design choices consist of structural choices, infrastructural choices, and integration choices. Structural choices identify key aspects of the physical delivery system including facilities, locations, layouts, technology, equipment, and network configurations for delivering service. The infrastructural design relates to people, leadership, and performance management. They define the necessary characteristics of employees and the organization’s policies, practices, and processes. Integration choices define mechanisms for coordination, learning and adaptation, and the nature of service supply chains. This collection of strategic design choices defines the realized service delivery system (Roth and Menor 2003).

Giloni et al. (2003) investigate service design choices in the selection of distribution channels to customers for property and casualty insurance. Traditionally, insurance products were distributed by agents; advances in technology choices enabled new forms of distribution that integrate web-based distribution supported by company call centers. Firms in the property casualty industry now face several service design issues including (1) how to determine the distribution channels and intermediaries, (2) how much of each type of intermediary to deploy in each channel, and (3) the service levels to provide the customer in each channel. The authors develop a framework for the design of distribution systems for property and casualty insurance and use empirical data to test for consistency. The model does not relate design choices to firm profitability.

A case study of the South Carolina Department of Motor Vehicles investigated service design principles and efficiency for a public service organization (Karwan and Markland 2006). Based on an adaptation of the Goldstein et al. (2002) government services planning model, the authors determine that strategic alignment, effective IT deployment, and clear separation of front and back office tasks are vital for increasing public sector service efficiency. Outcomes from improvements made to the South Carolina Department of Motor Vehicles include, a substantial decrease of customer wait times, a significant increase in transactions conducted on the web, improved process flows, and fewer complaints.

The structural service delivery design of the San Francisco Public Library were identified as contributing to service performance deficiencies by Apte and Mason (2006). Library customers’ experiences acquiring books through interlibrary loans were diminished by the realization of long cycle times and delivery variability. The structural design of this service was a hub-and-spoke network configuration with the Main Library serving as the hub. The recommendations of Apte and Mason (2006) enabled the library to significantly lower both cycle times and costs, and
increase system capacity by deploying a new network design consisting of a cross docking network with pre-sorting of materials and workload balancing of delivery routes.

Silvestro and Silvestro (2003) describe the service delivery system design for National Health Service Direct, a call center for patients in the United Kingdom. With data from the first three years of operations, the authors evaluate the strategic alignment of its service concept, operational objectives, and the design of its service delivery system. They identify a major deficiency in the process, the lack of an explicit service specification to serve as a basis for the design of each call center. In its absence, each call center assumed responsibility for the design of its services, and the organization’s national service delivery system became strategically misaligned.

Li et al. (2002) investigate the relationship between strategic design choices and performance for community hospitals. Model inputs include the structural choices of location, bed size (capacity), specification of equipment and process technology, and the outpatient service network. Infrastructural inputs specify details of demand management, workforce management, and continuous improvement programs. The model demonstrates causal relationships between structural and infrastructural choices on quality, cost, and financial performance outcomes for 151 community hospitals.

Tsikriktsis (2007) empirically links service operational performance and profitability in the US airline industry. The author creates a model that explicitly links capacity utilization, quality (delivery reliability), and focus to profitability. 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 are 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 focus directly on the effects of service structural design choices on profitability while Tsikriktsis’ study links performance metrics to profitability. We will argue later that structural design choices will influence the operational performance variables including capacity utilization and delivery reliability. We make no attempt to segment the industry, instead choosing to evaluate metrics of service network design for each airline. Tsikriktsis’ (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 of which are subjects of the Tsikriktsis (2007) study, operate from hubs at Atlanta and JFK, New York, both congested airports.

The choice of the structural design 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 and Cohn 2004). The problem of constructing a flight schedule may be thought of as a connected graph with vertices representing the airports (markets) served and directed edges representing the structural choice to schedule a flight between vertices u and g.
The most popular airline network routing structure is the hub-and-spoke strategy. Rosenberger et al. (2002) defines this 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. The degree of hub use in a network is a key metric that characterizes an airline’s service delivery network. An appreciation of network hub use is gained by examining the two extremes. The lowest possible hub usage for an airline’s service delivery network is achieved when there are no hubs and all passengers are routed directly from origin to destination. This is a fully connected graph with all N vertices having N-1 edges. Direct flights have the advantages of the shortest distances traveled (miles flown equivalent to distance between origin and destination) with fast passenger throughput times and high delivery reliability (quality). This service delivery strategy has the highest customer value and minimizes waste in the customer’s consumption process (Womack and Jones 2005). The disadvantage of this fully connected network is that some edges may not have sufficient demand to generate economical service. The other extreme in hub use is the single or mono-hub (Bania et al. 1998). The graph representation of this is a single vertex (the hub) with N-1 connections to each of the non-hub vertices. 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 with miles flown exceeding distance between origin and destination. 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 and undermining delivery reliability.

DATA DESCRIPTION AND EXPERIMENTAL METHODOLOGY

The US Airline industry is selected as the subject of analysis for this case because a substantial amount of operational performance data is available. This section describes the conceptual model tested in this case study, followed by a definition of the data sample used, the metrics employed, and the process of model estimation.

The conceptual model depicted in Figure 1 defines the structural service design choices as determinants of service profitability. The specific structural service design choices we investigate in this research are: (1) the structure of the service delivery network (i.e. the flight routing network); (2) the complexity of the aircraft fleet deployed; and (3) the scale of the service delivery operations and (4) a weighted average of the market rivalry across all flight segments.

Service delivery system design

The structural 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” of the network paths. Aircraft route structures are typically designed around the hub-and-spoke concept where an airline’s flights originate or arrive at a central location to allow for the consolidation and
redirection of passengers. Bania et al. (1998) identified several types of structures, including mono-hubs, dual hubs and diffused systems. A mono-hub has the lowest degree of directness, with all flights passing through the central hub and no direct flights between participating airports (except when the hub is the destination). By contrast, a diffused network design in the context of our study would route flights more directly from origin to destination, resulting in a high “degree of directness” and fewer average flight segments. Airlines using this form of structure are often referred to as point-to-point carriers (Ball 2007). With point-to-point flights, there is no need to wait for the transfer of baggage and for passengers from delayed connecting flights. Plane utilization is typically also increased (Flouris and Walker 2005). A central hub system provides economic advantages by aggregating passenger demand at the hub location and thereby enabling higher flight frequency. Passenger aggregation at hubs creates larger aircraft load factors (proportion of aircraft fleets with revenue paying passengers), which increases operational profitability (Fu et al. 2010; Ball 2007; Saunders and Shepherd 1993). This model appears to have economic advantages primarily on longer flights as opposed to shorter flight segments (Ball 2007).

The disadvantages of hub networks are the increased distance 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 (Fu et al. 2010). The structural choice of using a hub location may reduce delivery reliability and profitability as compared to airlines that focus on point-to-point flights. Tsikriktsis (2007) found focused airlines (e.g., Southwest Airlines), characterized by a high degree of directness, showed profitability more than double that of full-service carriers (i.e., those using a strong hub design and more complex fleet). Avoiding congested hub airports and using a simpler route structure allowed
such airlines to have greater delivery reliability and profitability. To be effective, the benefits realized from centralized hub networks must compensate for the higher costs of transporting passengers increased distances and the necessity of using multiple service encounters.

There is also a value and revenue effect on profitability generated by the design of the service delivery network. Sasser et al. (1978) first defined this as the “service concept,” which includes choices of service delivery methods and the customer's direct experience of both the service and the value of the service. The service delivery design decision directly influences value from the customers' perspective in the following way. Airline service delivery systems with a high degree of directness will, on average, provide shorter, more direct paths, while networks with low directness resulting from a hub design will have longer, slower paths. Service networks with a strong hub design 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 customer'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 variable of the average number of flight segments is a proxy to measure both the increased costs incurred in less direct flights and the reduced value of longer throughput times for the passenger.

**Hypothesis 1** Differences in structural choice of the service delivery network routing structure (V2) will be positively correlated with the operational profitability (V1).

The selection of the aircraft fleet is a second key structural service design decision. Fleet complexity naturally follows from the route structure choice so as to develop the fleet that matches best with the average degree of directness. The choice of aircraft types is often modeled as an assignment optimization problem that accounts for the many factors and constraints created by the route structure (Barnhart et al. 2009; Gao et al. 2009; Ahmed and Poojari 2008). In a study by Daraban (2012) it was found that airlines flying a predominantly point-to-point route structure maintain much more homogeneous fleets than full-service carriers. This is often cited as a contributor to low unit costs associated with point-to-point carriers. However, these carriers tend to choose routes or markets that match their fleet constraints rather than the other way around. Consequently, what occurs in practice with point-to-point carriers may not be the ideal, but is pragmatic in the near term.

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 for fleet complexity range from standardizing on a single “best compromise” aircraft from one supplier (low fleet complexity) to deploying as many as eight different aircraft from as many as three different suppliers (high fleet complexity). 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 (Lohatepanont and Barnhart 2004).

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 (Flouris and Walker 2005).

**Hypothesis 2** Differences in the structural choice of fleet complexity (V3) will be negatively correlated with operational profitability (V1).
The scale of operations is a structural choice determined by decisions made for the number and size of markets served, the frequency of service for each market, the choice of aircraft to serve the market, and opportunities for mergers with domestic competitors. Increasing the scale of operations directly impacts service profitability. A larger scale supports the deployment of aircraft with more seats, thereby decreasing 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. According to Nero (1999), increases in financial return are not constant as network size increases. However, increasing network size still provides competitive advantage. According to Rubin and Joy (2005), hub domination is also a form of economy of scale. An airline that dominates a hub airport has the ability to engage in predatory pricing to ward off market entrants. Larger full-service carriers often control long-term gate leases, making it difficult for others to gain access to the airport (Rubin and Joy 2005). Hub domination is not a true form of scale, but instead is a strategy for repelling competitors through price cutting, which can erode profits. For this study we consider true economy of scale as that gained through increases in network size to reach new markets.

**Hypothesis 3** Differences in the structural choice of operational scale (V4) will be positively correlated with operational profitability (V1).

Airlines often seek to increase their market share in order to increase profit potential. In the late 1990’s many low-cost airlines (i.e., point-to-point carriers) attempted to expand more aggressively into larger airports. Ultimately, many of them went bankrupt due to the hub domination effect described earlier (Daraban 2012). However, such decisions were not without merit and were taken with the idea that increasing operational scale would increase passenger traffic between origins and destinations in the flight network. Expansion into underserved or over-priced markets would certainly have this result. When such a prospect arises, it presents the opportunity to schedule more direct flights between some pairs of markets served. In fact, Ball (2007) argues that the short-haul market favors the point-to-point network structure, with most airline industry hauls classified as shorter haul. This argues in favor of market expansion to increase profit while reducing the number of flight segments. Further supporting this argument is the fact that the market share of low-cost carriers increased from 16% in 1993 to 36% by 2010 (Daraban 2012). We would therefore expect operational scale to be negatively correlated with the number of flight segments (our proxy for the directness of the flight network).

The forces of rivalry among existing competitors are addressed most recently by Michael Porter (2008). Porter concludes that price is the most likely form of competition when services offered by competing firms are nearly identical and when customer switching costs are low. Price competition is also fostered in economic environments where fixed costs are high and marginal costs are low. This environment entices firms to cut prices below average costs to a level approaching marginal costs. For the airline industry, the marginal cost of an additional passenger occupying an empty seat is extremely low, the additional fuel consumed in flight and whatever food and drink amenities that are provided without charge. Price competition is also prevalent when services are perishable. An empty airline seat is certainly a perishable service; it provides no value to the firm after an aircraft departs. The domestic airline industry is a prime example of price based competitive rivalry. Customer switching costs are low and price discounting is obvious to both customers and competitors. Fare discounts are quickly matched by competitors. A common advice in the travel industry is to book airline fares on Tuesday or Wednesday during the time period when airlines adjust fares and discounts are matched. Sophisticated search engines facilitate the process of identifying low price fares. Porter (2008)
concludes that price competition as practiced by the domestic airline industry is the most destructive basis for competition; it transfers profits directly from the industry to customers.

**Hypothesis 4** *Competitive rivalry (V5) will be negatively associated with service profitability (V1).*

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. Opportunities to expand into new markets are facilitated by mergers and acquisitions resulting from bankruptcies (Gong and Firth 2006). Through acquisitions, airlines can increase their market power or coverage, enhance operating efficiencies, or overcome regulatory entry barriers (Sherer and Ross 1990). For example, between 1989 and 1993 six major US carriers filed for chapter 11, with three closing down. The remaining airlines significantly improved their aggregate operational and financial performance (Jayanti and Jayanti 2011). Therefore, reorganization due to bankruptcy may improve the competitive position of an airline and have a positive impact thereafter on service profitability. Several airlines in our study filed for reorganization under Chapter 11. None of these companies were liquidated, but emerged from bankruptcy after reorganization.

**Hypothesis 5** *Bankruptcy events (V6) 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 on service profitability. These variables include the differences in (1) fuel costs between airlines that result from fuel hedging, (2) legacy labor contracts, (3) expenditures for food and beverages served onboard, and (4) advertising and promotional activities. Potential bias from these cost elements were removed by the following adjustments.

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.

There are notable differences in salary structures between airlines during the time period of this study. 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 was $32,000, while the Northwest Airlines pilot salary was $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 airlines’ employee costs were then restated based on these average 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 and beverages. 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 were then restated as a function of average flight length.

![Figure 2 Jet fuel costs by airline](image)

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 12.35 million flights. The timeframe of 2004-2007 for the study was chosen for two reasons. This timeframe had a reasonably uniform and stable economic environment. This reduces the potential to confound the experimental results with external economic disturbances. The banking crises started the year after the end of this study (2008) creating a severe recession and economic pressures on the domestic airline industry. There were also several mergers in the airline industry after 2007, 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 merging with Northwest Airlines.

The operational data is available from The Office of Airline Information of the Bureau of Transportation Statistics. Other empirical studies that use this data source include Tsikriktsis and Heineke (2004), Tsikriktsis (2007), and Deshpande (2012). 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 Tsikriktsis and Heineke (2004) and Tsikriktsis (2007). We therefore posit the data is appropriate for this research. We also note that the use of single industry airline data has the advantage of uniformity, as 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 an environment of pure price competition, differences in service profitability are largely caused by differences in service structural design and the execution of operational processes.

**The Definition of Metrics for Service Delivery Structural Design Variables**

This section provides a detailed description of the construction of metrics for each of the five structural variables for the conceptual model (Figure 1). All metrics are calculated quarterly for each airline for each of the 16 quarters in the study.

The profitability of the service system (V1) is measured by return on assets, a classical metric in financial analysis. The specific ratio used for each airline is the quarterly operating income derived from domestic operations divided by the assets employed in domestic flight operations. Operating income has the advantage that it excludes financial structure decisions and is a pure measure of the financial contribution from structural service design decisions. Adjustments to the stated domestic operating income were made for differences in fuel costs, food costs, salary structure, and advertising and promotion costs as described previously.

A key airline industry variable in the structural decisions defining the service delivery network is the degree of hub usage captured in the hub index (Bania et al. 1998). This characterizes the degree of centrality in the network structure (V2) that routes passengers from origin to destination. We chose to measure the hub index by the percentage of an airline’s flights that originate from its four most frequently used airports (four airport frequency). This metric is evaluated quarterly by airline for each of the 16 quarters of the study. Airlines that design a network with one or few hubs will have a high hub index as shown in the histogram of Figure 3 for Northwest Airlines. By contrast, the Southwest Airlines model of direct flights has a relatively low hub index. This metric is also used by Bania et al. (1998) and is an extension of the two group categorical variable (full service and focused) used by Tiskriktsis (2007). While there are a number of other metrics for network structure, we argue the four airport frequency is adequate since the airlines investigated have four or fewer hub locations. Sensitivity analysis for other measures of hub use, such as the Gini index, did not materially change the conclusions of this
research. While there is minor variation in the hub use metric from quarter to quarter, it does not change significantly over the timeframe of the study.

The structural service choice for the aircraft fleet to be deployed (V3) can vary significantly in complexity. Southwest Airlines structural choice is an example of low complexity. Until the recent merger with AirTran, their fleet consisted of one aircraft model from one supplier, the Boeing 737. The other extreme in complexity is US Air with eight different aircraft models: Boeing 737, Boeing 757, Boeing 767, Embraer 170, Airbus 320, Airbus 330, Airbus 319, and Airbus 321. The metric for fleet complexity (V5) is compiled by counting the number of distinct aircraft models for each airline for each quarter of the study. We do not count different configurations of the same model; the Boeing 737 200, 737 300 and Boeing 737 400 would be counted as one in the complexity metric.

![Figure Network routing structure design](image)

The operations scale metric (V4) is defined as the quarterly sum of seat miles flown on all domestic flight segments. It is the sum of the product of the number of aircraft seats times the distance flown for each flight segment.

A metric to assess the aggregate level of market rivalry (V5) for an airline was calculated as a weighted average of the number of competitors on each flight segment flown. The number of competitors on a flight segment varies from none to as many as five. The weights are calculated as the number of flight segments flown on a specific segment for each quarter to the total flight segments flown by the airline for that quarter.

Bankruptcy (V6) is modeled as an indicator variable with zero representing the absence of a bankruptcy proceeding and one the condition when the organization is currently in bankruptcy proceedings. Bankruptcy entry and exit dates are readily available in public databases.

Each of the 5 metrics for the model variables were tested for significant deviations from a normal distribution. In several instances, improved distributions could be obtained with variable transformations. These include network routing structure, load factors, and number of flight segments.
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 cross-sectional variables measured over 16 time periods. This data structure is commonly referred to as panel or time series cross-sectional data. Lant (1992) details estimation problems with panel data, including contemporaneous disturbances in the error term, and heteroscedasticity of the errors across the cross-sectional units of analysis. There are also potential problems with lagged endogenous variables, and inconsistency of OLS estimates with lagged dependent variables. Solutions have been developed by statistical software vendors to address these estimation issues. For example, SAS incorporates a procedure Time Series Cross Sectional analysis (PROC TSCSREG), which is used in this analysis. This procedure includes options for selecting one or two way fixed or random effects models. The fixed effects models use dummy variables to allow model intercepts to vary across airlines and/or over time, while the random effects models use dummy variables as an error term, allowing varying error variances across airlines and/or across time.

SAS includes specifications tests for the presence of fixed and random effects in the data. The statistical significance of fixed effects is determined by an F test of the null hypothesis that the fixed effects vector of parameters is null. Hausman’s (1978) m-statistic is used to test for random effects using the hypotheses of bias or inconsistency of an estimator. Specification tests for the airline panel data revealed no fixed or random effect models, and we therefore chose the use of Parks method for analysis. This method has previously been used for analysis of panel data by Tsikritsis & Hineke (2004) and Tsikritsis (2007).

The model used in this research is as follows.

$$Y_{it} = \sum_{p=1}^{P} X_{ip}B_p + u_{it}$$

where $i = 1 \ldots N$ is the number of cross-sections, $T$ is the length of the time series, and $P$ is the number of independent variables. Parks’ (1967) method is essentially a first-order autoregressive model with contemporaneous correlation between cross-sections in which the random errors $u_{it}$, $i = 1, 2, \ldots , N$, $t = 1, 2, \ldots , T$, have the following structure.

$$E(u_{it}) = \sigma_{ij}$$
$$E(u_{it}u_{jt}) = \sigma_{ij}$$
$$u_{it} = \rho u_{i,t-1} + \varepsilon_{it}$$

Parks’ method is appropriate for this research since it includes capabilities for estimating autocorrelation of variables over time in the quarterly measurements of independent variables, contemporaneous correlation of cross-sectional variables between airlines, and heteroscedasticity that might result from differing scales of airline operations.

The data consists of nine cross-sections (one for each of the airlines) and twelve time series observations (three years of quarterly observations). The dependent variable is defined as operating profit for domestic operations divided by the assets invested in domestic operations for each of the service providers. The primary explanatory variables are quarterly calculations of metrics for each airline estimating the network routing structure, the fleet complexity, the operations scale, and the extent of market rivalry.

RESULTS AND ANALYSIS
The SAS PROC TSCREG procedure was used to estimate Park's time series cross sectional regression model of Table 2. The structural choice variables are listed in order of decreasing magnitude of the standardized coefficient estimate.

The results provide strong evidence that structural service choices have a significant effect on operational profitability. The model's R-Square value of 0.826 is evidence that a significant proportion of the variability in operational profitability among the airlines is explained by differences in their choices for structural service design variables. T tests for the parameter estimates are all less 0.0001 providing strong empirical confirmation of the relevance of four structural design choices investigated in the research. The standardized parameter estimates of Table 1 suggest priorities for increasing profitability in this industry: 1) increasing operations scale; 2) focusing on flight segments with served by few rivals 3) reducing fleet complexity; 4) using the network structure to increase passenger aggregation and load factors.

Table 1 Parks standardized estimates of parameters

| Variable            | Estimate | Std. Error | t value | Pr >|t| |
|---------------------|----------|------------|---------|-----|
| Operations Scale    | 0.385    | 0.033      | 11.77   | .0001|
| Market Rivalry      | -0.368   | 0.041      | -8.94   | .0001|
| Fleet Complexity    | -0.256   | 0.051      | -5.06   | .0001|
| Network Routing     | 0.177    | 0.033      | 5.35    | .0001|
| Bankruptcy          | 0.147    | 0.044      | 3.38    | .0001|

The model results support the significance 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 0.385 (p=0.0001), confirming hypothesis 3. 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 two 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.

Model estimates of the market rivalry metric, a proxy for price competition, reveals that price competition between rivals’ flight networks is a major determinant of service profitability with a path estimate of -0.368 (p=0.0001). This evidence confirms hypothesis 4.

The service structural design decision defining aircraft fleet complexity has both costs and benefits 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. The benefits of higher fleet complexity are seen in the reduction of the number of flight segments. 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 passengers 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 -0.256 (p=0.0001) confirming hypothesis 2.

The parameter for the network routing structure variable is estimated to be 0.177 (p=0.0001). The sign of this parameter is interpreted to mean that, for this industry, more centralized service delivery networks that can aggregate passengers and increase load factors are associated with higher levels of profitability confirming hypothesis 1.

As expected, an improvement in profitability is predicted for airlines experiencing a bankruptcy event. The estimate of this improvement from contractual relief and restructuring of costs is 0.147 (p < 0.0001).

**DISCUSSION AND CONCLUSIONS**

There are several unique aspects of this research we would like to highlight for the reader. While many studies relate dependent operational variables to productivity achievements, our model measures direct associations with profitability. Our conceptual model jointly estimates the impact of differences of four strategic design choices for nine industry competitors. The nature of the data enables a time series cross-sectional analysis of quarterly changes in performance due to either external factors or internal processes focused on assessment of gaps and continuous improvement. Finally, we recognize a relationship between lean consumption (Womack and Jones 2005) and profitability. The customer’s perceived value of the total service concept can be gauged by our metric for network routing structure. Networks with higher routing structure create longer and less direct flights that the customer may perceive as lower value. Unfortunately, the data does not allow us to decompose the aggregate effect of network centrality into a customer value component and a cost economics component. The supply side cost economics are a complex tradeoff of the benefits of passenger aggregation and the costs of longer flights, more flight segments, and the variability induced by network centralization.

The analysis provides strong empirical support for the architecture of the Service Delivery System of Roth and Menor (2003) in a service factory environment. The conceptual model measures key elements of the Service Delivery System architecture including structural design choices, infrastructural design choices, service execution, and customer’s perceptions of value. Approximately 80% of the differences in operational profitability were explained by the four structural design choices investigated in this research.

While this research is limited to the domestic operations of nine large US airlines, we strongly feel there are lessons that generalize to the entire airline industry. We note that the results of this research are limited to a case study in an environment characterized as a service factory. It remains an open question if these findings generalize to other service environments.

**REFERENCES**


